High Integrity Processes & Alloys | Annual Report | MARCH 2024

DIE CASTING ENGINEER

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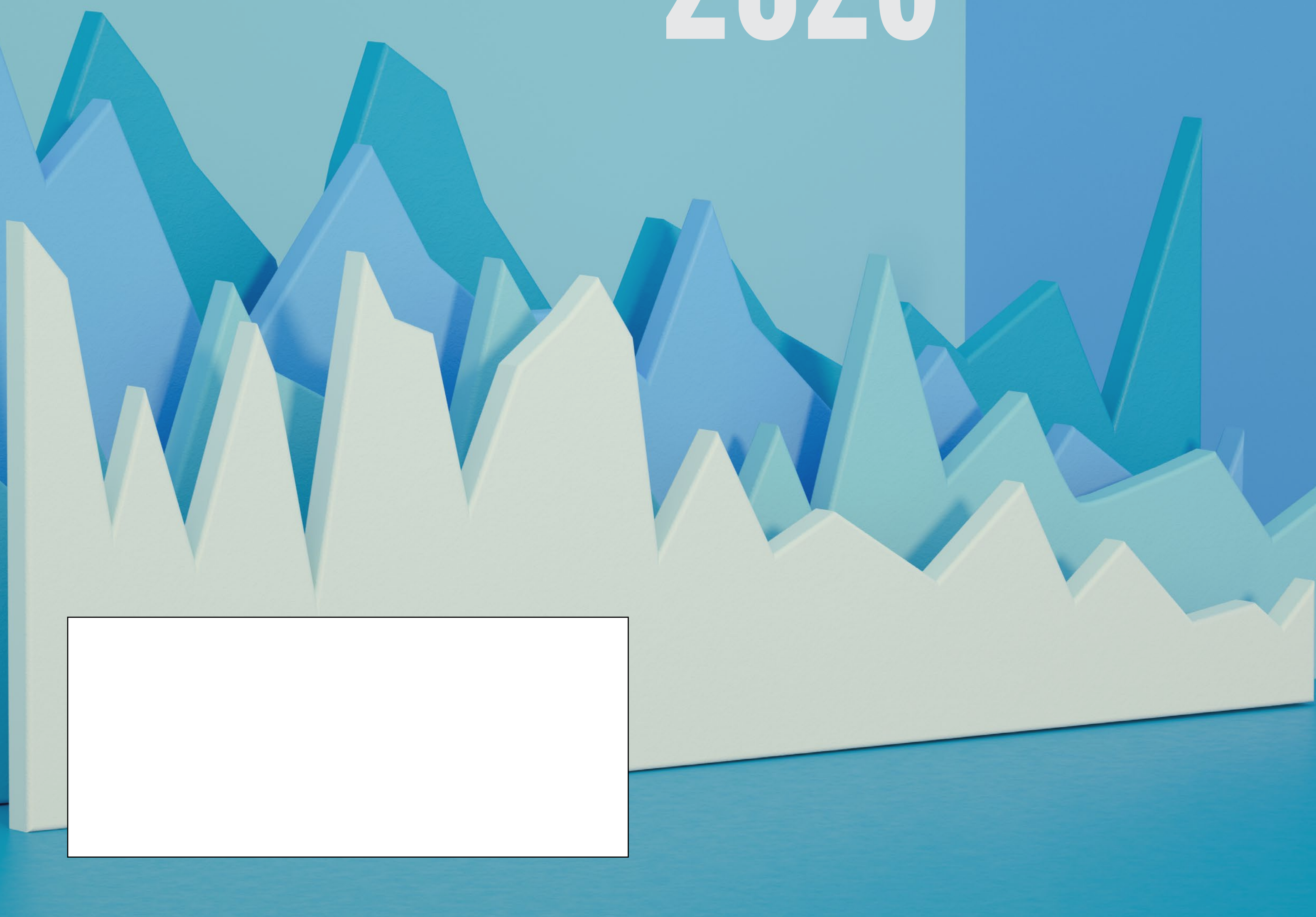
ANNUAL REPORT 2023



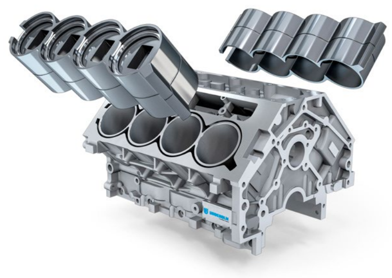
THE BEST OF TWO WORLDS

UDDEHOLM TOOL STEELS AND EIFELER PVD COATINGS

Combining the right Uddeholm tool steel such as Uddeholm Dievar© (≥ 18.4 ft-lbs. toughness value) or Uddeholm Unimax© with a PVD coating from voestalpine eifeler Coatings can increase productivity and achieve higher quality processed components.

FAILURES THAT CAN BE SOLVED BY THE RIGHT STEEL

Gross cracking, heat checking and indentations are failures which can be solved by changing the steel grade or the hardness level.



FAILURES THAT CAN BE SOLVED BY PVD COATING

Erosion, corrosion or soldering problems on cores, ejector pins and cavities (with simple geometry). Abrasive wear in Hot Stamping.

EXAMPLE OF COATINGS FOR HOT WORK STEELS

COATING	COATING TYPE	COLOR	KEY PROPERTIES	THERMAL LIFT
CROSAL®-plus	AlCrN	Slate grey	• High oxidation resistence • Outstanding hot hardness	2012°F (1100°C)
Duplex-TIGRAL®	AlCrTiN	Grey	• High hot hardness • Excellent oxidation resistance • Excellent abrasion resistance	1650°F (900°C)
Duplex-VARIANTIC®	TiAlCN	Old rose	• Good chemical resistance • Low friction • Good oxidation resistance in semi-warm-forming	1470°F (800°C)

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Chairman's Note

The Demand for EV's in a Changing Market

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"Neither a wise man nor a brave man lies down on the tracks of history to wait for the train of the future to run him over." - Dwight D. Eisenhower

As we enter spring of 2024, the environment in which we operate our businesses continues to be uncertain. The future of manufacturing will look completely different than today, with increased government regulation, tighter labor markets, absence of skilled workers, and economic regionalization changing the products offered and what/where processes are used for manufacturing. We already see decarbonization or carbon reduction efforts in most of the world driving radical changes in product design and manufacturing processes.

In the automotive sector, approximately 10% of vehicles sold in the US during 2023 were EV's, according to USA Department of Energy, with Canada also at 10% and Mexico at less than 1% EV market share. Clearly government incentives are helping to increase the demand for EV's while conflicting market forces still may cause the consumer to be reluctant to adopt these new technologies.

Total EV's registered in the USA accounts for slightly less than 5 million vehicles out of the 290 million vehicles registered, as reported by the USA Department of Transportation. With USA vehicle sales at 17-20 million per year and vehicle useful life at over 10 years, the bridge to a "carbon neutral" vehicle remains long and challenging.

Exactly what this transition timeline from internal combustion to hybrids to EV's will look like remains an unknown. Auto manufacturers are adjusting new product launches, extending current product volumes and powertrain mix, trying to meet both government regulations by supplying EV's to the market, and meeting market demands, which at times seem diametrically opposed.

How disruptive will this transition be for the die casting industry supplying to the automotive industry? Is this an industry opportunity or a threat?

In an internal combustion engine (ICE) powered vehicle, castings are mainly used for powertrain and structural components. Seating, mirrors, housings, mounts, etc. make up the remainder of smaller die cast parts used on all vehicle platforms.

In a hybrid vehicle, the powertrain and structural parts used on an ICE configuration remain, with the electric drive systems adding to the total castings used, although some components may be reduced in size and weight.

In a full EV, the powertrain is greatly simplified, with casting potentially used for chassis, body, battery enclosures, and drive systems.

As the power source/product mix transitions over time, the industry will need to be ready to meet the changes, having products and capabilities to match to the required demand.

How North American die casters and suppliers respond to the changing market will determine our long-term viability. Casters and suppliers will need to remain competitive and agile in these uncertain times. Continued investments in people and manufacturing capabilities are required to meet these changing future demands.

As an organization, NADCA can help by supplying our membership some of the tools to be successful in a changing world.

The theme for this issue of Die Casting Engineer issue is High Integrity Processes & Alloys and Die & Plunger Lube/Plunger Tips.

Research and development in the die casting industry continues to provide new technologies and processes to expand the die casting market by producing higher quality parts while potentially lowering the manufacturing costs.

New alloys can expand the addressable market for castings and reduce costly post cast processing steps, reducing costs. These innovations are being developed and introduced by suppliers or supported through NADCA R&D funding.

Take advantage of the competitive tools that are available to increase your competitiveness for the future. Don't lay on the tracks waiting for the train of the future to run you over!

"Exactly what this transition timeline from internal combustion to hybrids to EV's will look like remains an unknown."

Andrew Ryzner
Editor
North American Die Casting Association

"NADCA is debuting a Young Professionals Organization (YPO) in 2024 which we feel is very important for the future of our industry."

A Smooth Transition at NADCA

NADCA is now a few months underway with a change in leadership at the position of president. In my opinion, the transition has been very easy for NADCA staff and has gone very smoothly. We've achieved some of the things we have set out for early on with much more to come. Look for NADCA staff to visit a chapter near you this year, if they haven't already by the time of this writing - we are planning to do visits all over the country to engage with members and of course to give presentations such as the State of the Die Casting Industry.

At the time of this writing, I will be seeing some of you coming up in Arizona at the upcoming Executive Conference. This an interesting event because it will be the debut of the Young Professionals Organization (YPO) as an effort from NADCA to get the under-40s more and more involved in the industry. Hopefully both the veterans of the industry as well as the younger members can learn from each other to keep the future of the industry bright and informed. I believe this can continue to be achieved by talking and listening to all ages regardless of experience level.

Lastly, this issue of the magazine contains NADCA's Annual Report which gives a brief overview of the happenings around NADCA. I think that particularly of note is the portfolio of research and development projects that have been written about in this section. The advancement of technology and education on said technology is a huge part of the future of our, and every, industry in the world. Staying on top of the latest findings and tech can never be a bad thing to help your company in a positive way.

Hopefully you are off to a good start in your year as we soon move on to warmer weather (and baseball season, my favorite) in 2024.

Thanks for reading.

NADCA NEWS

NADCA Awards 14 Students David Laine Memorial Scholarships

Arlington Heights, IL - NADCA's David Laine Memorial Scholarship has awarded more than $34,000 to 14 undergraduate students across North America for 2023. The scholarship program was established in 1975 and its main objectives are: to provide financial assistance and encouragement to students who are interested in careers in the die casting industry; to foster and improve engineering education in die casting technology; and, to stimulate awareness of and interest in the die casting process.

The scholarship is awarded every year to applicants that have worked internships or co-ops in the die casting industry. Students reported that they gained experience in die design and maintenance, customer service, quality control, building work relationships between different departments, maintenance, robot and PLC programing (and more). A more in-depth story will be in an upcoming issue of DCE.

Thirteen of the fourteen scholarship winners worked internships at NADCA Corporate Member companies! If your company is interested in learning more about the process of hiring an intern, we may be able to put you in touch with a colleague that you can speak to. Contact intern@diecasting.org.

Cast Your Company's Future by Hiring an Intern

Arlington Heights, IL - NADCA has a resume database of engineering students looking for summer internships on its Web site. Please consider hiring an intern and introduce that student to the world of die casting! Students from universities across North American are currently looking for opportunities and many are willing to re-locate for the summer.

The database is password protected, so you will need to login to your MyNADCA account for access. Once logged in, to review the available candidates, visit: www.diecasting.org/intern-resumes. Students may be contacted directly, and if you hire a student, let us know, (intern@diecasting.org) so we can limit their contact information.

Students that complete an internship in the die casting industry are eligible to apply for the David Laine Scholarship Program. That program opens for applications August 1. For additional information, visit: www.diecasting.org/scholarship.

Is there a school close to your plant that you would like to pull candidates from? Send a message to the intern@diecasting.org, and we can reach out to the Engineering Department(s) there.

UPCOMING EVENTS

NADCA Plant Management Conference to Feature Tour of Tesla

Arlington Heights, IL - NADCA is pleased to announce that it will be hosting its annual Plant Management Conference at the DoubleTree by Hilton Hotel Newark - Fremont, CA on April 30-May 2, 2024. Featuring a tour of Tesla Fremont and Tesla Lathrop.

The Annual Plant Management Conference provides a venue for operations and plant management personnel to meet and network with peers from other die casting facilities. Together, attendees can share experiences and gain knowledge and information through round table discussions, topical presentations and facility tours.

Hot topic discussions are curated by attendee interest, making this conference both unique and extremely valuable to participants.

This years plant tours of Tesla will include:

Tesla Plant Tour - Fremont California

- Tour the die casting area - 6100 ton Giga Machines
- Tour assembly of the Tesla vehicles
- Test drive a Tesla

Tesla Plant Tour - Lathrop California

- Tour the die casting area
- Tour the assembly lines

For more infomation or to register visit: www.diecasting.org/pm

NADCA is Heading Back to Indy for the 2024 Die Casting Congress & Exposition

Arlington Heights, IL - The Die Casting Congress & Exposition will be held September 30 - October 2, 2024, at the Indiana Convention Center in Indianapolis, IN. This event will include three days of Congress sessions given by experts from around the world.

In addition to the Congress sessions, this exposition show will feature more than 120 exhibitors, the International Die Casting Design Competition and the Die Casting Industry Awards Luncheon. Attendee registration will open in the summer of 2024.

Save the date! We hope to see you there! For more information please visit: www.diecasting.org/congress.

Dr. Die Cast

High Integrity Castings and Alloys

If you have been in the die casting business more than a month, you have heard something like the following comment: "How is it that you have sent us thousands of good castings and then sent 3 of the following *%#@&^ junk pieces?" The complaint probably also arrived with a demand for a "Corrective Action Report" that asks, "What is the 'assignable cause' and the 'Irreversible Corrective Action'?" Since making a bad casting is not a capital offense punishable by hanging, we are stuck with the alternative. Identify which of our processes and procedures allowed parameters to drift out of tolerance.

Dr. W. Edwards Deming said "If you can't describe what you are doing as a process, you don't know what you are doing." Throughout my career I have often been approached with the lamentation "My machine was making good parts yesterday and I'm doing everything exactly the same and I can't get a good part." Something changed, you just did not look broad enough. It usually boils down to overlooking a basic machine parameter setting or one of the outside inputs such as molten metal delivery, cooling water, compressed air, or central die lube or tip lubricant. If you cannot measure an input, you cannot control it. Or as Dr. Deming said: "Without data you're just another person with an opinion."

I have experienced at least one event when every machine in the plant started making bad castings! After checking several of the machine processes in a row, we finally looked at the "heat number" tags on the new ingots. The alloy certification told us everything we needed to know. The alloy was off spec and they shipped it anyway. And *we assumed* the supplier would never ship off-spec material. We had procedures in place to verify the alloy before using it. It was skipped. Your system and processes must be reliable no matter who is present or absent.

Solving problems takes work. Sometimes, problem-solving is made more difficult by the lack of reliable measurements, such as defective wiring, gages, transducers, or no gages at all. SMED is of little benefit when the process can not be properly documented and controlled from day one. Some problems can only be identified at the source of the problem, not at a desk or in a conference room full of opinions. While there is value in problem solving teams the most important member is often absent and that is the person or persons who operate the machines every day. They have a wealth of inside information that is overlooked and underappreciated. One simple observation from an operator stating "every day between 6 and 7 PM #2 drill spindle faults out." It was summer and the machine only ran on first and second shift. It took at least 11 to 12 hours of continuous operation in the summer heat to develop enough heat in the control cabinet to trip the breaker. Only one person witnessed the problem occur. He would reset the breaker and resume running, but missed the fact that the interruption had just produced a defective part. In addition to solving the overheating problem, electrical interlocks were added to the machine program to make it essential to complete the operation before proceeding.

So, roll up your sleeves and be prepared to go deep. There is great satisfaction in solving problems. And greater satisfaction in having happy customers.

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NADCA Government Affairs

House Passes Critical Tax Bill

Today, January 31, 2024, the House of Representatives has passed a critical bipartisan tax bill restoring critical tax provisions used by NADCA members such as modifications to Section 174 R&D expenditures, Bonus Depreciation, the Section 163(j) deduction, and Section 179. Addressing these tax issues will restore a significant amount of capital to the bottom lines of small and medium-sized manufacturers, allowing them to invest in and grow their businesses.

The Tax Relief for American Families and Workers Act of 2024, which the House passed by a vote of 357-70, delays until 2026 the R&D amortization provision and reinstates full expensing, restores full expensing for capital investments, reinstates the EBITDA standard for interest deductibility, and raises the maximum Section 179 expending deduction to $2.5 million.

Thanks to the work of NADCA, and our coalition partners, this vital bill heads to the Senate and is one step closer to becoming law.

Administration Releases Unified Agenda

The Biden administration has released the semi-annual preview of its regulatory agenda, outlining the priorities and regulatory actions for each agency for the coming six to twelve months. Issued by every administration and formally known as the Unified Agenda, the release offers a blueprint on how the Administration will move forward to implement their priorities within each agency. The agenda sets out non-binding deadlines for pending rules across the executive branch.

This comprehensive document provides insight into the current priorities for each of the government's major regulators from the EPA to OSHA. NADCA regularly files comments on behalf of its members to make sure policymakers at critical federal agencies understand the impact of their actions on NADCA members.

Several regulatory actions that are pending that affect manufacturing businesses, like NADCA members, which appear in the Unified Agenda include plans to issue the final rule for multi-pollutant emissions standards for light and medium duty vehicles model years 2027 and later as well as GHG emissions standards for heavy-duty vehicles in March 2024; release a proposed rule in August 2024 to update Lock-Out/Tag-Out; issue a proposed rule on occupational exposure to crystalline silica in January.

The Unified Agenda also shows that OSHA intended to issue a final independent contractor classification rule and the Department of Energy intended to release a request for information related to the advanced technology vehicle manufacturing loan program in November, while the EPA intended to issue a final fine particulate matter (PM2.5) national ambient air quality standard (NAAQS) in December, indicating that the agencies believe movement on those regulatory actions is imminent.

No target dates have been set for some of OSHA's other controversial regulations. The Unified Agenda only lists a November 2023 date for the agency to "Analyze Comments" for the Worker Walkaround Representative Designation Process regulation. Likewise, the only regulatory step listed for the Mechanical Power Presses Update was for OSHA to analyze comments in December 2023. OSHA was also set to analyze the recently published SBREFA report in January 2024 to help shape a future proposed heat standard.

Final Rule Regulating Methylene Chloride Under Review

The final rule regulating methylene chloride under the Toxic Substances Control Act (TSCA) has been submitted by the Environmental Protection Agency (EPA) to the White House for review. On January 24, 2024, the White House Office of Management and Budget's Office of Information and Regulatory Affairs (OIRA) received the regulation titled "Methylene Chloride (MC); Regulation Under the Toxic Substances Control Act (TSCA)." The typical review process takes about 90 days, but the duration may vary depending on the specific actions involved. EPA has indicated that it expects to issue the final rule in March 2024.

This rule aims to prohibit the manufacturing or importing, processing, and distribution of methylene chloride for consumer use. Additionally, it seeks to restrict most industrial and commercial applications of methylene chloride, commonly utilized as a degreaser in metal manufacturing operations. EPA first proposed the rule on May 3, 2023.

The proposed rule outlined a 15-month timeframe for phasing out the majority of methylene chloride uses. However, a small subset of "critical" uses would be subject to a 10-year deadline. These critical uses include the chemical's manufacture, its utilization as a feedstock for climate-safe refrigerants, as well as its role as a degreaser for civilian aircraft. Certain applications within the Department of Defense (DOD), NASA, and the Federal Aviation Administration would also fall under the critical use category.

For the limited instances where continued use is permitted, the proposed rule would necessitate the implementation of a workplace chemical protection program (WCPP). This program would include monitoring and limitations on inhalation exposure, recordkeeping, and requirements for notifying downstream entities. Exceptions to the rule would be available for uses of methylene chloride that could "otherwise significantly disrupt national security and critical infrastructure."

EU and U.S. Extend 232 Trade Truce

The United States and the European Union (EU) have decided to prolong their truce related to the Section 232 tariffs dispute. On December 19, 2023, the European Commission announced a 15-month suspension of the retaliatory measures extending from January 1, 2023, until the end of March 2025, shortly after the winner of the 2024 presidential election takes office.

The U.S. and EU reached a deal in 2021 to end the Section 232 steel and aluminum dispute which implemented a tariff-rate quota system (TRQ) allowing the EU to export steel and aluminum duty-free into the U.S. at levels around 3.3 million metric tons of steel and 384,000 metric tons of aluminum a year while removing EU retaliatory tariffs imposed on a host of U.S. goods, including wine, whiskey, and spirits. The two sides also agreed to begin negotiations on a longer-term, global arrangement to address overcapacity and spur decarbonization in the steel and aluminum sectors. The deal was set to expire at the end of 2023.

Updated Electronic Reporting Requirements Now Effective

The updated occupational injury and illness recordkeeping requirements, finalized under the Occupational Safety and Health Administration's (OSHA) "Improve Tracking of Workplace Injuries and Illnesses" rule are now in effect with reports for 2023 due March 2, 2024.

The new rule, released on July 21, 2023, mandates that businesses operating in high-hazard industries and employing 100 or more individuals annually submit case-specific information from their OSHA Form 300 (Log of Work-Related Injuries and Illnesses) and Form 301 (Injury and Illness Incident Report).

Additionally, establishments with 20-249 employees in designated industries (including all manufacturing) will continue to be required to electronically submit data from Form 300A (Summary of Work-Related Injuries and Illnesses) on an annual basis. For establishments with 250 or more employees, electronic submission of information from Form 300A is also mandatory.

The high-hazard designated industries include 3315-Foundries, 3321-Forging and Stamping, 3327-Machine Shops; Turned Products; and Screw, Nut, and Bolt Manufacturing, 3331-Agricultrue, Construction, and Mining Machinery Manufacturing, 3335-Metalworking Machinery Manufacturing, and 3363-Motor Vehicle Parts Manufacturing.

Information must be submitted electronically via OSHA's Injury Tracking Application (ITA), which opened on January 2, 2024. To determine the filing requirements under the new rule for your company, you can visit OSHA's ITA Coverage Application.

Joint Employer Rule Challenged by CRA Resolution

The House of Representatives has approved the Congressional Review Act (CRA) resolution, H.J.Res 98, to overturn the National Labor Relations Board's new joint employer rule, which would expand the factors that can establish a joint employment relationship to include indirect and unexercised control over the terms and conditions of a job.

On January 12, 2024, the House voted 206-177, with 8 Democrats joining 198 Republicans to approve the CRA which provides formal "congressional disapproval" of the NLRB's "Standard for Determining Joint Employer Status" rule. This formal disapproval under the CRA would repeal the regulation as well as prohibit the agency from issuing any rules that are "substantially the same" as the overturned regulation.

The bicameral resolution was introduced on November 7, 2023, by Representatives John James (R-MI), Virginia Foxx (R-NC), and Speaker of the House Mike Johnson (R-LA), as well as Senators Bill Cassidy, M.D. (R-LA), Joe Manchin (D-WV), and Senate Majority Leader Mitch McConnell (R-KY).

Passage in the House now sends the resolution to the Senate, where at least two Senate Democrats need to join all Republicans in approving the resolution. Should the Senate give its approval, the resolution will proceed to the White House. However, President Biden has already indicated his intention to veto the CRA.

The rule is set to take effect on February 26, 2024, after the NLRB extended the effective date to account for legal action against the rule.

Expansion of EPA "Good Neighbor" Rule Proposed

The Environmental Protection Agency (EPA) is proposing to expand the Good Neighbor Plan (GNP) to an additional five states. The "Federal 'Good Neighbor Plan' for the 2015 Ozone National Ambient Air Quality Standards," which has been in effect since August 4, 2023, expanded interstate air pollution requirements to ensure that states meet their "good neighbor" obligations under the Clean Air Act (CAA). The CAA requires additional emissions controls for states that have a "significant contribution" of emissions which impact the ability of downwind states to meet the 2015 national ambient air quality standard (NAAQS) for ozone, set at 70 parts per billion (ppb).

The GNP covers a total of 23 states, with 22 states participating in the summertime ozone season NOx trading program for power plants. The rule also established NOx emission rate limits for nine new industry sectors in 20 states.

These industries include reciprocating internal combustion engines in pipeline transportation of natural gas, kilns in cement and cement product manufacturing, reheat furnaces in iron and steel mills and ferroalloy manufacturing, furnaces in glass and glass product manufacturing, boilers in iron and steel mills and ferroalloy manufacturing, metal ore mining, basic chemical manufacturing, petroleum and coal products manufacturing, and pulp, paper, and paperboard mills.

The new emission limits for manufacturing industries will apply in Arkansas, California, Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, Nevada, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Texas, Utah, Virginia, and West Virginia. The remaining states under which only power plants are covered include Alabama, Minnesota, and Wisconsin.

The new supplemental proposal released on January 23, 2024, would add Arizona, Iowa, Kansas, New Mexico, and Tennessee; despite the fact the final GNP rule is currently stayed due to legal action in Alabama, Arkansas, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Nevada, Oklahoma, Texas, Utah, and West Virginia.

Additionally, the Supreme Court is set to hear oral arguments on February 21, 2024, regarding emergency applications by Ohio, Indiana, and West Virginia to halt the rule nationwide.

EPA Establishes Updated Social Cost of Carbon Estimate

In recent rulemaking, the Environmental Protection Agency (EPA) has included a final updated approach to calculating the social cost of carbon (SCC).

Similar to the initial proposal put forth in November 2022, the finalized approach has been incorporated into the final rule to strengthen oil and gas methane standards.

In addition to implementing the updated SCC values in the final methane rulemaking, the EPA released the final "Report on the Social Cost of Greenhouse Gases." This report presents considerably higher assessments of the societal damages resulting from each additional ton of greenhouse gas emissions released into the atmosphere—nearly quadrupling the interim central estimate of $51 per metric ton of carbon dioxide (CO2) established by the Biden administration's Interagency Working Group (IWG).

The final report sets the societal cost of a metric ton of CO2 at $190 for the year 2020. The figure also increases over the years, with a metric ton of carbon dioxide being assumed to cost society $204 in 2023, $230 in 2030, and $308 in 2050.

While the new SCC figure only applies to EPA rulemaking, the remains engaged in its ongoing efforts to formulate a comprehensive government-wide SCC figure intended to guide all federal policymaking.

Penalties for EPA and OSHA Violations Increased

The Environmental Protection Agency (EPA) and the Occupational Safety Administration (OSHA) have revised the penalties for violations of various statutory programs subject to civil enforcement to adjust for inflation. Both the minimum and maximum penalties have seen an approximately 3.2 percent increase.

Regarding the EPA, the updated civil penalty levels are now applicable to violations under statutes such as the Toxic Substances Control Act (TSCA), Clean Water Act (CWA), Clean Air Act (CAA), Resource Conservation and Recovery Act (RCRA), Safe Drinking Water Act (SDWA), and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), among others. For instance, the minimum civil penalty under the CAA has risen from $5,761 to $5,580, while the maximum penalty has increased from $446,456 to $460,926. In the case of the CWA, the minimum statutory penalty has gone up from $6,696 to $6,913, and the maximum penalty has seen an increase from $323,081 to $333,552. Under TSCA, penalties now range from $11,524 to $48,512, up from $11,162 and $46,989, respectively. These new statutory penalty levels apply to all civil monetary penalties assessed on or after December 27, 2023, for violations occurring after November 2, 2015.

For OSHA, there has been an increase in the maximum penalties for "serious and other-than-serious" violations, failures to post required materials, and failure to rectify cited violations, increasing from $15,625 per violation to $16,131. The maximum penalty for "willful or repeated" violations has risen from $156,259 to $161,323 per violation, while the minimum penalty has increased from $11,162 to $11,524. These adjustments are effective for any penalties assessed after January 15, 2024.


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Weldability of HPVDC Structural Alloy: Impact of Surface and Core Characteristics

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Abstract

High-integrity die castings are often welded into complex structures. Compared to conventional die castings, high-vacuum can significantly reduce weld porosity after gas-metal arc or laser welding. However, achieving robust welding remains an industrial challenge due to the large number of variables involved. Surface characteristics, in addition to core material, are known to play a significant role in weldability. This paper investigates the impacts of die lubricant type, location on the part, cleaning method, and welding process. Critical factors contributing to robust joining capability were identified using a combination of advanced characterization and machine learning models. A 3-mm thick flat die insert with edge features was designed to generate detrimental filling patterns within the available envelope. Specimens were cast with the Aural™-2 alloy and welded in the F temper. Before welding, specimens underwent non-destructive testing by immersed ultrasound, with millimeter-scale traceability. Surface characteristics were also investigated after surface treatment using infrared spectroscopy to quantify oxides and remaining traces of die lubricants. Specimens were then welded in a bead-on-plate configuration with GMAW or autogenous laser processes. Given the potential shot-to-shot variations, five specimens were tested for each case. Post-weld quality was evaluated with 2D X-ray inspection and segmented along each weld. Finally, since inputs and outputs were traceable along the specimens and weld lines, quality was correlated with casting and welding parameters using visual interpretation methods and statistical analyses. This work highlights the impact of surface characteristics on post-weld quality to identify favourable process windows for robust joining procedures.

Introduction

High-integrity aluminium die castings, especially the larger automotive components that are becoming more widely used, allow integration of multiple parts and functions in thin-walled, lightweight structures. These components still need to be assembled into larger packages such as car bodies. The high-integrity high pressure vacuum die casting (HPVDC) process and alloys make a range of joining processes feasible. For instance, high-ductility alloys especially after solution heat treatment allow self-piercing riveting to be used.[1] The low porosity resulting from high vacuum also facilitates application of fusion welding processes, as even small initial porosity in the casting will result in large post-weld porosity.[2,3] Conventional die castings, with typically higher porosity, can also be welded but more complex variants such as non-fusion, high-force friction-stir-welding, or particular joint designs[4] need to be used. Fusion weldability of HPVDC has already been demonstrated, for instance by Scheibner et al.,[3] but porosity still remains and sometimes has to be further reduced to achieve performance targets. As a result, more complex variants such as laser welding in a vacuum,[5] with mechanical vibration or electromagnetic assistance[6,7] have been developed but have industrialization challenges. Laser systems with dual beams or beam oscillation[8] have been developed in the last few years and have shown benefits for joining wrought and cast aluminium,[9,10] for different joint configuration e.g. overlap, edge and butt joints. While in a majority of the research the focus has been on understanding the feasibility of laser welding and the effect of different laser welding parameters on geometrical characteristics, little research has been performed to analyze the root cause and various variants in porosity formation. Therefore, understanding and optimizing the complete casting, surface treatment, and welding chain to reliably achieve performance targets with relatively simpler welding processes is an attractive option for efficiently joining structural castings into larger assemblies.

There are a number of casting process factors affecting weldability.[3] Part, gating and vacuum channels design plays a critical role on entrapped gas and must be addressed before die manufacturing. Once the tooling is installed, casting quality starts with melt management upstream from the die casting machine which includes preparation and transfer methods to control hydrogen content (often estimated through the density index),[5] avoid segregation in the bath, and minimize formation of oxide films. At the die casting machine, plunger lubricant is also known to contribute to porosity and alloy contaminants and decrease general weldability,[7] and should be minimized while maintaining its protective function. Process parameters such as the slow shot speed or vacuum level in the cavity can also impact porosity levels.[11,12]

In addition to the casting internal quality, surface characteristics such as presence of moisture, oxides, or chemicals from die lubricants (also known as release agents) are known to decrease weldability.[2,3,6,13] Die lubricants have been the subject of increasing interest in the recent literature with a focus on their multiple functions and increasing importance in structural applications. For instance, Graf and Kallien investigated the deposition and heat extraction capability of different lubricant formulations as a function of die temperature.[14] Tomazic and Belyk showed in the ProGRess project that advanced die lubricants, among other benefits, can reduce carbon contamination thickness, reduce lubricant-induced porosity, and be more easily cleaned, which are factors that can improve weldability.[13] In addition to composition, a good lubricant application method was required to achieve good weldability at different dilution levels, as evidenced by re-melt tests. Experiments by Nishi showed improved filling from increased lubrication in very thin walls.[15] More recently, the insulating effect of the die lubricant under melt flow as a function of its composition was investigated using a splash test.[16] While the experiments differed from the fast flow and pressure typically observed in die casting, results suggest that die lubricant contributes to the heat transfer characteristics at the die-melt interface, which could impact filling and also have an effect on weldability, for instance from laminations or cold shuts defects especially further from the gates.[17] On the other hand, a thicker lubricant layer could generate more porosity-inducing humidity and decomposition products.[17] In practice, lubricants can be described to some extent in terms of solids content analysis to compare active ingredients content and thermogravimetric measurement to evaluate the thermal stability of lubricants at high temperature up to the ash content;[15,16,18] determining composition requires other methods such as Fourier transform infrared spectroscopy to identify what the active ingredients are.[16] However, lubricant recipes often remain an industrial secret which can complicate direct comparisons.[18] While relative content of different active compounds can be tailored, their practical selection and application may not always be optimal due to the complexity of their performance requirements even when using structured but time-consuming evaluation procedures.[19] The variations of deposition efficiency as a function of die temperature as well as spray geometry and parameters such as pressure have also been widely investigated for process optimization.[20-22] This was quantified for instance through a surface glossiness metric that correlated well with friction measurements.[20] Furthermore, castings generally go through cleaning steps that use various chemicals and that can further affect their surface characteristics. Through their effect on the cast surface, die lubricants and surface treatments methods could therefore play a significant role on the weldability of structural die castings.

There is a range of welding variants that can be used for joining structural castings. Gas metal arc welding (GMAW) is often used in the automotive sector and has already been demonstrated as the optimal process for short robotized seam welds on a door frame with an Al-Mg-Si casting welded to an extruded profile.[3] This process is most often conducted in butt and fillet configurations and is generally tolerant to geometrical gaps. While the GMAW process is very well established in the industry, there are still instances of poor weldability for die castings in terms of post-weld porosity. There is therefore interest in determining an optimally robust welding window, especially for castings requiring long weld lengths or leak-tightness as even local welding defects can lead to costly rework or rejection. For this variant, arc stability, filler wire type and shielding gas are known to be important factors.[23]

Laser welding is gaining interest for joining aluminium alloys as it can achieve faster welding speeds with low distortion, which can become economically advantageous for long weld paths, as well as overlap welds.[3] New variants, such as wobbling or dual-core fiber, have already shown improvement of the keyhole stability which improves the weld surface aspects and minimizes the occurrence of internal porosity due to keyhole collapse.[24] In addition to keyhole-tip instability phenomena in aluminium alloys, laser welding is made more challenging for die-cast alloys due to the interaction of dissolved hydrogen with the localized heat input and fast solidification behind the beam.[7]

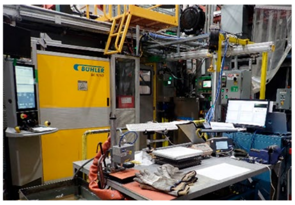
This paper therefore investigates the fusion weldability of structural die castings in terms of the critical characteristics that promote robust weldability. The first focus is on quantifying the surface characteristics arising from different lubricants, cleaning treatments and flow patterns during filling. The second topic is on correlating the local surface and internal characteristics of as-cast specimens to the resulting weldability using the GMAW process. Finally, this study compares the behaviours of the GMAW and laser processes in terms of porosity distributions to show the potential benefits of laser welding for joining structural die castings.

Experimental Methods

HPDVC Experiments

In this work, a test specimen was designed within the available envelope in existing die blocks. This led to constraints on using existing gates and vacuum channel locations. A 3-mm thick planar geometry was used for simplicity, but the contour was designed iteratively to generate different filling patterns locally based on air entrainment and oxides outputs from process simulations, towards edge weld trials. The tooling insert was installed on a 530-ton Bühler SC N/53 die casting machine fitted with a Fondarex HighVac/ExVac vacuum system and a Rimrock spray actuator and head (Figure 1).

(a)



(b)

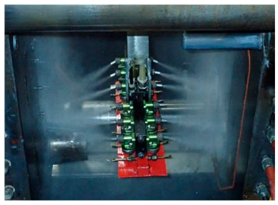


Figure 1 – (a) General view of the die casting cell. (b) Example of die spray operation.

The alloy used in the tests was Aural™-2 with a composition range over 4 days shown in Table 1. A mix of 70% primary alloy and 30% feeds and overflows was melted and held in a resistance-heated crucible furnace. Melt treatment with fluxing and rotary argon degassing was conducted and magnesium and strontium contents were adjusted each day to maintain as much as possible a constant density index and composition. The density index was calculated at the start and end of each casting run and remained in the range of 1.4 to 3.0% for the specimens reported herein. K-mold specimens were also observed to confirm melt quality and

Table 1 – Alloy composition range for casting alloy (actual) and filler material (nominal), in % mass.

Alloy	Aluminum	Silicon	Magnesium	Iron	Manganese	Titanium	Strontium
Aural™-2	Bal	10.5-10.7	0.30-0.32	0.18-0.19	0.50-0.51	0.06	0.009-0.013
ER5356	Bal	≤0.25	4.5-5.5	≤0.40	0.05-0.20	0.06-0.20	-

did not show significant inclusions. Melt was then transferred using a robotic ladle during each cycle. In a wider series of tests not reported in this paper, the melt was sometimes also deliberately degraded by addition of previously cast feeds and overflows to assess the impact on weldability, up to 5-7% density index.

There are many parameters on the die casting machine that could impact casting quality. In this work, a small subset of factors were varied while keeping others as stable as possible, as summarized in Table 2. An ester oil-based plunger lubricant (Chem-Trend PL-176) was applied in the cold chamber using a positive displacement pump through apertures behind a Caro-Prometa plunger tip during the return stroke. The estimated plunger lubricant consumption was 0.7-0.8 g/shot for the 80-mm diameter cold chamber and was kept nominally constant. On the other hand, die lubrication was varied in terms of product and dilution as this factor was expected to alter surface characteristics. Two lubricants from Chem-Trend, labelled L1 and L2 herein, were selected: L2 is designed for deeper draws and minimal draft. Lubricant L2 was reported to have a lower solid fraction and was also used at a lower concentration, therefore resulting in a smaller amount of solids sprayed. Both lubricants were diluted in tap water. The die spray lines were purged and the die cavity was cleaned and repolished when changing lubricant type. For consistency, diluted die lubricant was stored in pressurized tanks at 5.5 bar and robotically applied at each cycle using a Rimrock linear actuator and nozzles operating with the same sequence. The setup is illustrated in Figure 1b. The estimated lubricant consumption was on the order of 90 g/cycle over 4 seconds for the complete die, with a large fraction being sprayed on the runner and overflows as the objective was to avoid over-cooling the die in the thin-wall region. It should be noted that the measured melt density index was slightly higher in the trials with lubricant variant # 2. Die temperature was approximately 270-280°C at the start of spray. Shot profile and pressure as well as cycle time were kept the same throughout the reported experiments. Die, cold chamber and plunger thermal management as well as melt temperature were also kept constant. Reported vacuum level remained in the range of 54 to 64 mbar, and may be overestimated by ~15 mbar as maintenance revealed a sensor calibration issue following these trials. It should be noted that melt temperature varied quite significantly when reaching the lower furnace levels, compared to a conventional guideline of 5.5°C for thin-walled castings.[25] Welding specimens were only taken from steady-state die and cold chamber temperature regimes.

Table 2 – Selected casting process parameters.

Parameter	Range or value	Parameter	Range or value
Die lubricant	1. L1 diluted at 3%	Intensification pressure	500 bar
	2. L2 diluted at 2%	Die thermoregulation	240°C
Slow shot speed	0.1 m/s	Melt temperature	704-714°C
Metal velocity at gate	45 m/s	Cycle time	70 s

Castings were dried promptly after quenching in tap water and care was taken not to handle the surfaces. While the selected die lubricants were not advertised as weldable without cleaning, half of the castings for each case were brought to welding in the as-cast state. Lubricant residues were thoroughly removed from the remaining castings using a specific sequence of solvent degreasing identified for each of the two lubricants. At every stage, the surface was gently scrubbed with a solvent-resistant polymer brush, ensuring no scratching or sanding occurred. Since this study was also interested in investigating the influence of oxides on the level of porosities found in the weld,[23,26] it was crucial to preserve their nature and thickness during the degreasing steps. For this reason, the use of organic solvents was favored over alkaline aqueous degreasers that may etch the surface. In the initial degreasing step, a 1:1 mix of acetone and hexanes was utilized for L1, while ethyl acetate was preferred for L2. Subsequently, xylene, methanol, and acetone were used in sequence to degrease castings prepared with both lubricants.

Characterization Methods

In order to determine critical factors for weldability, the internal and surface characteristics of as-cast and cleaned specimens were quantified using a range of methods. Throughout the experiments, part-to-part and within-part traceability was carefully kept to establish correlations on a local basis. Each casting was individually characterized, as shot-to-shot statistical variations were observed especially for micro-porosity towards the edges near the gates. Within each casting, the as-cast and post-weld inspection and welding zones were accurately located on the castings so that weldability in individual segments could be related to the local characteristics of that segment, as illustrated in Figure 2a. This was for instance intended to determine whether post-weld porosity originated from as-cast voids, surface features, or possibly from a welding instability.

Figure 2a displays the two distinct weld locations labeled A and B. Given the expected weld pool length of roughly 10 mm, welds A and B were divided into thirteen and ten segments respectively, each 10-mm long. Consequently, when performing point-to-point comparisons and correlations between inputs and outputs, the average values in these 10-mm long segments for the indicated parameters were utilized.

Due to the filling pattern and depending on the degreasing steps, the casting surface exhibits visually different zones with varying glossiness and shades of gray as illus-

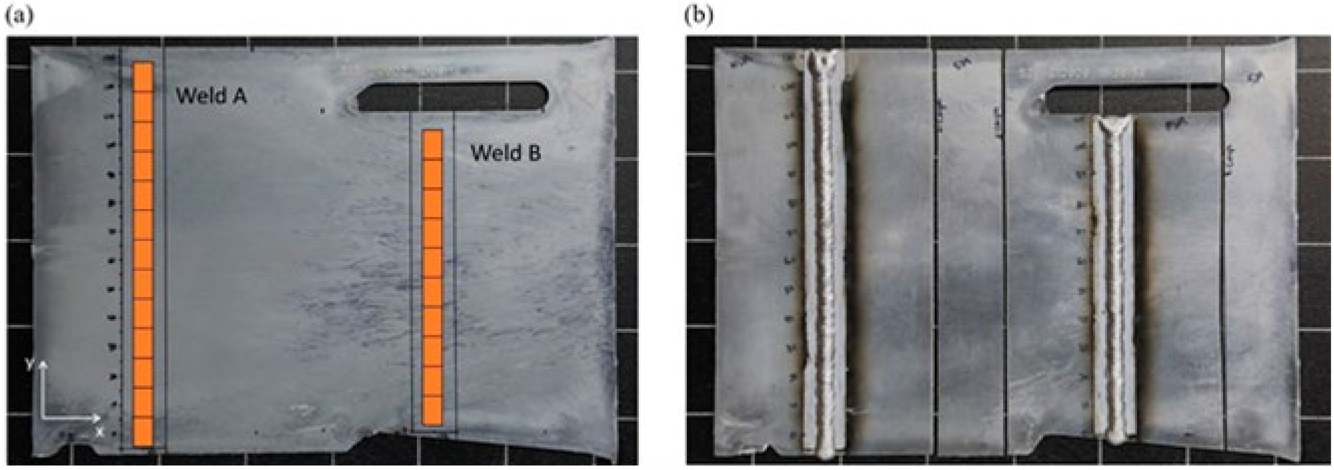


Figure 2 – (a) Segmentation on the casting of welds A & B areas, prior to welding, in 13 and 10 segments, respectively; (b) Picture of GMAW welds A & B on the casting. Filling is from left to right in the figure.

trated in Figure 3b-c. These hues were quantified using a grayscale analysis, regardless of whether these shades are connected to the presence of residual lubricants, oxidation levels, surface topography, or the content of porosity beneath the surface both before and after welding. The average grayscale of every 10-mm segment was calculated using the perceptually-tuned luminosity method that accounts for human perception. As human vision is more sensitive to green than other colors, green is weighted most heavily and the calculated grayscale value is given by:

$$\text{GS level} = 0.2989 \times \text{Red} + 0.5870 \times \text{Green} + 0.1140 \times \text{Blue} \quad (1)$$

Due to the relatively small variations of quantified grayscale levels throughout the images, pictures from which grayscale data were extracted were taken under constant illumination and imaging conditions in the laboratory to avoid potential measurements bias.

Surface characteristics were further quantified in terms of surface molecular structure and composition using infrared reflection-absorption spectroscopy (IRRAS), a powerful and sensitive variant of infrared spectroscopy used for the investigation of thin films and monolayers. This method involves the interaction of infrared (IR) radiation with a material, resulting in the absorption of specific wavelengths of light which correspond to the vibrational frequencies of the chemical bonds in the material. The specificity of IRRAS technique is that it involves an incident IR radiation polarized in the plane of incidence, and interacting with the surface at a grazing angle (80° vs. normal vector). An 8-mm diameter mask was used with the IRRAS accessory to measure spectra at the same 10-mm intervals as those reported for other analytical methods.

Figure 4 show the typical infrared signatures of a degreased casting, along with those of dried lubricants, showing oxides, hydroxides and organic and inorganic compounds present on the surface. While the full interpretation of infrared spectra is beyond the scope of this discussion, we will explore the key elements here. The casting using L1 was intentionally not thoroughly degreased using acetone, demonstrating how residual lubricant might interfere with the absorption band attributed to aluminum oxide (Al-O), at 938 cm-1. Aluminium oxide is an unavoidable product of the interaction of the aluminium with air. The shoulder peak centered at 1075 cm-1 indeed belongs to the L1 lubricant. A similar molecular vibration is found in L2, with an intense peak centered at 1095 cm-1, assigned to the Si-O-Si antisymmetric stretch. A sharp peak at 1260 cm-1, particularly prominent in the L1 spectrum, can also be attributed to a silicone-like compound, specifically, to CH3 symmetric deformations in Si-CH3. The observed bands in the 3000-2800 cm-1 region correspond to the symmetric and antisymmetric stretching vibrations of C-H bonds in methyl (-CH3) and methylene (-CH¬2-) groups. These originate from the lubricants and further suggest the presence of residual lubricant or a reaction product of the die lubricant with the incoming melt on the casting surface that has not been adequately degreased with acetone. In the spectral range from 1750 to 1285 cm-1, numerous vibration bands appear in both lubricants but are absent from the degreased casting. Attributing specific molecular features to these bands would necessitate the use of complementary techniques. Lastly, the broad band at 3450 cm-1 on the casting surface belongs to -O-H vibrations in aluminum hydroxides. This must be interpreted with caution,

Figure 3 – (a) Die insert used to manufacture the cast specimens. (b) Typical as-cast surfaces with die lubricant variant # 1. (c) Typical as-cast surfaces with die lubricant variant # 2.

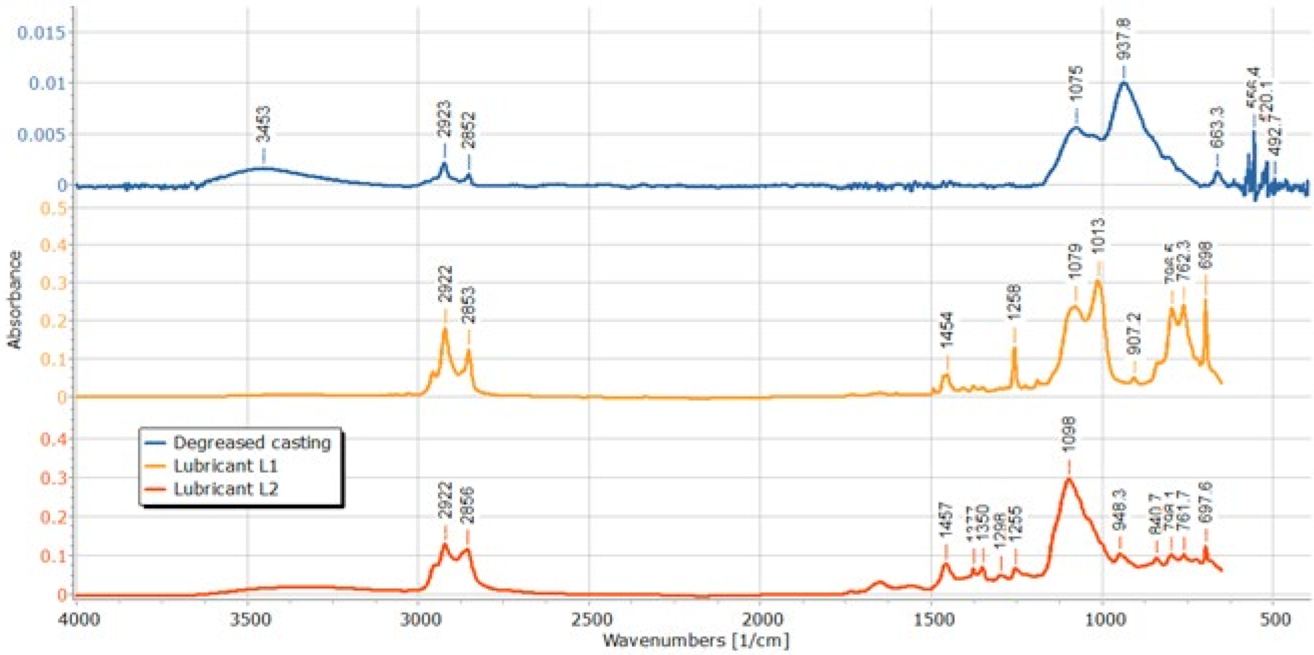


Figure 4 *– Typical IRRAS spectra acquired from a degreased casting (acetone was used to partially remove the L1 lubricant). Spectra shown for lubricants were recorded on furnace-dried lubricant samples (8 h at 40°C) using attenuated total reflectance IR spectroscopy technique (ATR-IR).*

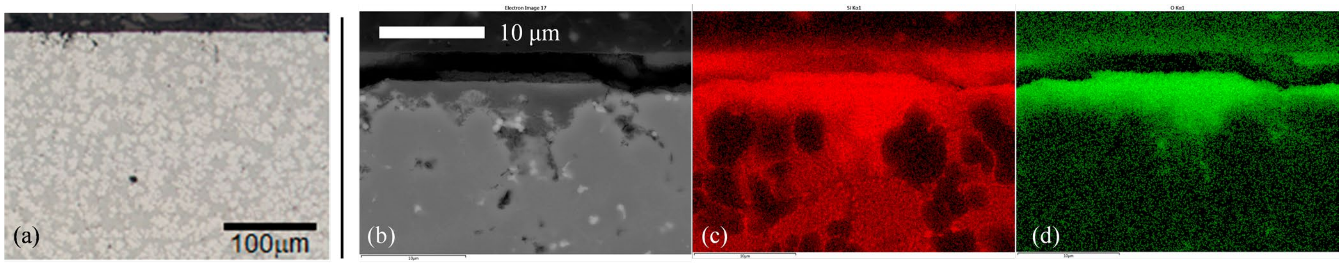


Figure 5 *– (a) OM imaging showing surface cracks. (b) SEM imaging showing a lubricant residue; (c) Relative silicon concentration (red); (d) Relative oxygen concentration (green). Casting with lubricant L1.*

as hydroxyl functions are also present in both lubricants. The areas under the IRRAS spectrum curve within specific wavenumber ranges were finally used to quantify the relative presence of each functional group towards correlations; the absolute amounts were however not quantified.

Cross-section observations of similar castings under optical microscopy (OM), scanning electron microscope (SEM) and associated energy-dispersive X-ray spectroscopy (EDX) mappings showed presence up to 20-µm deep microcracks which contain a high silicon and oxygen lubricant residue consistent with the IRRAS spectra (Figure 5). While fluorescent penetrant inspection was also considered as a non-destructive test method, presence of such microcracks was however not systematically quantified or included in the high-volume correlation analyses.

In terms of internal quality, as-cast micro-porosity is known to affect weldability as small porosities formed under high pressure in the die cavity can expand to large volumes when the material remelts during welding. Density measurement is a proven way to assess the extent of voids in a casting,[3] but provides global information on the part. While specialized high-resolution micro-computer tomography was demonstrated to detect small porosity in the range of 30 µm equivalent diameter,[27,28] the available X-ray equipment did not have sufficient resolution.

Cast specimens were instead inspected using a 30 MHz focalized ultrasound probe in an immersion bath: previous cross-sections had suggested that this method could detect small porosity on the order of 50 µm in the core of the casting. However, ultrasound inspection has "blind" zones near the surfaces (especially on the input side) due to high signal amplitude, but the skin layers generally exhibit minimal porosity. Typical inspection images (C-scans) in the weld regions are presented at Figure 6. The small turquoise dots represent the internal cast defects, mainly voids, while a sound zone is presented as a background blue color. The intensity of the instances depends on the reflected ultrasonic signal amplitude but in this study no defect sizing was applied, only a threshold value which corresponds to the minimal color change (25-30 dB). In the specimens used in this study, a few instances of potential cold flakes, which are known to contribute to blisters, [17]were detected especially around location A closer to the gate, but were located outside the weld regions. The area fraction of instances in 5-mm wide tracks, corresponding to the approximate melt pool width, centered on the weld lines was finally quantified using automated image analyses as a metric of as-cast porosity before welding.

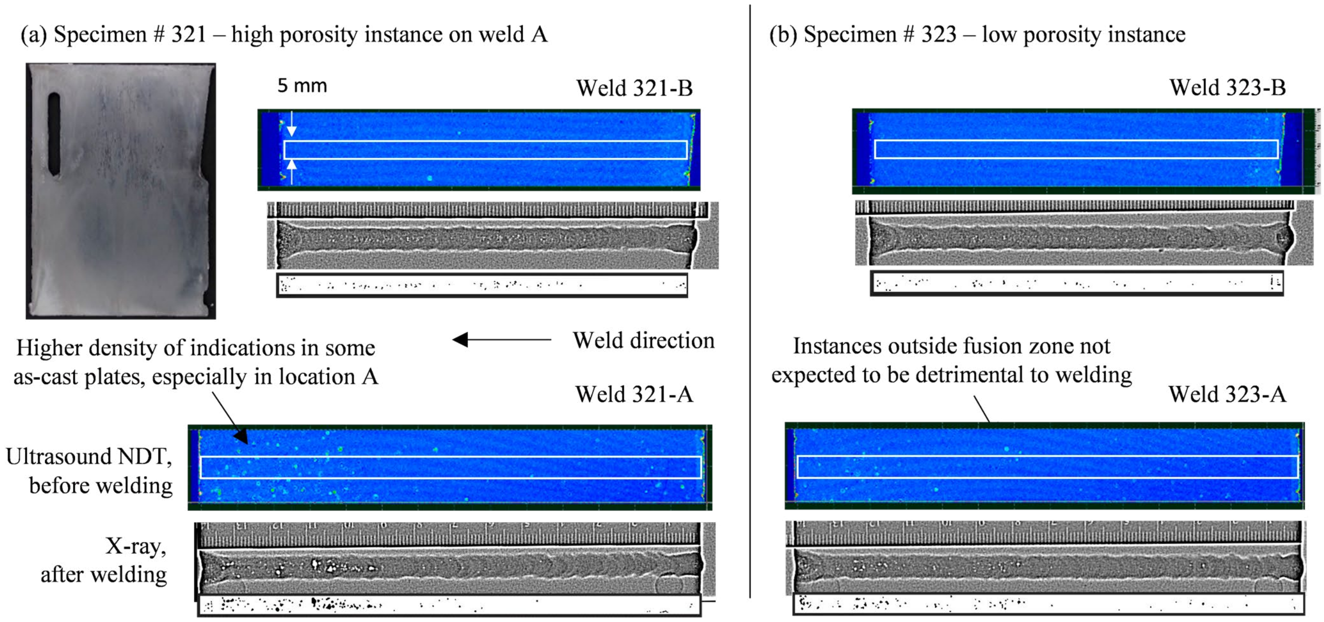


***Figure 6** - Examples of ultrasound inspection before welding and X-ray inspection after welding for instances with (a) higher as-cast porosity instances and (b) lower instances density. Insets are image analysis results for automated defect detection and quantification.*

This inspection was conducted after surface infrared spectroscopy as castings were immersed in tap water for durations on the order of 10-15 minutes during inspections, which could have altered the surface to some extent before welding. The HPVDC cast plates were then subjected to a drying procedure at 35°C for at least 3 hours before welding. A destructive blister test can also provide more information on the likely locations of porosity with respect to the intended welding locations,[3] but was not suitable for the part-by-part traceability required in this investigation.

Welding Experiments

In this work, laser and GMAW processes were selected to perform the welding in a bead-on-plate (BOP) test configuration to compare the effect the two welding processes. The BOP conditions were selected to study the effect of casting material surface condition on weld qualities as well as to simplify the welding execution. This is similar to a tungsten inert gas (TIG) remelting test.[2,13] The casting material was melted to the penetration depth of approximately 2 mm. ER5356 filler metal with a composition listed in Table 1 was used in GMAW welding process while the laser welding was performed in autogenous mode without the addition of external filler material. The ER5356 wire composition was preferred compared for instance to ER4043 reported in literature for A356 to AA6061 butt joints due to the higher mechanical properties that can be obtained.[23]

For GMAW, five cast plates were selected sequentially for each lubricant/surface combination, for a total of 20 specimens. Two welds were made on each plate across the width of the specimen at different distances from the gates, at the locations depicted in Figure 2. This was intended to sample different types of casting defects possible as a function of distance from gate and to highlight differences across surface characteristics. For instance, cold flakes and large externally solidified crystals may be more likely to be found near the gates (weld A) while the risk of oxide films, cold shut and laminations may be higher further from the gates (weld B).[17] This approach provided five weld beads for analysis for each lubricant/surface/weld combination, for statistical sampling.[5]

The GMAW experiments were conducted using a Fronius CMT TransPuls Synergic 4000 welding source mounted on a Motoman 45-kg payload robot (Figure 7a). The GMAW pulsed process parameters in Table 3 were initially developed over as-cast plates. For comparison, literature suggests a similar wire diameter and argon shielding gas flow rate up to 53 cfh for butt joints of 4-mm thick A356 castings to AA6061 with a similar travel speed.[23] The optical micrograph in Figure 8a gives an example of the weld macrostructure and fusion zone penetration depth achieved during BOP trials. This test method therefore remelted the surface layer, the dense skin layer as well as part of the core material that is generally more prone to porosity.

The laser welding experiments were conducted in autogenous continuous mode, without filler wire, using a 10 kW Trumpf TruDisk source coupled with a Precitec YW52 wobbling head and mounted on a Fanuc M800iA 60-kg payload robot (Figure 7b). The laser system was equipped with a collimating lens of 150 mm, a focal lens of 300 mm and a fiber diameter of 0.2 mm and nominal focal spot size of 0.4 mm. The defocus distance of 4 mm above the specimen was used for all the experiments which gives a focal

***Table 3** - Nominal GMAW welding parameters.*

Filler wire diameter	Wire feed speed	Travel speed	Voltage	Current	Shielding gas flowrate
mm	m/min	m/min	V	A	cubic feet/hour
1.2	7.8	0.5	20	120	45

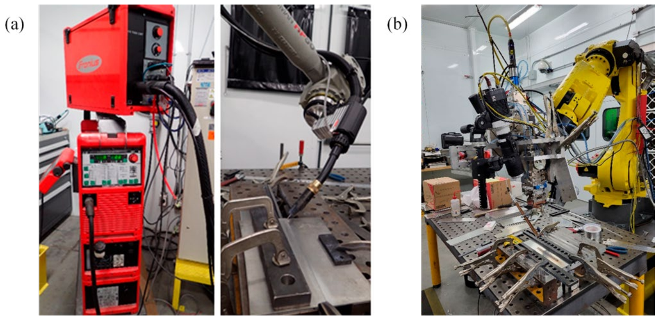


Figure 7 - (a) Fronius CMT TransPuls Synergic 4000 GMAW source mounted on a 45-kg payload robot. (b) YW52 Precitec wobbling laser processing head integrated on a 60-kg payload robot.

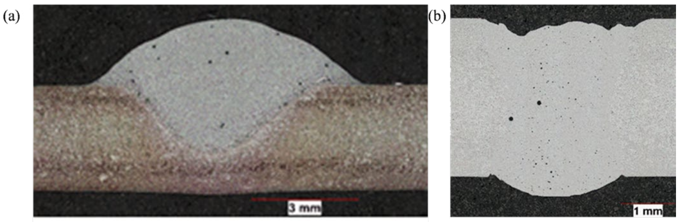


Figure 8 - Micrograph of a typical (a) GMAW and (b) autogenous laser bead-on-plate weld on cast plates.

spot size of 520 µm based on PRIMES analysis. The laser welding main process parameters are provided in Table 4. Pure argon was also used as shielding gas during autogenous laser welding. Unlike partial-penetration GMAW experiments, the laser welding process parameters were developed in order to penetrate through thickness of the cast plate (3.0mm) and pass the requirements in overall porosity content as per ISO 13919-2; Class C standard under 2D X-ray analysis (surface area of pores <3%).

For the investigation reported herein, five additional specimens cast using lubricant configuration # 1 from Table 2 without surface cleaning were laser welded to compare weldability to GMAW. In this case, traceability of the core and surface characteristics was not followed, since the main intent was to evaluate the porosity characteristics of laser welding on structural castings, a process with different heat sources characteristics which allows significantly higher travel speed compared to GMAW (Tables 3 and 4).

Table 4 - Autogenous laser welding principal process parameters.

Laser power	Travel speed	Nominal spot size	Oscillation amplitude	Oscillation frequency
kW	m/min	mm	mm	Hz
6.7	6	0.4	0.7	500

Post-Welding Characterization Methods

In this study, post-welding characterization was conducted using 2D X-ray imaging. Cross-section image analysis has often been used to quantify post-weld porosity in castings,[2,3] but a non-destructive method was preferred for high-volume traceability. However, unlike cross-section, 2D X-ray provides information on occurrences along the full length of the weld, but not on the porosity distribution through-thickness. The 2D X-ray analysis was calibrated using a IQI #5 indicator and a ruler was positioned across the weld to serve as an image analysis calibration tool, as shown in Figure 6. Using this IQI indicator, porosity ≥ 0.4 mm could be detected. An automated image analysis routine using ImageJ® software was developed to extract each individual porosity size and position. The porosity area fraction over 10-mm-long sections was then calculated along the entire weld length for further correlation to surface quality and initial microporosity content prior to welding. As for ultrasound inspection, porosity is reported by projected area fraction viewed from the top: this is likely to yield higher porosity metrics compared to volumetric fraction determined by 3D tomography.[5] It should be noted that, given the different contrast mechanisms and detection thresholds, ultrasound-based as-cast porosity and X-ray-based post-weld porosity should be analyzed in relative rather than absolute terms.

Throughout this work, the initial and final few millimeters of the segments have been excluded from the results to ensure that only the segments welded under a constant regime, free of starts and stops, are used for analysis. This corresponds to 2 mm at the start (bottom of Figure 2a) 8 mm at the end (top of Figure 2a. In the end, a data set of 460 points was generated from 40 welds in individual 10-mm segments.

Results and Discussion

GMAW Welding Correlations

As-cast inspection showed that the specimens had generally good internal quality with minimal porosity, which is expected from HPVDC for such a simple geometry. Some individual specimens still exhibited local clusters of contrasted instances in immersed ultrasound scans especially at location A close to the gate, as illustrated in Figure 6 and summarized in Figure 9a. The casting process conditions leading to this micro-porosity could not be clearly determined, as available process data did not highlight noticeable differences in temperatures and shot profiles.

Figure 10 summarizes the average porosity percentages measured for all five welds of the same type, both before and after GMAW welding. In the case of plates cast using lubricant # 2, irrespective of whether the surfaces underwent degreasing, the post-welding porosity levels were markedly lower for weld B compared to weld A. This overall trend may be attributed in part to the reduced occurrences of high-initial-porosity instances at the sites B compared to the sites A (Figure 9a). When it comes to plates cast with lubricant # 1, a lower percentage of as-cast porosity also characterizes the sites where weld B is to be made. However, despite these initially low porosity levels, weld B on plates cast with lubricant variant # 1 exhibit 3-4 times more porosity than the corresponding welds B on plates cast using the alternative lubricant configuration. However, due to the casting-to-casting variability illustrated in Figure 9 and the relatively small number of specimens, it is difficult to accurately evaluate the effect of the lubricant alone. This challenge is further compounded by uneven instances of elevated micro-porosity, which can introduce bias. Similarly, while it appears degreasing could improve the weldability of castings, especially with lubricant variant # 1, the benefit of

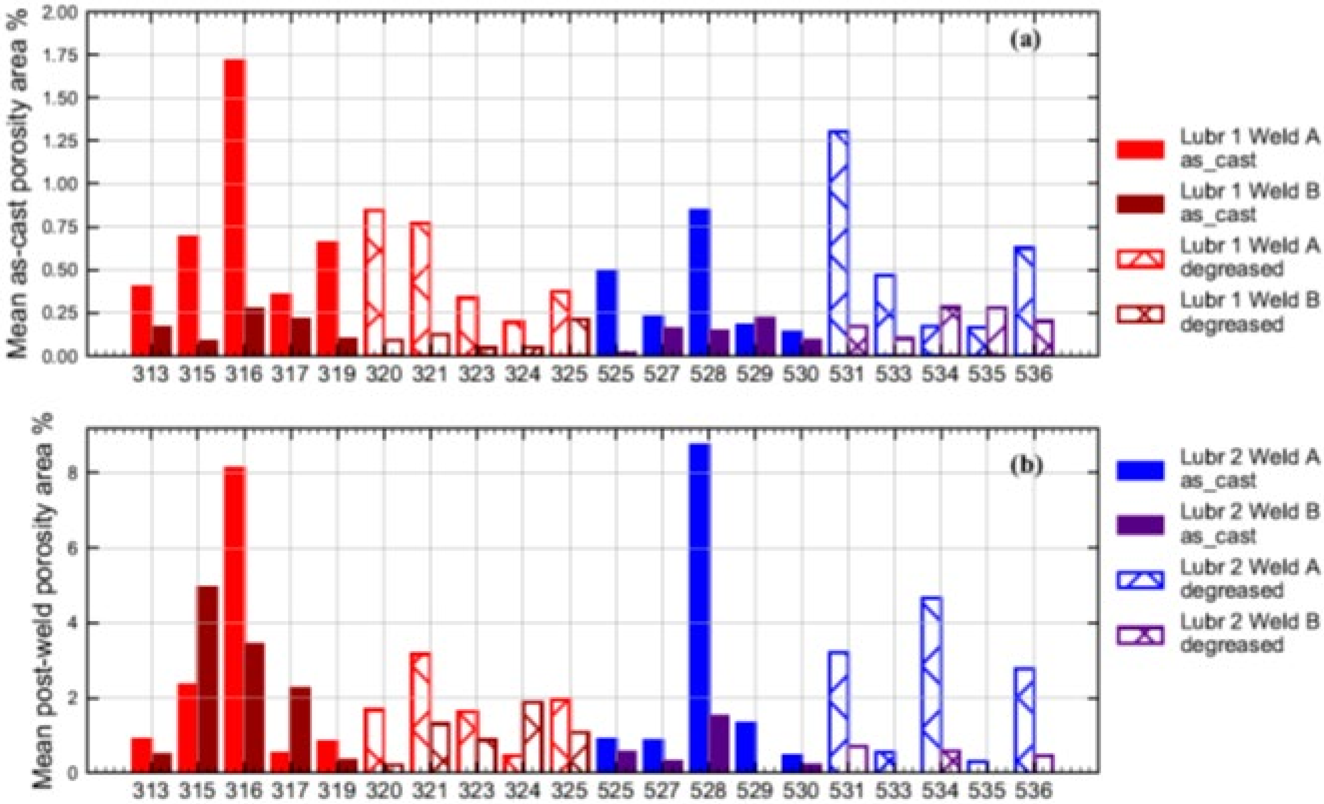


***Figure 9** – Summary of (a) mean as-cast porosity area fraction from ultrasound inspection and (b) mean post-weld porosity area fraction from X-ray inspection for 20 cast plates and 2 welds per plate. Abscissa is cast specimen identification (cycle number). Weld locations are illustrated in Figure 2.*

degreasing is difficult to isolate as the specimens welded in the degreased state also exhibit lower initial porosity levels, from statistical sampling.

To minimize the impact of part-to-part initial porosity variations, the problem has been simplified by honing in on the comparison of welds B on plates cast with the two different lubricants, as this location exhibited lower initial porosity and less part-to-part variation (Figure 9a). As illustrated in Figure 11a, and as previously noted, the level of internal porosity prior to welding alone does not account for the levels of porosity found in welds B when the analysis disregards the type of lubricant used. Consequently, no correlation between these two factors is observed. However, Figures 11b-c reveal that two IRRAS absorption

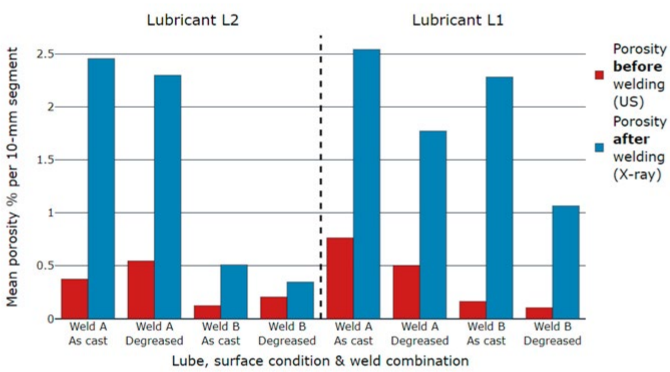


***Figure 10** – Average porosity percentages in each 10-mm segment for each of the lubricant/surface/weld combinations, measured before welding and post-welding. Each combination incorporates data from five weld beads to account for typical part-to-part variation. Complete dataset contains 460 rows, processed and grouped into 8 rows, i.e., 1 row per group of bars.*

bands detected in the infrared signatures of both lubricants exhibit a trend in their average concentrations that mirrors the porosity levels found within the welds. Therefore, the lower porosity levels measured in welds B of casting made with lubricant variant # 2 could potentially be attributed to the reduced impact of die lubricant or its residues on the as-cast plate, which could arise from its composition or its reduced concentration (Table 2). In addition, for both lubricants, the degreasing step noticeably decreased the magnitude of the two selected bands, which appears to improve the weldability especially in the case of lubricant variant # 1 with a higher amount of solids sprayed.

Figure 10 showed the average porosity area fraction observed after welding and calculated considering total weld lengths of 650 and 500 mm for welds A and B, respectively. On the other hand, it is also possible to focus on analyzing the local appearance of porosities after welding, in the sense of individual 10-mm segments. To this end, Figure 12a displays a typical Pearson correlation plot, showcasing the relationships between different parameters characterizing both the casting before welding and the weld. The Pearson correlation coefficient (r) is the most common way of measuring a linear correlation. It is a number between -1 and 1 that measures the strength and direction of the relationship between two variables. It is important to note that the 'y' parameter represents the location of the 10-mm segment along the casting width (refer to Figure 2a). Based on the observations from Figure 12a, for castings prepared with lubricant # 2 and welded in their "as cast" condition at weld A, the level of porosity initially present in the casting (measured by ultrasound method) serves as the best, and virtually only, predictor (r = 0.6) for the porosity found post-welding (measured by X-ray method). Similar conclusions can be drawn (figures not shown) regardless of the variations in lubricant, welding location, and surface state. This is consistent with prior literature on welding of die-cast parts with other processes.[5]

Figure 12b presents the data derived from the relationship between pre- and post-welding porosity levels just mentioned earlier. The dataset for weld B is also included. The significant scattering of data points in Figure 12b conveys that the post-welding porosity level cannot be linearly explained solely by considering the level of internal porosity prior to welding. As per Figure 12a, none of the other surface characteristics exhibit a strong linear correlation with the level of post-welding porosity, with all other correlation coefficients being considerably less than 0.6. It is worth pointing out that, in Figure 12a, the grayscale level (GS level) displays some degree of correlation with the location of the analyzed segment y, but beyond that, no other significant correlations are observed with this parameter.

In practice, each weld can be considered as an independent event while the weld pool can span a considerable length and moves across the specimen. The local properties of the casting prior to welding may influence the behavior of the molten metal over larger distances, that may vary from weld to weld, which is not accounted for when averaging multiple welds (Figure 10) or in segment-by-segment analyses (Figure 12). In addition, welding instabilities could occur locally, independent from the surface characteristics, and add noise especially at the segment-by-segment scale. Therefore, it became relevant to consider the average properties of the weld across its entire length. To this end, each data point utilized in Figure 12a was collapsed into its corresponding weld. Subsequently, the average characteristics of each of the five welds A on as-cast surfaces with lubricant # 2 were assessed. Pearson coefficients were calculated again using these average values, and the results are presented in Figure 13a. The high correlation coefficient values indicate a strong correlation between post-welding porosity and the majority of the other parameters, which could raise analytical concerns. Figure 13b provides a detailed view of the three strongest correlations identified with post-welding porosity, specifically with pre-welding porosity and two bands measured in IRRAS that are attributed to the presence of lubricant. For each of the graphs in Figure 13b,

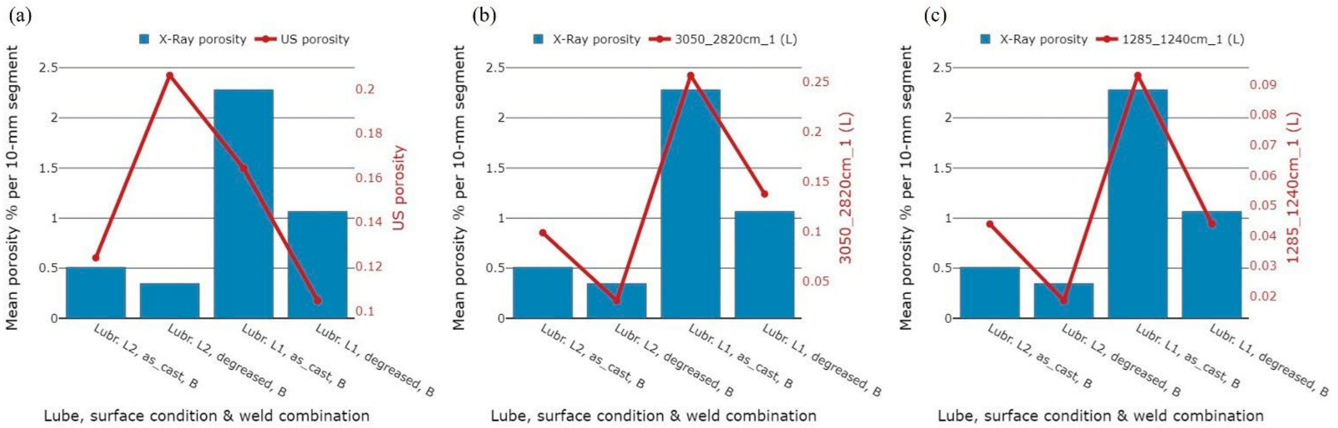


***Figure 11** – Comparison of observed trends between post-welding porosity levels and: (a) pre-welding ultrasound-measured porosity levels, as well as the intensity of IRRAS bands (b) 3050–2820 cm–1; and (c) 1285–1240 cm–1, which are attributable to the lubricant. These comparisons are based solely on weld B, and include both as-cast and degreased surface conditions of plates cast using both lubricants. Dataframe size: 200 rows of data available for weld B, processed and grouped into 4 rows.*

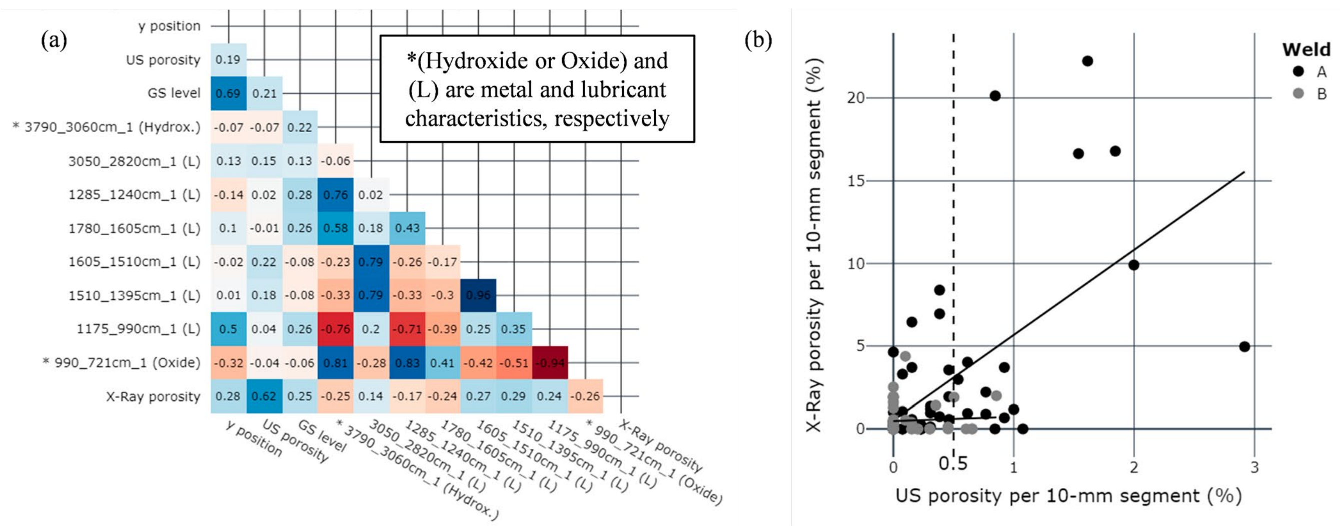


***Figure 12** – (a) Pearson correlation plot for weld A on as-cast specimens with lubricant # 2, built using 65 individual 10-mm segments. (b) Post- vs. pre-welding porosity levels for welds A & B on as-cast specimens with lubricant # 2 (115 rows of data).*

four out of the five points form a cluster, and the fifth point, significantly distant from this cluster, accounts for the high correlation coefficients calculated for many of the inputs. This also makes determining the most important features affecting weldability a challenge. Although this method could be valuable in situations where a larger number of full-length welds were considered, it should be noted that in the present case, it is not viable due to the low dispersion of post-welding porosity levels (four of the five welds were very similar).

The point-by-point approach presented in Figure 12 shows some correlation between the occurrence of "local" porosities before welding and the level of porosity measured post-welding. Moreover, indications suggesting that the presence of lubricant or its reaction products also plays a role in inducing porosity during welding are presented in Figures 10 and 11. Nevertheless, the detailed study of the porosity found on weld A of casting made using lubricant # 2 and welded as-cast did not allow to pinpoint, at a local scale, the individual contribution of these two factors, namely, pre-welding porosity and the presence of the lubricant. Thus, another analytical approach, not reliant on simple linear correlations, must be employed to determine to what relative extent these two factors contribute to inducing porosities at a local level of 10-mm segments. Random Forest is a supervised learning algorithm that can be used for regression tasks and that has already been applied in the field of die casting.[29,30] It works as an ensemble learning method by constructing a multitude of independent decision trees during training and outputting the average prediction of the individual trees. Random Forests have the advantage of being able to model complex, non-linear relationships. They are also relatively robust to outliers and do not require advanced data pre-processing, such as scaling. The algorithm also provides an estimate of feature importance, which can be very useful in understanding which variables are contributing the most to the prediction and physical phenomena.

Figure 12b shows that the highest post-weld porosities are associated with high pre-weld porosities. Hence, in order to reduce the possible noise associated with very small initial internal porosities, a threshold has been set to keep segments with initial porosity greater than 0.5% (dashed vertical line in Figure 12b) to develop a model aimed at predicting local post-weld porosity levels. Using this threshold, the dataset was significantly reduced from a size of 460 to 52 rows. As a result, a leave-one-out cross validation was applied to determine the predictive power of a Random Forest model using this data set. Sequentially, one out of the 52 rows of data was excluded from the set, and the remaining 51 were used to construct the model. Then, the model was applied to the data from the row that was excluded from the dataframe (except for the porosity after welding, which is the target). The predicted value was then compared with the experimental one (i.e., the hidden data on the excluded row). Figure 14a shows an example of the model predictions, comparing the experimental porosity level with the predicted level for a set of 10-mm segments from as-cast weld A. While the model accurately predicts some points, others show larger discrepancies. Points with the highest observed post-weld porosity appear to be the most challenging as their response is under-predicted. This could be in part due to their smaller number in an unbalanced data set. This also suggests that other important factors may not be accounted for. For instance, micro-crack instances such as those illustrated in Figure 5 may play a role on weldability but may not be well quantified with the features measured herein.

Figure 14b presents the predictors importance, through the Percent Increase in Mean Squared Error (%Inc.MSE) parameter. In a Random Forest, the model performance can be evaluated by the mean squared error (MSE) of its predictions. If a particular variable is very important for the predictions, then randomly permuting the values of that variable (i.e., maintaining their distribution but randomly removing their association with the output variable) should significantly worsen the accuracy, leading to an increase in the MSE. Therefore, a higher %Inc.MSE indicates that a variable is more important for the prediction, which provides a way of ranking the variables' contributions to the model. Pursuing this line of thought, it is apparent in Figure 14b that only two (perhaps three) variables serve as

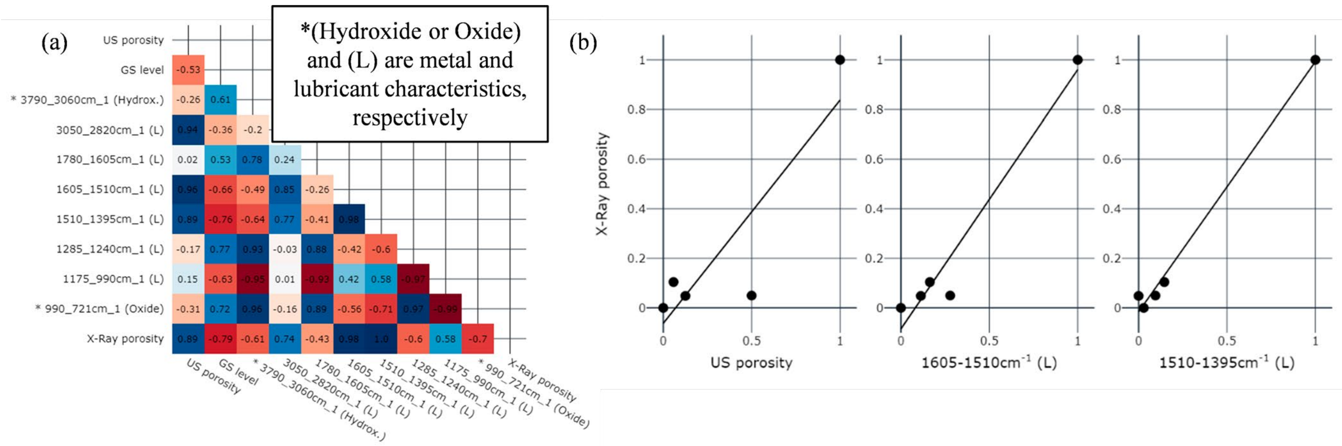


Figure 13 – (a) Pearson correlation plot for weld A on parts cast using lubricant # 2, and generated using average parameter values calculated for individual welds A (5 data points). (b) Details of the correlations between post-welding porosity and (a) as-cast ultrasound porosity (pre-welding content); (b) IRRAS band at 1605-1510 cm-1 (L); and (c) IRRAS band at 1510-1395 cm-1 (L), of parts cast with lubricant # 2 (data scaled in the 0 to 1 range).

good predictors for the porosity observed after welding: the pre-welding porosity, as anticipated, and the IRRAS band located in the wavenumber range 1780-1605 cm-1, which is attributable to the lubricant. This ranking was seen across multiple runs, each with a different data point excluded from the set. According to the %Inc.MSE index, the two parameters are virtually of equal importance. This result is very interesting, especially since very few experimental data were available to build the model (51 rows) and that the importance of this IRRAS band cannot be deduced for the Pearson correlation plot for weld A only in Figure 12. Upon identifying the nature of the two main predictors, the next step was to determine whether an analytical relationship makes it possible to link them to the target. It is important to note that in the case of complex decision tree-based models, such relationships typically do not exist.

The most straightforward method to analytically combine these two predictors towards the target is through a multilinear correlation. For the present case, this relationship could be represented as T = k0 + k1P1 + k2P2 where T is the target, ki are constants, and Pi represent the predictor values. Figure 15 presents the outcome of the multilinear correlation carried out while setting the pre-welding porosity threshold level from 0 to 1.6%. As illustrated in Figure 15a, the value of R2 tends to increase when the threshold value is raised, coinciding with a reduction in data quantity available for conducting the multilinear regression. This pattern could potentially be attributed to a clustering effect, such as what was observed in Figure 13b. It is interesting to note that in the threshold range of approximately 0.5 to 1%, the probability value (p-value) of the two predictors trend across the entire threshold range explored. By analyzing the data using more advanced methods than simple linear correlation, it is possible to identify highly probable factors contributing to the development of porosity during the welding process. These insights underscore the need for more extensive future investigations involving a larger number of castings.

Laser Welding Behavior

Examples of three X-ray inspection images of autogenous laser welds carried out on nearly sequential cast specimens using the same parameters are demonstrated in Figure 16. Four out of the five specimens show total porosity lower than 2%, which is within the range of the most stringent ISO 13919-2 standard class (≤ 3%, as per Level B), and comparable to the GMAW results shown in Figure 12b. The 5th specimen, illustrated in Figure 16c, exhibited much higher porosity (~9-11%). Unfortunately, as the individual casting characteristics were not quantified before welding, and process parameters were not continuously monitored during welding, the root cause for this specific instance could not be explained and would be the topic of future work. No noticeable anomaly was seen in the die casting equipment outputs. The GMAW experiments (Figure 9) had shown occasional occurrences of high post-weld porosity sometimes arising from as-cast microporosity, but these were generally much more prevalent at location A, which suggests that a different root cause may be at play here and should be identified and addressed.

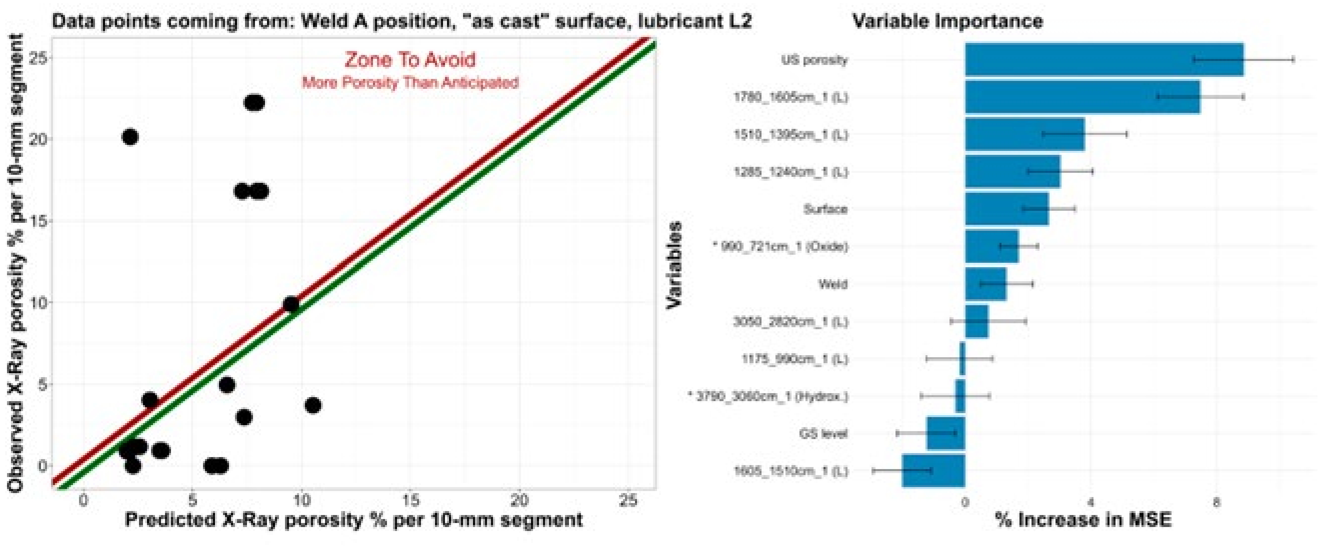


Figure 14 – Typical output from a Random Forest model with a minimum threshold of 0.5% on as-cast ultrasound porosity. The modeling, focusing on the behavior of welds on castings prepared with lubricant # 2, excludes rows tagged with lubricant # 1. This results in a final count of 52 rows available for modeling.

identified using the Random Forest model is low, thereby rendering them statistically significant. The pre-welding porosity level becomes even more statistically significant as the threshold is low, while the opposite trend is observed for the IRRAS band between 1780-1605 cm-1 that gains a high statistical significance as porosity threshold level is ≥0.5%. The 3rd predictor, i.e., the IRRAS band located at 1510-1395 cm-1, exhibits a high p-value with no evident

An example of the transverse micrographs of autogenous laser weld on specimen 360-A as well as the area fraction of micro-porosities measured using an image analysis routine is provided in Figure 17. The total area fraction porosity of 0.7% with respect to the fusion zone area was measured in this cross-section, which is lower than the minimum requirement criterion of the ISO 13919-2 standard quality class (level B) and the dimensions of porosities fall below 50 µm.

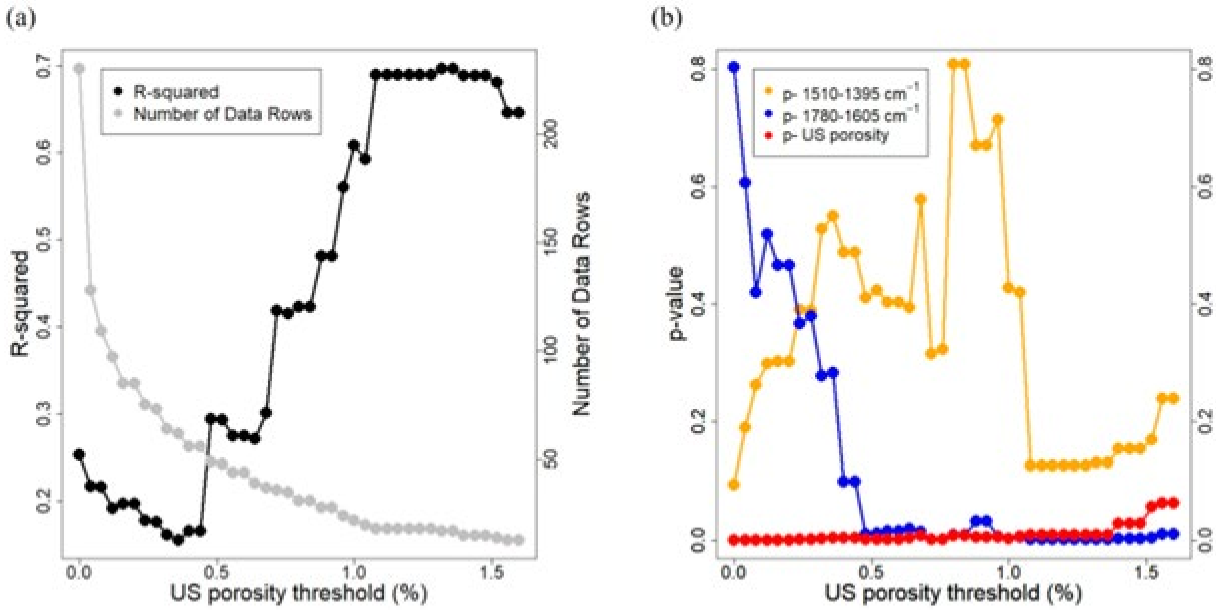


***Figure 15** - Statistical outputs of a multilinear correlation model constructed using predictors identified via the Random Forest model illustrated in Figure 14. It presents variations, as function of the pre-welding porosity threshold, of (a) R2, and (b) the probability value (p-) for IRRAS bands at 1510-1395 cm-1, 1780-1605 cm-1, and the pre-welding porosity level.*

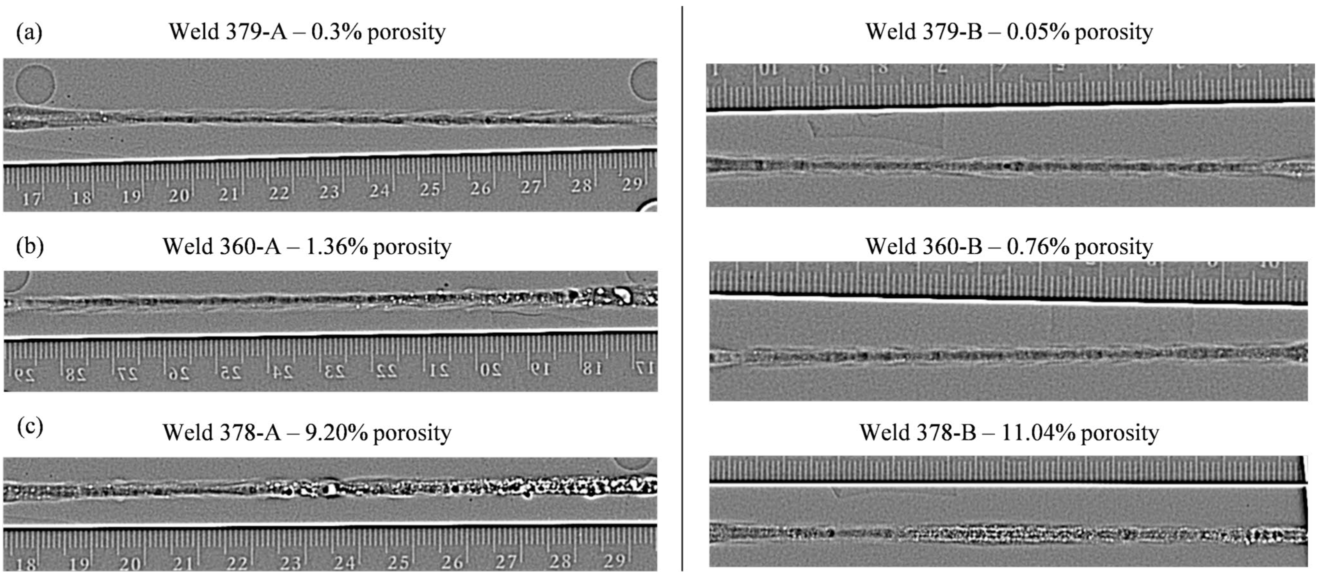


***Figure 16** - Examples of three laser welds at locations A and B on as-cast specimens using lubricant # 1, with varying extent of post-weld porosity.*

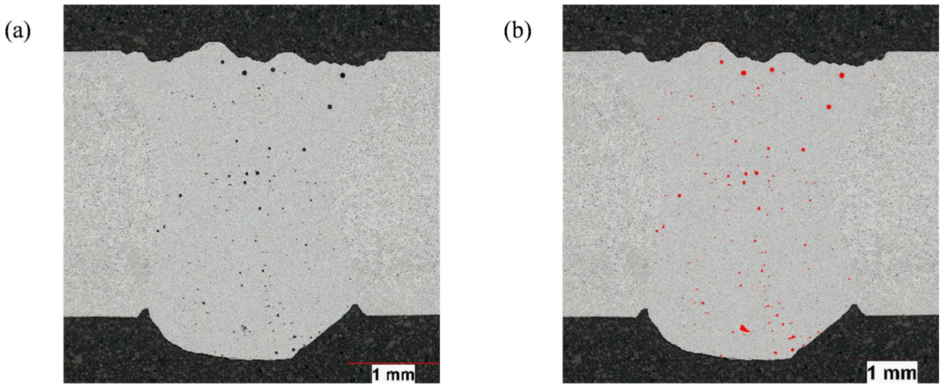


***Figure 17** - Examples of (a) autogenous laser weld transverse micrograph, (b) after Clemex Vision® routine.*

Conclusion

This investigation confirmed the important role of as-cast porosity on weldability of high-pressure vacuum die cast aluminium alloys and further highlighted other potential factors related to surface characteristics that could explain the gaps in correlation when looking only at as-cast porosity. Infrared methods, especially IRRAS, provided quantified information on the presence of oxides and lubricant residues on the castings that showed some correlation with weldability.

Different strategies to evaluate weldability of structural castings were tested, from segmenting each weld into individually-characterized sections to averaging a series of similar welds. The former works on local information to recognize the variations within and between cast specimens but is labor-intensive, while the latter may be more practical for e.g. lubricant selection but may be biased by initial variations in the cast specimens porosity. In terms of metrics, the correlations of infrared bands to post-weld porosity sometimes varied between data sets, which highlights the challenge of integrating interrelated chemical signatures into predictive models. The simple grayscale may present some potential as a cost-effective characterization method, but requires further investigation over a wider range of conditions. The extent of post-weld porosity could however not be fully explained with the models herein. This suggests that other factors related to casting (e.g. surface topography and micro-cracking[17] or small composition variations from casting to casting[2] that were not quantified) or welding, such as locally occurring instabilities, could also contribute to post-weld porosity. The methods herein could be applied at a wider production scale to refine the correlations, and extend them to processes like laser welding that are gaining attention to increase productivity. Alternative numerical methods based on clustering could also be tested in an attempt to improve the predictive capabilities.

This work also highlighted the complexity of optimizing multi-variate process chains. With a large number of factors with potential interactions at different steps in the manufacturing cycle, or even multiple process options for a given step, determining an optimal, robust process window can be challenging. In this study, welding parameters were for instance optimized by themselves using a single "reference" casting configuration; in practice, co-optimizing casting and welding could lead to a more globally efficient solution, but this brings an impractical number of variables to handle with common design of experiment (DoE) methods. Similarly, correlations between actual process parameters and weldability could be established to identify the highest-value factors to control in a process with a large number of variables: this could for instance be used to assess the part-by-part impact of variations such as melt temperature oscillations or local welding responses along the joint length.

Acknowledgments

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HPDC with Improved Melt Delivery Technology

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Abstract

The HPDC process is a series of co-ordinated steps leading to the desired cast part. The process has seen numerous improvements from the application of state-of-the-art technologies. Arguably one area that has not benefited so much is the important overall melt delivery phase. This is traditionally done by lifting the required prepared melt from the holding furnace to the shot sleeve port, by either ladle dosing or low-pressure pump dosing, and thereafter through the die via the shot sleeve plunger stroke. Atmosphere control technologies used in broader advanced manufacturing, including semi-conductor fabrication and metal additive manufacturing, potentially could be more rigorously applied to the HPDC dosing steps. After reviewing the current dosing process characteristics and limitations, a simple novel means to adapt these technologies is presented. Prototyping of this solution is the necessary next step to demonstrate the projected technical and production benefits versus any added capital and operating costs. This appears to be an excellent candidate for the NADCA R&D program with involvement of the industry user, research and supplier base.

Background

In the broad field of metal casting, unconstrained dropping of melt into a mold or die is well known as highly problematic, and to be avoided to the full extent possible. Thus elaborate melt flow paths of sprues and runners and gates, flow filters, etc. are used to control the flow into the casting cavity. These are primarily attempts to have optimized melt enter the cavity in a laminar fashion so that detrimental oxides and such are not formed with turbulent interaction with air, and then distributed throughout the casting.

A second deleterious problem encountered is entrained and trapped gas, or gas that is in solution with the melt and then released as it solidifies. Thus the final casting is prone to contain gas porosity, along with the oxides and foreign matter.

It is well known that the quality of cast metal is significantly affected by porosity as well as dross and foreign particle defects, with the diminishment in achieved physical properties directly related to the defect size, shape, distribution and number. Thus the metal casting industry has focused on the means to greatly reduce such defects.

The high-pressure die casting (HPDC) process is widely used to manufacture near net parts with good properties. The dominant horizontal cold chamber HPDC process requires that a dose of melt be dropped in to the shot sleeve port, after which the plunger injects the dose into the die cavity. This dosing requirement is handled by ladling or low-pressure (LP) pumping. Dosing has two primary requirements, first, to transport the melt from the holding furnace to the shot sleeve, and second, to provide the required mass with minimal temperature change and melt damage. Then, however, the dose is invariably simply dropped down into the shot sleeve, reaching classic turbulent flow before even entering the chamber, and well before hitting the bottom, with subsequent harsh 3-D flow along the shot sleeve. This gross turbulence forces the melt to react with the air in the shot sleeve environment, which is highly prejudicial to high quality index castings. And then in Phase II injection the dose is pushed into the air filled die in a violently turbulent manner. Arguably, there is no other casting process where the melt is moved to and through the part cavity in such a crude and harmful manner!

Air is approximately 78% nitrogen and 21% oxygen, with 1% predominantly argon with trace gases. Argon is completely inert, while nitrogen is near inert for aluminum melts, even though aluminum nitrides indeed can form when, for example, much higher temperature conditions are encountered. So it is the oxygen that reacts so well with most melts, instantly creating oxides. Plus, the format of oxides can further compound the deleterious effect, in particular oxide films, and especially the folded oxide films as per renowned Professor John Campbell et al, University of Birmingham.

Note that aluminum was just mentioned as it is the most commonly used metal in the HPDC process. Magnesium and zinc often use the hot chamber HPDC process, although cold chamber is also used, especially for larger castings. Interestingly, atmosphere control is an unavoidable aspect of all magnesium casting formats, while most people are not aware that turbulent molten zinc flows react with air in a notably more prejudicial manner than aluminum.[1]

Oxygen can be removed from an enclosed gas volume by vacuum application, as indicated in the table immediately below.[2] Note that at the highlighted c. 50mbar vacuum level that the atmospheric oxygen content has been reduced to the equivalent of a 1% oxygen atmosphere. Interestingly, such values are really only "rough vacuum" levels and nowhere near the higher vacuums necessary to essentially eliminate oxygen as required in scientific instrumentation and such, as well as for the processing of semi-conductors, or even the AM (additive manufacturing) processes ever more commonly used for HPDC conformal cooling cores and spreaders.

***Table 1** – Vacuum Protection from Undesirable Gasses*

	Pressure in mbar	Total Vol.-%	O2 Vol.-%	N2 Vol.-%	O2 ppm	N2 ppm
 HVHPDC	1013 50 mbar	100 1% O2	20	79	200*103	790*103
	1	0.1	0.026	0.1	264	1040
	10-1	0.01	0.0026	0.01	26.4	104
	10-2	0.001	0.00026	0.001	2.64	10.4
	10-3	0.0001	0.000026	0.0001	0.264	1.04
	10-4	0.00001	0.0000026	0.00001	0.026	0.1

Note that c. 50 mbar vacuum levels are typical of HVHPDC although they are only reached in the shot sleeve/casting die system once the dose is in the sleeve and the plunger has passed the port opening, thus producing the necessary fully enclosed volume to evacuate. The dose is typically just dropped through the shot sleeve port in air, so there is no beneficial reduction in oxygen during this turbulent dosing phase.

It would seem attractive to drop the dose in a pre-evacuated shot sleeve to eliminate this major source of dross creation. However, this requires the dose delivery into the shot sleeve to be through a fully enclosed volume, which is not readily accomplished by conventional dosing equipment.

It is thought-provoking to hear that a unique fully enclosed and evacuated dose delivery system is used by Tesla for their pioneering 'Gigacasting' process.[3] Apparently these very large complicated dies with core pulls could not be sealed well enough to generate the required HVHPDC vacuum levels by conventional means, and the much longer time that vacuum is applied through their pre-evacuation process resolved this problem. Interestingly, the associated low residual oxygen level this provides produces less dross in their castings. Further, as there is far less gas volume in the shot sleeve that the incoming dose must displace and less concern about splashing with little air to create dross, they are likely to have faster dosing times.

While not discussed thus far, replacing air with an inert gas can also very effectively eliminate oxygen. Gas purity then becomes important when the highest inertness is required, although this is much more inertness than the c. 1% remnant oxygen achieved in HVHPDC. However, it is important to note that just replacing air with inert gas by itself does not prevent gas porosity in cast metal.

The HPDC industry has found that replacing air with reactive gas can eliminate gas porosity, where oxygen flushing of the shot sleeve and die actually harnesses the turbulence to convert all the gas to widely dispersed oxide matter. This so called Pore Free Die Casting process (PFDC) was patented by ILZRO concerning zinc die casting.4 Nippon Light Metal subsequently did a lot of work on aluminum PFDC as can be understood from the example patent referenced.[5] They did use this process for OEM alloy wheel production in Japan for many years, although ductility was not at the level of their squeeze cast competitor U-Mold (Ube), or even the much more common LP, or tilt pour permanent mold/die cast wheels.

An interesting use of argon inert gas in casting near net shape parts is found in the magnesium thixomolding process[6], which is a hybrid HPDC- injection molding process. Here magnesium chips are fed into a feed screw shot sleeve arrangement for melt plasticization under an inert atmosphere. The argon gas environment is necessary to prevent detrimental reactions with air as the solid material is turned into a homogenous semi-solid before immediate injection into the die.

When talking of atmosphere in casting, it is important to understand that a very small amount of residual gaseous moisture is always an issue in melt handling, particularly with molten aluminum as it breaks down to hydrogen and oxygen at melt temperatures, leading to both hydrogen gas porosity and oxide product formation. Thus, controlled atmosphere casting must also address the reality of detrimental gaseous moisture. Lubricant carriers are another important related volatile issue to control in HPDC processing.

Inert gas is commonly used to remove the hydrogen gas in solution in aluminum melts by various sparging approaches, with RID (rotary impeller degassing) most common. However, this does not address the air encountered in moving melt to and through the shot sleeve/die system – the dosing dilemma.

There is thus an opportunity, if not a pressing need, to explore the use of specialty gases alone, full evacuation alone, or the two in combination for the complete HPDC dosing task, which are the so called atmosphere control technologies used in broader advanced manufacturing. However, this implies the need for a suitable robust means to apply comprehensive atmosphere control to HPDC dosing.

The Ultimate Dosing Solution

Before presenting a simpler means to advance our HPDC industry, it is useful to present a vision of the ultimate dosing solution. Note that dosing in this context is melt delivery into the shot sleeve and through the die; i.e., everywhere turbulent liquid metal can react with air, although it must also include dose pickup from the holding furnace. Further note this ultimate solution is applicable to conventional HPDC, HVHPDC and the nascent field of pre-evacuation HVHPDC processing, where the dose is dropped into the shot sleeve under vacuum, before the ensuing HVHPDC process.

Below in Figure 1 is a system to "correct" the conventional dose dropped through the shot sleeve port. The authors are calling this a "Flux Capacitor" system as the flow (flux) is captured and stored before release (capacitor); a quite different use for the term famously used in the movie Back to the Future!

Note that the conventional individual LP, or a ladle dose is simply dropped into the Flux Capacitor rather than the adjacent shot sleeve. As such, this delivery can be by any dosing technology, as long as optimized melt is not compromised on pickup and transport. Further note this happens one casting cycle ahead of the next shot, and inside this device the mass is adjusted, as is the temperature, to the desired optimum levels, and then held until the HPDC machine calls for the next dose. Then, the "corrected", now perfect dose is simply dropped through the shot sleeve port.

To be clear, the flux capacitor is essentially a miniature isothermal, inert atmosphere furnace, with internal capabilities as necessary to achieve the desired perfect dose delivery.

Further, the flux capacitor can be directly connected to the shot sleeve for particular beneficial additional capabilities, in particular by using inert flushing and/or pre-evacuation to eliminate melt delivery damage into the shot sleeve, and subsequently through die filling.

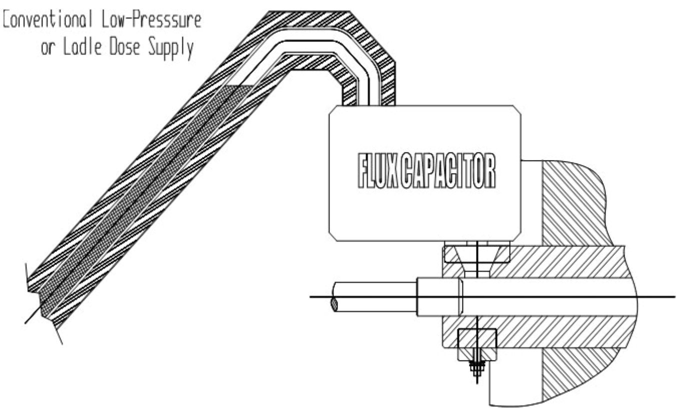

***Figure 1** - The Flux Capacitor.*

To illustrate somewhat how the conventional dose mass might be corrected, an earlier version of a flux capacitor is shown below in Figure 2. This was a patent pending solution shown to several interested parties some years ago. Note that the incoming melt is collected in a tilting ladle mounted on a load cell system inside a small furnace, so that mass is set by closed loop control, unlike the cruder open loop control of conventional LP dosing as well as open ladle dosing.

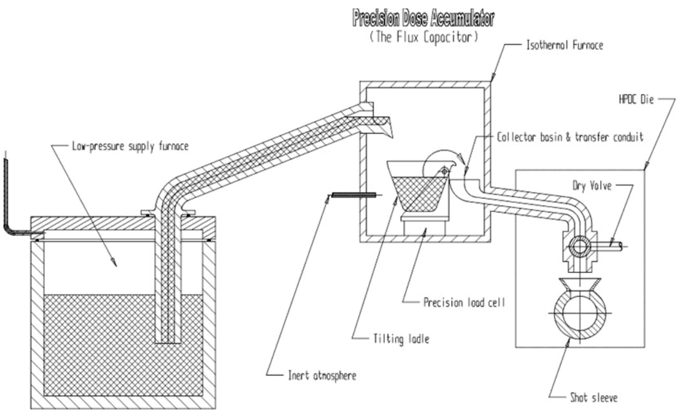

***Figure 2** - An earlier dose accumulation concept.*

A major HPDC supplier with in-house experience with centrifugal pumps, LP pumps and robotic ladling suggested that the melt flow into the above flux capacitor could not likely be controlled to the extent required. While this may not be absolutely correct, the advice has wisdom, and this concept was subsequently considerably reworked, and then expanded upon.

This brief introduction is merely to suggest the broad capabilities required to enhance HPDC processing through perfecting dose melt delivery. This description by itself is not necessarily novel; however, the technologies required to provide the capabilities most certainly are. The authors in fact have several flux capacitor variants detailed for presentation to interested parties under suitable non-disclosure agreements. Note however, these are concepts and not physical testing results, as full prototyping development of the ultimate dosing system involves notable investment of time and monies. This alone makes it prudent, if not even necessary to first explore the potential techno-economic benefits by a lower cost means.

Simple Means to Demonstrate Ideal Dosing Requirements

The key deficiencies of conventional dose delivery are melt compromise, mass variation and temperature variation, although there are multiple associated aspects in play – see the Appendix. The achieved technical levels in all HPDC parts suffer from these shortcomings, and certainly they also have an effect on the casting economics. However, the extent to which the techno-economics are effected is presently unknown, with some people thinking they are negligible, while others believing they are truly significant.

Melt damage from dosing into the shot sleeve and through the die can be ameliorated by use of inert/specialty gas purging/flushing, comprehensive vacuum or a combination thereof. Typically the dose dropped into the sleeve is already compromised with dross, which can be chiefly corrected with holding furnace melt flotation; and/or settling; and/or filtering; and/or avoiding or minimizing contact with the holding furnace surface on dose pickup; and/or appropriate use of atmosphere control.

Dose mass variation can be essentially eliminated by closed loop control, i.e., by use of appropriate accuracy and precision measurement capabilities in combination with the required fine control of incoming melt flow.

Melt temperature variation is necessarily best handled by the melt preparation and holding system, as well as the dose delivery into the flux capacitor with little variation. However, this alone will not provide zero temperature variation, where active heating and cooling of the working melt in the flux capacitor is required.

Given that melt damage is a significant issue, a simple means to determine the effectiveness of various levels and combinations of inert or specialty gas flushing and vacuum is an appropriate first exploration step. Note this is for conventional HPDC, HVHPDC and the nascent field of pre-evacuation HVHPDC. Then, with positive results, more in depth follow-on R&D on the individual dosing shortcomings is likely to be more readily fundable.

Shown below in Figure 3 is a stopper rod valve tundish setup that was used by one of the authors and associates to demonstrate pouring of zinc into a nitrogen flushed slab ingot mold.[1] When the enclosed mold atmosphere was plant air, there was much floating dross created after the plug valve was opened to allow turbulent melt free fall into the mold, while always maintaining a minimum melt level in the tundish to prevent air entrainment through the valve. Trials progressively reducing the oxygen levels before dropping in the melt showed less and less surface dross, and at c. 1% oxygen the solidified surface looked the same uniform grey color as the remainder of the slab ingot. Interestingly, melt temperature influenced this minimum dross color, a nice reminder of the importance of full temperature control. Surprisingly, when the atmosphere was essentially only nitrogen the cast surface looked like a polished mirror! This simple setup amply demonstrated the benefits of atmosphere control when transferring melt turbulently, and suggests a comparable need for trials on a horizontal cold chamber HPDC machine.

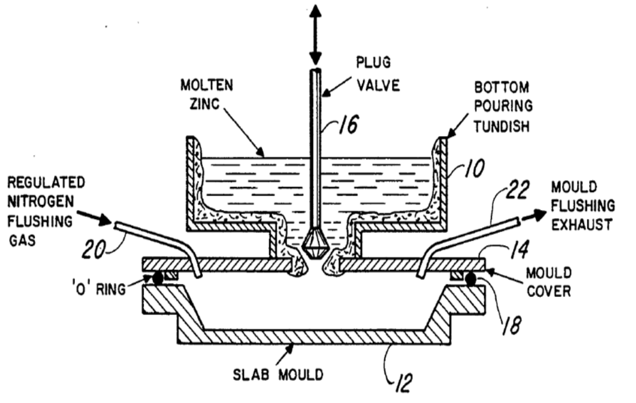

Figure 3 - *Mold atmosphere control using a stopper rod tundish.*

A key attribute of this zinc casting atmosphere control setup is a fully enclosed volume via a temporary sealing cover, which then is flushed with an inert specialty gas. Note that the melt delivery on/off valve, a so called stopper rod plug valve, is part of this cover and enclosure. Interestingly, the referenced patent features a means to provide atmosphere control without cover contact seals, and without requiring the on/off plug valve for melt flow control. Nonetheless, a stopper rod valve tundish, as part of a temporary enclosed melt delivery acceptance volume, may be a straightforward means to fully explore HPDC dose delivery atmosphere control.

A review of commercial foundry offerings revealed that while most ladling systems use a tilt-pour open ladle, at least one company uses the stopper rod valve tundish principle in a HPDC dosing ladle. Illustrated below in Figure 4 is a vacuum dosing ladle somewhat similar to the Meltec GmbH product.[7] Interestingly, their units have some patented features, based around the use of a load cell to measure the mass, which is an improvement on their earlier method of using melt contact probes to control the dose mass, as is most often used in open ladle dosing.[8] Thus, a load cell is now used to weigh the ladle and dose in a closed loop control system, and subtraction of the constant ladle system mass provides the dose mass, with both improved accuracy and process robustness. Meltec claim their equipment has the best accuracy of all commercial dosing equipment, between 0.2% and 0.5%, depending on the unit size. Conventional tilting ladle accuracies are more typically in the single digit range. LP dosing systems are notably less accurate than tilting ladle dosing, and biscuit correction feedback to the dose mass setting often becomes a necessary operational procedure, even if of limited value.

The Meltec patent teaches that the interior of the ladle is flushed with inert gas on dose delivery. To pick up the next dose, only the entry portion with the closed stopper rod valve is lowered into the holding furnace melt. The valve is then opened and vacuum is applied to the fully enclosed, inert atmosphere volume, to pull up melt from below the holding furnace surface into the ladle interior. Then, once the desired dose mass is reached the valve is closed. The ladle with the optimum cleanliness melt dose now protected by an inert gas and under vacuum is lifted up and out of the holding furnace, moved over to the shot sleeve region, and tilted generally at c. 45 degrees for dose drop delivery access to the port, as illustrated below in Figure 5. The ubiquitous 6-axis robot section shown provides precision movement, although other motion automation devices can be used.

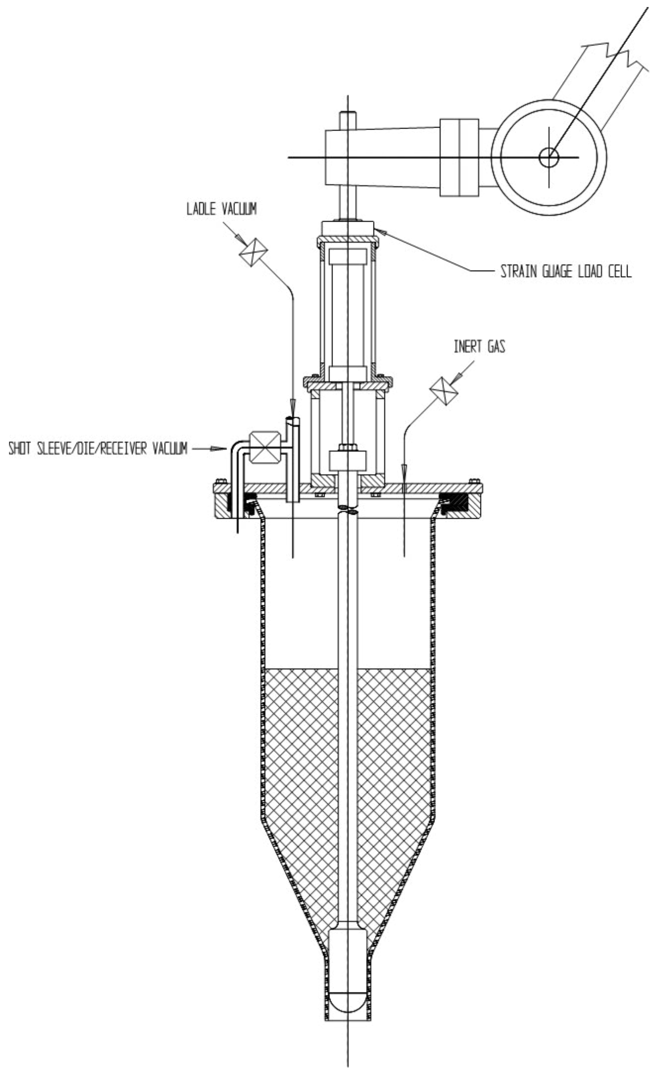

Figure 4 - *Meltec format ladle, adapted for enhanced dosing.*

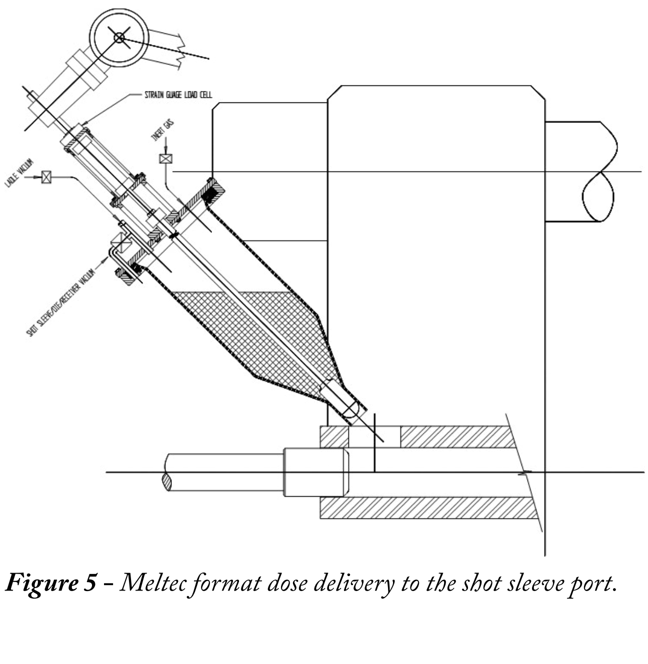

Figure 5 - *Meltec format dose delivery to the shot sleeve port.*

Note that the melt picked up by this stopper rod valve ladle dosing system format, that features inert atmosphere plus vacuum, has been handled with considerable care, and there is likely to be little damage so incurred. However, the melt is then dropped into the shot sleeve similar to all dosing methods, causing the considerable damage discussed earlier.

The key to adapting the discussed stopper rod valve dosing ladle format as a means for full atmosphere control is a simple metal receiver housing attached and sealed to the shot sleeve, as shown below in Figure 6. Note that there is a machined plate flange with sealing element to mate with the revised ladle flange once the ladle is seated in the dose delivery position. This receiver housing can be fastened by a machined mating surface with drilled and tapped holes directly in the shot sleeve, or it can be fastened with a clamping or strapping system as used for e.g., with clamp on devices for below the port shot sleeve cooling. The receiver housing can not be permanently attached since the shot sleeve must precisely fit through the mating hole in the fixed die half.

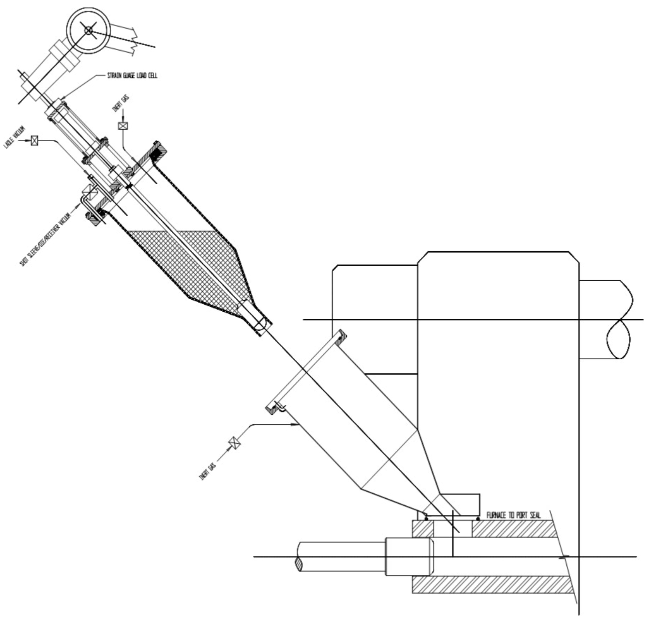

***Figure 6** - Meltec format ladle & shot sleeve port receiver housing.*

The stopper rod valve dosing ladle is shown fully inserted into and sealed to the shot sleeve receiver housing in Figure 7.

As shown in earlier Figure 4, the ceramic ladle is clamped to the revised ladle assembly metal cover through a sealing gasket, as in the commercial Meltec product. To suit the goal of dose delivery improved with specialty gas flushing and/or comprehensive vacuum, a similar sealing gasket is also used on the opposite annular ceramic ladle flange, sealing to the metal clamping ring. This ring and the cover are also sealed together, and are somewhat larger in diameter than the original Meltec product, as they are now used to seal to the receiver housing as shown in Figure 7. Note that the stopper rod conventional sliding seal to the cover is not shown in the illustrations.

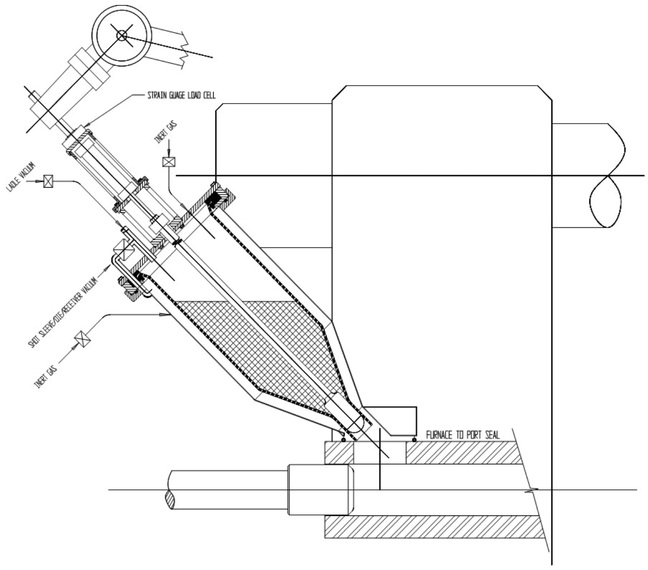

***Figure 7** - Meltec format ladle seated in the receiver housing.*

A second added capability shown in these illustrations is a tubular conduit that connects the Meltec ladle inert gas plus vacuum environment system to an appropriate region of the metal cover flange clamp through an on/off valve. Alternatively, a more advanced valve, such as a proportional control valve system or such, can be used if beneficial. This valve is normally closed so that the conventional Meltec format ladling system of vacuum melt intake can be used. However, once the ladle is seated and sealed to the receiver hood as shown in Figure 7, this conduit provides a functional gas connection path from the ladle interior to the generally annular volume between the ceramic ladle exterior and the metal receiver housing attached to the shot sleeve port, and thereafter the shot sleeve proper via the port.

As also shown in Figures 6 & 7, there is an inert/specialty gas supply to the ladle receiver housing interior through a simple powered on/off valve. Alternatively, this could be supplied through the ladle clamping flange, in a radial position and means similar to the interconnection tubular conduit, since the Meltec format equipment already has inert gas service to the ladle.

The just described changes/additions to the commercial Meltec vacuum ladle system format are clearly modest. Also note that the Meltec dosing system, featuring inert gas flushing with vacuum melt pickup to eliminate melt damage, is not fundamentally changed, and their self-proclaimed industry leading, closed loop system dosing accuracy is retained. However, once the improved format ladle is seated on the receiver housing and in position to drop the dose through the shot sleeve port, the additional hardware facilitates potentially powerful operational benefits.

Specifically, the adapted system provides an enclosure around the exterior of the ceramic ladle to the shot sleeve. Thus, on die closure there is a fully enclosed volume independent of the ladle interior, which can be immediately evacuated just before the dose delivery into the shot sleeve starts, i.e., the dose pre-evacuation process talked about earlier. It can be expected that this system will reach higher evacuation levels than normal HVHPDC since the vacuum is applied throughout the normal dose delivery time plus the conventional die injection time, which in total is, for example, something like c. 9 seconds versus the conventional c. 1 second of HVHPDC, just as Tesla discovered. Also note that with the interconnection gas conduit between the ladle interior and the annular housing volume, the vacuum on the melt can readily be equalized directly, proportionally or through any other such relationship to the enclosure vacuum as beneficial. Alternatively, the Meltec format ladle vacuum system itself can be similarly controlled in relationship to the enclosure vacuum provided by the conventional HVHPDC vacuum system, and then the interconnection conduit and valve are not required. In either case, once the dose is in the shot sleeve, the ladle interior and exterior, and the shot sleeve interior plus the die end up with a common high vacuum level when the plunger advances for die injection.

The above description covers the enhanced use of vacuum as one beneficial atmosphere control possibility. Inert or specialty gas purging/flushing is a further possibility. Specifically, once the ladle is seated in the receiver housing, the annular chamber connected to the shot sleeve can be immediately purged with inert or other specialty gas, exiting through the open shot sleeve end before die closing. This will also flush out the moist plant air in the shot sleeve as well as drive off lubricant volatiles, so that when the die is closed a short pulse in flushing gas pressure and flow is an option to purge the die. In any case the specialty gas in the sleeve will be pushed into and through the die during Phase I & II dose injection.

Note that controlled gas flushing implies the ladle is docked in the dose delivery position earlier than normal, as effective flushing takes more time than near instantaneous evacuation. This suggests it may be necessary to compensate for the extra heat loss from the ladle before the dose is delivered into the shot sleeve. It is possible to insulate, or even add and/or store heat around the ladle cylindrical portion that is not lowered into the holding furnace melt on dose pickup. Alternatively, insulation, plus heaters can be added on the exterior of the ladle receiver housing. Thus, an even earlier seating of the ladle in the housing can actually add back into the melt the heat lost during the ladle journey from the holding furnace to the shot sleeve.

With any of these or similar design possibilities, the shot sleeve open die system is flushed with an inert or other specialty gas, which continues when the die closes. Then the dose is turbulently dropped into the sleeve as in the normal HPDC process, but with essentially no detrimental gross dross creation and mixing. And just as importantly, this also applies to Phase I and the ultra-turbulent Phase II injection filling of the flushed die.

In the case without pre-evacuation, the incoming dose will displace the inert/specialty gas filled fully enclosed system, and thus the contained gas will be compressed and driven through and out the die venting. If this is problematic, as in impeding the dose drop into the sleeve, pulling the ladle back a short distance on the housing centerline will open the mating sealing flanges as a simple enhanced venting remedy. Then, once the dose is in the shot sleeve the ladle can be reseated as appropriate.

Note that this general description of inert/specialty gas flushing is without vacuum, as typical of conventional HPDC, although equally applicable to conventional HVHPDC, where the flushing gas and high vacuum would be combined once the plunger moves past the port. Further note that the flushing and vacuum can be applied before dose delivery – pre-evacuated dosing - for the expected ultimate dosing atmosphere control.

What has been described is a simple, low added cost modification to a commercially used stopper rod valve ladle system that can be used to explore a full range of inert/specialty gases, a full range of vacuum possibilities, and a full range of combinations of these two technologies. Such comprehensive atmosphere control is expected to greatly minimize melt damage in HPDC castings and produce notable techno-economic benefits.

Note that Meltec GmbH has had no input, nor any knowledge of this proposed testing equipment arrangement. Further note that stopper rod valve dosing ladles by other manufacturers can be readily adapted in a similar fashion. In essence, the Meltec system has been discussed because it is known to the HPDC industry, and its modus operandi is clearly spelled out in their referenced patent.

What is now required is an initial prototyping program to confirm the expected technical advantages resulting from comprehensive atmosphere control for minimizing melt damage, as well as yielding reliable indications of the all-important production economics. Then, with confirmed clear techno-economic benefits in HPDC production, studies on the remaining dosing shortcomings may be justified.

While this concept for comprehensive atmosphere control does not fully represent the first introduced ultimate dosing system, it actually goes a long way towards this ideal, in particular as it also has very good mass and temperature variation capability, in concert with near ideal melt pickup. Thus, systems based on this simple novel solution are expected to naturally lead to commercial use. To encourage this innovation through the equipment supply industry, utility patent protection has been filed for to help protect the required commercialization investment.

Summary

- There is significant melt damage during dose delivery from the holding furnace into the shot sleeve, and then through the die filling from highly turbulent reactions with air, negatively affecting the techno-economics of all HPDC processes, although to an unknown degree
- High sophistication industries such as semiconductor manufacturing, aluminum brazing, AM of die cores and spreaders, etcetera rigorously use specialty gases, true high vacuum, or combinations thereof to enable their strict performance requirements
- Specialty gas and/or vacuum have been explored somewhat in the past, and to an extent are currently used in the HPDC field, although not to comprehensively address the dosing dilemma (the air in the holding furnace/ladle/shot sleeve/die system)
- A simple novel means to modify a particular commercial HPDC dosing process has been conceived to enable comprehensive atmosphere control, and is presented herein to raise interest in exploring the potential significant techno-economic benefits

- This dosing enhancement features an equipment format with the best known minimum dosing mass variation, in parallel with optimized melt pickup and decent temperature control, all which will help clarify the techno-economic benefits of comprehensive dosing atmosphere control
- This dosing atmosphere control system is equally applicable to cold chamber aluminum, zinc and magnesium alloy HPDC processes
- Prototyping program partners and funding is currently required, with the NADCA R&D program a seemingly excellent candidate to play a key role, with the desired involvement of the industry user, research and supplier base

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Appendix

Dosing Issues

- Melt mass variation into the shot sleeve dictates extra dose mass for every shot and the associated compounded costs
- HPDC injection is rarely started at the ideal moment since dose mass variation has a significant unaccounted for effect on injection timing, affecting quality, die life, etc. and the associated economics
- Delivered dose temperature variation has a significant effect on casting, which is predominantly always a thermal balancing act
- Similarly, dose mass variation also affects the thermal balance throughout the casting process
- Dropping melt through the shot sleeve port results in considerable turbulence, which in the open plant atmosphere creates and entrains harmful oxide films and general dross, which ends up throughout the gross and net casting, prejudicially affecting quality production cost
- The dose dropped through the sleeve inevitably already has melt damage and entrained dross that also negatively affects the results
- Continuously dropping each dose onto the same shot sleeve region immediately under the port compromises shot sleeve life, as well as creating significant geometry distortions, affecting the overall plunger/sleeve performance and the resulting castings
- The dose delivery time is a significant portion of the casting cycle, and this time can be reduced if the above negatives are resolved, providing a noteworthy decrease in quality casting costs
- All the various dosing shortcomings listed interact synergistically to increase variation and cost beyond each individual contribution
- As stated by the most famous quality guru, W. Edwards Deming, "Uncontrolled variation is the enemy of quality" and thus casting economics, the key to business success

2023 ANNUAL REPORT

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NADCA
NORTH AMERICAN DIE CASTING ASSOCIATION

LETTER FROM THE PRESIDENT

DEAR DIE CASTING PROFESSIONAL,

The first half of 2023 was fairly strong for our die casting industry, while the second half of the year slowed due to economic uncertainty and the UAW strike of the Big 3. Despite the strike, light vehicle sales were over 15 million in 2023, up over 1 million units when compared to 2022. While there is a strong push to transition to electric vehicles (which will have significant die casting content), almost every automaker has tempered their EV projections for both 2024 and 2025. Housing, the second largest market served by high pressure die casting, surged to 1.5 million privately-owned housing starts (annually) in Q4 of 2023, despite high interest rates. While the general sentiment is concern for our economy in 2024, many are also optimistic, especially for the second half of the year.

Mike Meyer
President, NADCA

NADCA was very active in 2023. Three podcasts were completed: Past, Present and Future, Die Casting in Our Everyday Lives, Economic Outlook and Trends in Die Casting, and 3D Printing Applications for High Pressure Die Casting. A total of 17 Webinars were held, with 8 having new content. The Harbour Group assisted our members with 10 plant assessments in 2023. From an R&D perspective, 12 projects were closed in 2023, with 8 new projects being kicked off. Since August, 5 projects were kicked off. Additionally, we received approval on 2 proposals; Characterizing, Identifying, and Controlling Factors to Improve the Production of Thin-Wall Ferrous High-Pressure Die Castings, and Advanced Thermal Management for High Pressure Die Casting. The funding for these 2 proposals is provided by the DLA, and is $2.5 million, excluding our cost share. 2024 promises to be an extremely busy year for our team!

“ENSURE THAT YOU ARE UTILIZING AS MANY OF NADCA'S SERVICES AND PRODUCTS OFFERED AS POSSIBLE!”

The in-person events that were held in 2023 were the Executive Conference, Plant Management Conference, Government Affairs Briefing and Fly-In, and our Congress & Exposition. Additionally, we held many State of the Industry Presentations for our Chapters. Our plan is to visit every chapter in 2024. I am looking forward to seeing everyone at our “big” show, The Die Casting Congress and Exposition, in Indianapolis, September 30 – October 2, 2024.

In the Annual Report that follows, you will find additional information and details on the major activities and accomplishments of NADCA during 2023. The information is intended to not only provide a report on 2023, but to heighten the awareness of progress that is being made and all that NADCA has to offer its membership base. Members, ensure that you are utilizing as many of the services and products offered as possible. They are for your company’s continued success and your personal success. Non-members, gain all of the benefits you are missing out on by becoming a member today!

Lastly, I wish to express my sincere thanks and appreciation to the membership base, exhibitors, speakers, researchers, committee chairpersons and committee members, the NADCA Board of Governors, and Chairman of the Board, Hal Gerber for all the support you provided throughout 2023! Together we can continue to keep our association and our industry strong. Looking forward to seeing as many of you as possible in 2024.

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Stephen Udvardy*
President

**In August 2023, Mike Meyer stepped down from his previous role to assume the position of President at NADCA. Stephen Udvardy retired in 2023.*

MEMBERSHIP

THE ASSOCIATION'S FOUNDATION

As the industry's trade association, NADCA represents a range of companies directly and indirectly involved in the die casting industry, including captive die casters, custom die casters, suppliers, OEMs and job shops.

NADCA is incredibly pleased to welcome these 19 companies that joined (or were reinstated) the ranks of NADCA corporate membership in 2023: DME Company, LSP Technologies Inc., Centrifugal Castings, Castool Heat Treat, Pace Industries Port City 2, Bridgeport Fittings Inc., Dart Casting Incorporated, Nexthermal Corporation, Marchesi Light Alloy, Kwikset Corporation, Caldwell Casting Company, Kirby Metal Recycling, Finkl Steel, Finkl Steel - Sorel, Schlage De Mexico, Stotek Inc., Hanson International, Cottingham & Butler and Dalite.

Membership had an uptick in 2023 with 306 NADCA corporate members. Education was identified by Corporate Members as being one of NADCA's best benefits. In 2023 Corporate Select education block was created - giving Corporate members over 64 hours of online training for free. Note that 16 of those hours are training available in Spanish and NADCA will continue to increase that in 2024.

Once again, access to the show floor at the Die Casting Congress & Tabletop was free for all 1766 individual members. Individual membership increased by over 70 members this year over last. Individual members receive discounted pricing to attend other networking events, purchase courses and publications.

MEMBERSHIP PLUS PROGRAM

NADCA Membership Plus continues to have a strong membership base among the engineering community. Membership Plus is an upgrade that offers access to exclusive engineering calculators and an online technical community for interacting with other North American-only engineers. Plus members had access to the Online Flash Predictor, Gating App, the PQ^2 App, Fill Time App, Greenhouse Gas Calculator v1.4, Aluminum Property Estimator v0.1 and Frequently Used Equations. A revitalization of this membership is coming in 2024. Be on the lookout.

PLANNING FOR THE FUTURE

NADCA's Commitment

NADCA is committed to promoting industry awareness, domestic growth in the global marketplace and member exposure.

Areas of Concentration

CHAPTER RELATIONS: Foster community and local business relations, attend speaker and networking events, influence both association direction and industry change.

RESEARCH AND DEVELOPMENT: Identify industry needs and expand funding sources that optimize die casting processes and techniques.

EDUCATION: Present industry knowledge for creating improved die cast parts and processes, incorporating the latest standards and educational curriculum.

MEETINGS AND EXPOSITIONS: Provide public and networking opportunities to develop customer relations and position association members as leaders in die casting.

MARKETING: Bring business and engineering focus to die casting as the process of choice.

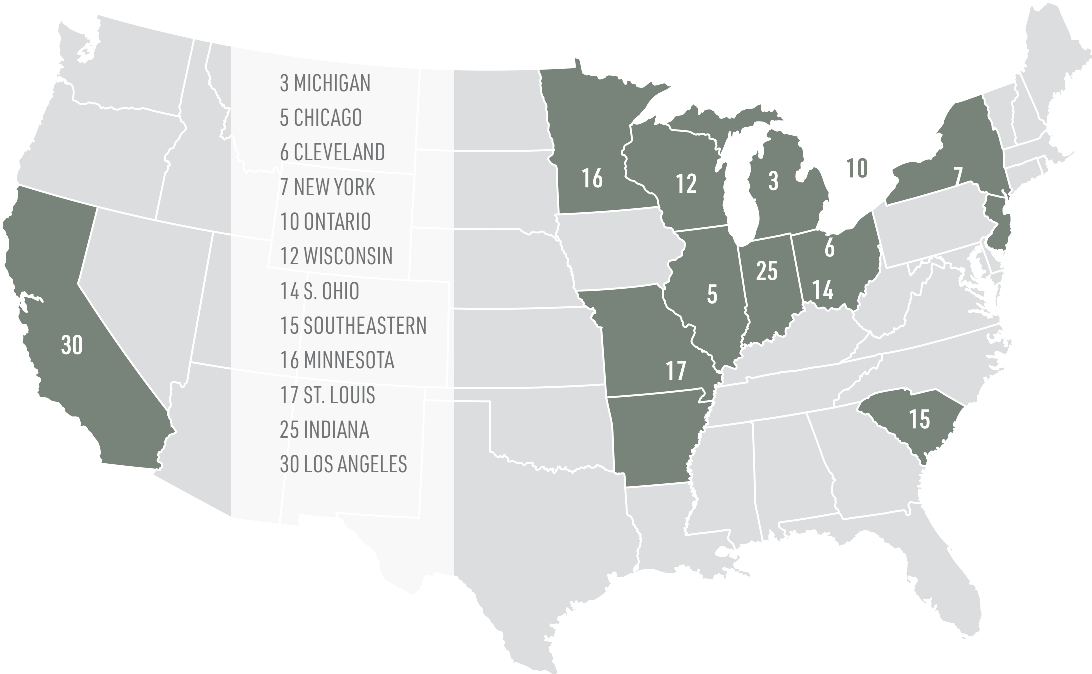
MEMBERSHIP: Provide member base with industry news, technical information, promotional activities, networking and referral opportunities and trade events.

GOVERNMENT AFFAIRS: Foster strategic alliances and increase grassroots efforts to effectively bring industry matters directly to leaders in legislature and Washington.

GLOBALIZATION: Assert NADCA's member die casters' presence in the global and domestic markets.

NADCA CHAPTERS
MEMBERSHIP AT A LOCAL LEVEL

NADCA membership and resources are represented across the country through the efforts of its 12 active area Chapters. In person events and meetings were back in full swing in 2023. Chapter dinners and presentations, as well as golf outings, filled local chapter calendars. Active chapters are located in:



Chapters receive a special rate for hosting NADCA training and in turn, may charge their attendees what they feel is a reasonable price for courses. Some chapters even offer free courses to any NADCA member.

In addition, NADCA provides its chapters (in good standing) a rebate program, based on total membership. In 2023, NADCA provided each chapter with options for utilizing their rebates such as:

- A Chapter In-Plant Course.
- Events including live webinars, national education courses and conferences.
- Orders including publications and courses through NADCA's Online Education System.

INDUSTRY AWARD WINNERS

TECHNICAL COMMITTEE MEMBER OF THE YEAR

Rob DeNeff

BEST CONGRESS PAPER

A.I. Vision System for Automated Casting Quality Inspection

Boxiang Zhang, Xiaoming Wang, Baijian Yang (Purdue University); Corey Vian (Stellantis)

EMPHASIS ON EDUCATION

Kamtek Castings

SAFETY, ENERGY & ENVIRONMENT

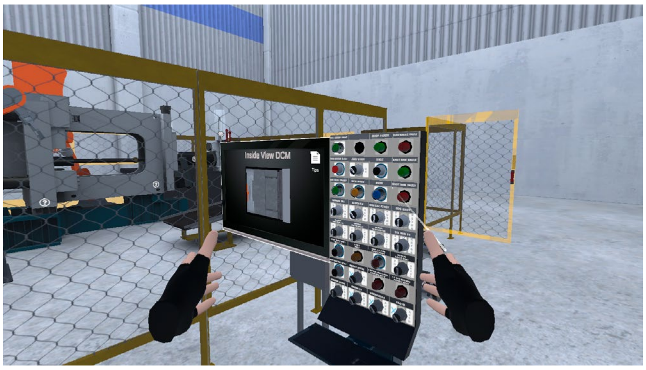
2023 was the hottest year on record for global temperatures, with a temperature 0.27°F higher than the previous record set in 2016. These increasing temperatures and the extreme weather conditions are influenced by human activity. The U.S. government, along with governments in Europe and other parts of the world, is attempting to reduce the carbon emissions by pivoting to renewable energy sources. This extends to automobiles, which is the largest market for die castings. For die casting to continue to thrive the industry will need to start producing more parts for electric vehicles, which historically use less die castings than internal combustion engine vehicles.

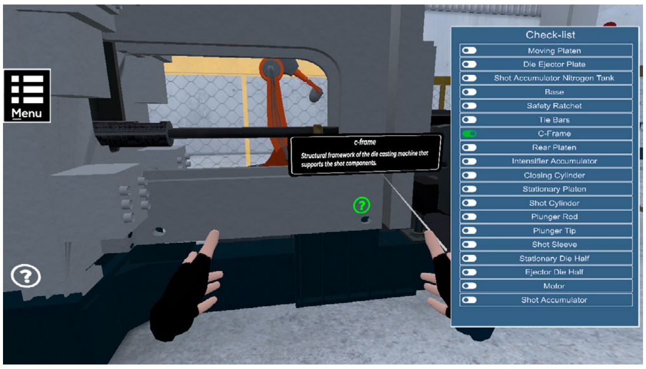
During the 2024 Die Casting Congress a discussion panel was held on decarbonization. There was good discussion on the causes of climate change and what can be done to improve it. Part of the takeaway from the discussion was the need to look at the entire life cycle of the product. The International Zinc Association (IZA) has mapped out the life cycle for zinc products. Most of the carbon emissions for the zinc market come from mining and smelting, highlighting the need to utilize more recycled metal.

If we were to analyze the aluminum life cycle mining and smelting would have an even larger chunk of the carbon emissions than for zinc. Fortunately, for die casting, recycled aluminum is commonly used and the light weighting benefits to the end market reduces the end product's energy usage. That leaves production of the casting as the life cycle sector to review. A project has been proposed to NADCA for gathering data on energy usage in die casting. This would provide a benchmark for a fossil fuel reduction roadmap.

Safety in die casting continues to improve. The Days Away, Transfers, and Restrictions (DART) rate for the die casting industry dropped in 2022 to 2.4, from 3.4 in 2021. NADCA continues to provide in-plant and online safety courses, as well as incorporate safety in many other courses. The Virtual Reality (VR) die casting machine and furnace, as well as the die casting fire safety are available for corporate members. The programs run on the Meta Quest 2 or Quest 3 headsets. Anyone interested in obtaining the software should contact NADCA.

As we move into 2024 we should look to make die casting cleaner and safer for ourselves, our coworkers and our community.





KEYS TO PROGRESS
BENCHMARKING, SURVEYS & STATISTICS

NADCA's benchmarking, plant assessments, surveys, and statistics generate pertinent information for making wise business decisions and improving overall company performance and profitability. The benchmarking effort captures information on key data and performance indicators and provides a company specific confidential report for each participating company, showing how the company compares to the population. Indicators include revenue and efficiency, average interest to total debt, return on capital, and inventory turns to cite a few. Other data includes capital spend, die cast utilization, scrap levels as a percent of revenue, material cost as a percent of revenue and more. Plant assessments, which are conducted in 1 to 2 days, provide a scorecard for various departments based on a series of questions and observations, and a company specific report showing how the various departments rank among the population and best-in-class. What is revealed are areas that can be improved upon for better performance. What is shared are best practices for driving improvement. Several companies have made improvements through these highly effective assessments. In 2023, 10 Plant assessments were completed. Due to the importance and usefulness of benchmarking information and the effectiveness of the plant assessments, these activities will continue in 2024 in partnership with Harbour Results Inc. The benchmarking survey report is free to Corporate Member participants and NADCA will fund $5,000 towards the plant assessments for our Corporate Members.

The Wage & Benefits Survey is conducted on an annual basis and covers wage levels for various job functions, health insurance cost, paid vacation and paid leave policies, pension plans, and profit sharing. With attracting and retaining a qualified workforce as one of the top challenges confronting the die casting industry today, the wage and benefits data is invaluable! Also in 2024, NADCA will be soliciting Census data from our members. We will gather the number of machines in North America, tonnage sizes, alloys cast, etc. Additionally, we will soon be releasing the number of new cells installed in North America in the last 5 years, the number of cells and tonnage sizes.

In addition to the above surveys and plant assessments, NADCA conducted 10 other surveys in 2023 related to shipments, quoting activity, capacity utilization, personal protective equipment, and events. The surveys were as follows:

- Quarterly Business Barometer (four)
- Executive Conference Attendee Survey
- Plant Management Conference Attendee Survey
- Heat Mitigation Programs in the Die Casting Facility
- NADCA Education for Corporate Members Survey
- Congress & Tabletop Exhibitor Survey
- Congress & Tabletop Attendee Survey

Survey participation ranged from 15-70 companies.

The 2024 Executive Conference will feature presentations on the US Economy, status update on the US Manufacturing Sector, Industry 4.0, Rising Insurance Costs, an R&D Update, a Washington Update, and a 2024 pricing strategies presentation by Ducker.

INTERNATIONAL DIE CASTING COMPETITION

NADCA organized the International Die Casting Competition in 2023. Winning castings were displayed prominently at the 2023 Die Casting Congress and Tabletop. Since 1972, the competition has featured the top designed die castings annually. Seven winners in various categories were selected. The list of winners includes:

ALUMINUM - UNDER 1 LBS
DYNACAST - LAKE FOREST

ALUMINUM – 1 TO 10 LBS
IMPERIAL DIE CASTING,
A DIVISION OF RCM INDUSTRIES

ALUMINUM - OVER 10 LBS
MERCURY MARINE -
MERCURY CASTINGS

ALUMINUM STRUCTURAL
SERES AUTOMOBILE CO.,LTD.

ALUMINUM - ASSEMBLY
MICHIGAN DIE CASTING LLC.

MAGNESIUM OVER 0.5 LBS
MERIDIAN LIGHTWEIGHT
TECHNOLOGIES

ZINC UNDER 6 OZ
LAKESIDE CASTING SOLUTIONS

ZINC OVER 6 OZ
BRUSCHI S.P.A.

MEETINGS & CONFERENCES

In 2023, NADCA conducted the Executive Conference, Plant Management Conference, Government Affairs Briefing and Die Casting Congress & Tabletop.

The Die Casting Executive Conference was March 5-8, 2023, on Marco Island, Florida at the Hilton Marco Island. The annual conference was a three day event that featured presentations on: Tactics and Strategies the Smartest Leaders are Making to Navigate and Grow in 2023 and 2024, government affairs update, Die Casting Opportunities in the Battery Market, Trends in Die Casting: Applications/Design - Alloys - Processes, and Emotional Intelligence for Extraordinary Leadership. This event also featured a panel discussion on Dealing with Supply Chain Issues. This meeting had record setting attendance for an Executive Conference.

The 2023 Plant Management Conference was May 2-4 at the DoubleTree by Hilton Columbus Dublin in Dublin, Ohio. Special presentations included Workplace 2023: Tactics and Strategies for Finding and Retaining the Best Talent and Leaders & Managers. The conference also featured Hot Topic break-out discussions. Honda Transmission Manufacturing Plant provided a tour for conference attendees.

The Government Affairs Briefing took place on June 20-21, 2023, in Washington, D.C. Twenty-one attendees joined NADCA and The Franklin Partnership for visits to Capitol Hill. This gathering offers a distinctive opportunity for members to journey to Washington for face-to-face discussions with their U.S. Senators and Representatives. It's a prime occasion for manufacturers to convey directly to government officials how their policies impact millions of businesses and their employees.

The Die Casting Congress & Tabletop was held on September 19-21 at DeVos Place in Grand Rapids, Michigan. Sponsored by solely NADCA, the event attracted over 100 exhibiting companies and over 900 attendees. This event featured three days of Congress sessions during which technical and management presentations were given by experts from around the world. These presentations offered sessions in several different fields of metalcasting, including: Analyzing Mechanical Properties of Die Castings, Data Driven Process Control, Extending Die Life, Use of Additive Manufacturing for Improved Tooling, Technology and Processes for Secondary Operations, Advanced Die Casting Alloys, Improving Metal Melting & Handling and Utilizing Computer Simulation & Modeling.

TRAVEL-FREE EDUCATION

WEBINARS

In 2023 webinar participation was lower than usual. Simply put, NADCA did not offer as many webinars this year. With busy instructor schedules and research projects efforts were shifted to different areas. However, NADCA webinars will bounce back in 2024 bigger and better than ever. Members still value the cost and time saving aspect of online education. We are working hard on providing more topical content and advancements in technology.

NADCA is also looking to expand its offering by converting courses into different languages for our membership. This process and exploration is still in its infancy but as technology and AI grow so does the opportunity to utilize it for course conversion.

An excellent option for those companies looking to run a full regiment of Online Education is still, the administration features. This feature allows tracking by an assigned admin and can be very helpful when following up on course completion. Purchasing access to an individual course through the system allows you access to the recording, presentation, support material and quiz for one year. New webinars will continue to be made available through the Online Education System within one week of their air date. To view all course available, visit the NADCA Marketplace and search "online education".

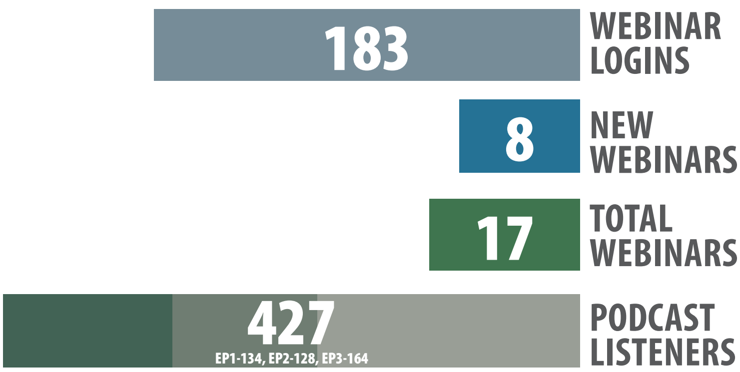
NADCA looks forward improving and expanding our webinar and online education options.

To view or register for upcoming webinars, visit www.diecasting.org/webinars.

PODCASTS

Launching the podcast program in 2023 year posed several challenges, particularly in coordinating schedules with busy individuals. While the program was well received, it fell short of our anticipated listener numbers. In 2024 NADCA will revamp the podcast format and explore topics that resonate more strongly with our members. Stay tuned for exciting updates!

WEBINAR & PODCAST SNAPSHOT



2023 WEBINAR COURSE OFFERINGS

Are You Running Perfect Every Time?

Driving Flexibility into Your Business

Good Leaders Go See, Go Act

Gating & PQ2 Series

How to Reduce Your Carbon Footprint

Technical Overview of Frech's Zinc Hot Runner Gating and Dosing System

2023 PODCAST OFFERINGS

Episode 1 - Past, Present and Future: Die Casting in Our Everyday Lives

Special Guests: Corey Vian, Mechanical Engineering Manager of Stellantis – Kokomo Castings, Todd Olson, CEO of Twin City Die Castings Company in Minneapolis, Minessota & Dave Haener, Engineering Manager of Dynacast Elgin.

Episode 2 - Economic Outlook and Trends in Die Casting

Special Guests: Greg Risch, President & CEO of Gibbs Die Casting Corporation & Eric Treiber, President & CEO of Chicago White Metal Castings Inc. .

Episode 3- 3D Printing Applications for High Pressure Die Casting

Special Guest: Ante Lausic, Lead Process Engineer of Metal AM at General Motors & Dr. Steve Midson, President of The Midson Group.

NADCA ONLINE

WWW.DIECASTING.ORG

In 2023, NADCA continued to add to its website on a regular basis.

In every year, the Technical Archives are updated continuously. Articles from Die Casting Engineer magazine are added on a bi-monthly basis, and Technical Papers presented at each year's Die Casting Congress are added. NADCA held the Die Casting Congress & Tabletop in Grand Rapids, Michigan.

Look for updates on the website this year as NADCA staff aims to visit every single NADCA chapter at some point. Presentations such as the State of the Industry report plan to be given. Come engage with NADCA staff and tell us in person what we can do for you!

NADCA continues to be very excited to be able to offer all its services to its members and will continue to keep the website, content and services relevant to your needs. Any feedback and constructive criticism is always welcome as NADCA looks to provide the services that you, the member, would like to see.

MARKETING

You can always grow, improve and do more. The NADCA website has continued to do just that in 2023. Gaining feedback about the site allowed us to adjust certain areas to be more prominent and easier to access. The Die Casting Capabilities Directory and Suppliers Directory are now spotlighted on the NADCA homepage, making one of our greatest tools just a click away.

Marketing our industry to the next wave of workers is tremendously important. NADCA has created a video that highlights the industry and it's workers. If you haven't seen it yet, "Die Casting: Shaping America's Future," can be located here: http://tinyurl.com/tbv778y5. Feel free to us this video in youth outreach activities and to post to your socials.

NADCA continues to monitor the performance of the Die Casting Design website. The site averages roughly 3,000 visitors a month with its top preforming pages being: Product Specification Standards Download and Standards for High Integrity and Structural Die Casting Process Downloads, Design (Parting Lines), Aluminum Alloys, Die Casting vs Powder Metallurgy, Stamped Metal, Die Casting vs Metal Extrusion, Design (Parting Lines) and Aluminum Alloys.

This year at the Die Casting Congress and Tabletop we honored the winners of the International Die Casting Competition. The winning castings were on display in the exhibit hall paired with 3D rotating images. Winners can be viewed in more detail online here: www.nadcaawards.com.

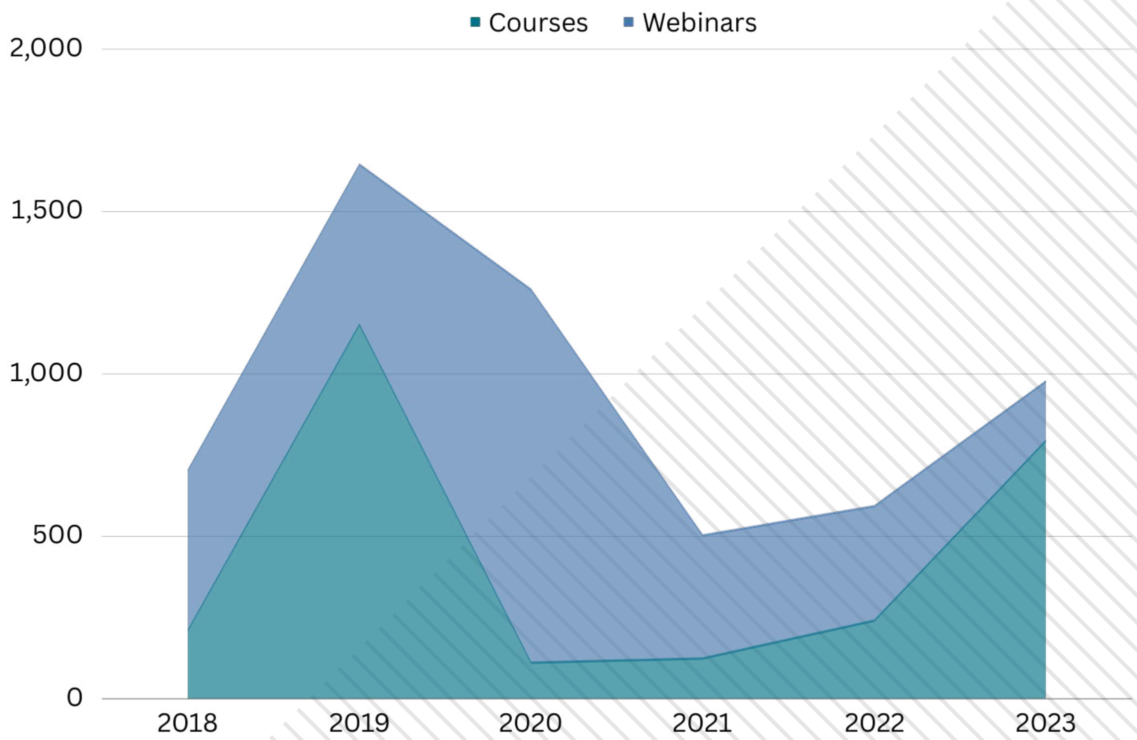
EDUCATION

Chapter, In-Plant, In-House and Train-the-Trainer attendance in 2023 totaled 786 students for 37 course offerings extended by NADCA. There were two chapter courses with 58 students and 35 In-Plant courses with 728 students. We did not offer any additional training seminars or workshops in 2023. We continued National Courses held in Arlington Heights, Illinois. We held 5 courses with 9 students. Therefore, the grand total for 2023 attendance was 795.

The online education system uses webinars and existing online courses to make up its catalog of over 300 hours of training. A course in the online education system includes a recording of the course, a PDF of the presentation, any applicable books to support the course, and a test. Courses are sold either in training blocks to companies (available for corporate members only), and job kits or individual courses to individuals in North America. In 2023 NADCA launched an initiative for corporate members to utilize select trainings as part of their dues. In 2023, 5 training blocks and 8 job function kits were utilized by corporate members. 32 individual courses were sold in 2023.

Webinars saw a decrease in attendance in 2023. These hour-long presentations typically run every week and cover many topics. Around 183 people attended webinars in 2023. A total of 17 webinars were held.

COURSE & WEBINAR ATTENDANCE LEVELS 2018-2023



There were nineteen (19) R&D projects in the beginning of 2023 with a total leveraged value (direct funding plus cost share) of approximately $6,601,000.00. During the year 12 projects were completed. #211 Properties Versus Section Thickness for Specifications and Standards, #212 Die Casting High Temperature Alloys, #213 Rapid Creation of Tooling with Conformal Cooling, #214 Advanced Engineered Coatings with Extended Life for Tooling, #215 High Pressure Die Casting Process Simulation Development for the Shop Floor, #220 Effect of Duplex PVD Coated H13 Steel on Thermal Fatigue Cracking, #223 Die Lube Splash Test Development, #226 Die Casting Manufacturability Analysis Tool – CastView, #228 SPR joint quality for HPDC,#231 Failure Analysis of Additively manufactured Components, #232 Corrosion and Crack Resistance of Die Internal Cooling Lines for Different Tool Material, Manufacturing Processes, and Water Quality, #236 Virtual Reality – Fire Safety.

6 Projects were started in 2023, bringing the portfolio to fourteen active projects at the end of 2023. The projects added to the portfolio include:

#240 Enhancing Performance & Longevity of Copper Plungers for Diecast Applications through Graphene Surface Coating.

#241 Properties Versus Section Thickness for High Elongation Structural Alloys.

#242 Surface Roughness on the Fatigue Resistance of Die Inserts Additively Manufactured Die Steel.

#243 Modeling Steel High Pressure Die Casting.

#244 Externally Solidified Product (ESP) Formation and Control in Die Casting

#245 Characterizing the Microstructure, Hardness, and Aging Response of Nine Compositions of Steel Die Castings.

2022 ACCOMPLISHMENTS

Project #211: Properties Versus Section Thickness for Specifications and Standard was completed by Paul Brancaleon at the North American Die Casting Association. The project tested the mechanical properties of five common aluminum die cast alloys from four different thicknesses. The alloys tested were A380, A360, B390, B360 and A304. The thicknesses tested for each alloy were 2mm, 3mm, 5mm, and over 8mm. The mechanical properties tested for each thickness was the Ultimate Tensile Strength (UTS), the Yield Strength (Ys), and Percent Elongation (E%). The Summary data has been published in the NADCA 402 publication.

Project #212: Die Casting High-Temperature Alloys was completed by Dr. Charlie Monroe of the University of Alabama, Danny Portillo and Carlos Larrazabal of the University of Alabama and the University of Alabama Birmingham. Also, by Dr. Steve Midson of the Colorado School of Mines. The project started by determining the viability of die casting titanium alloys. Due to the complexity the project was revised to focus on die casting steel. The trials were run using a single cavity die cast die running in a 900-ton Lester die cast machine (DCM). The DCM was fitted with a monitoring system to give real time feedback on the shot parameters and the shot profile. There were five separate trial runs casting 15-5 PH, 17-4 PH 316 and S7 stainless steels. In total there were nine separate stainless-steel alloys used to produce die castings. The process utilized an on-demand melting system by melting precut round slugs using an induction coil developed at the University of Alabama. The die casting had a single runner and was a round disc shaped casting.

The microstructure of the steel parts were also evaluated. The structure showed three microstructural zones. 1) A thin surface chilled layer similar to that observed in aluminum die cast parts. 2) a columnar dendritic zone further into the casting and 3) a cellular type zone towards the center of the die casting.

Project #213: Rapid Creation of Tooling with Conformal Cooling by Dr Carl Soderhjelm from the University of California Irvine. This project confirms that metal additive manufacturing enables highly custom design of cooling lines in tools/inserts for high pressure die casting. This flexibility in cooling line placement offers highly efficient heat extraction which decreases the operating temperature by more than 15%, which was confirmed by both simulation and industrial trials. The benefits shown in this project are reduction in downtime and reduction in scrap rates, which will improve production lead times. Part of the downtime in a studied tool was due to die soldering on the insert which was completely removed when conformal cooling was applied. The casting produced suffered rejections due to high pressure oil leakage which was reduced by 30% after conformal cooling was applied.

Project #214: Advanced Engineered Coatings with Extended Life for Tooling was completed by Dr. Stephen Midson of the Colorado School of Mines. This project was to identify die casting parameters and coatings that could be applied to the surfaces of die casting dies to minimize or eliminate the need for conventional die lubricants during the die casting process. As demonstrated by the tests performed at The Ohio State University, totally covering a simple configured die casting die with a thin-film coating such as AlCrN can allow the production of die castings without the application of any die lubricants (i.e., running in the lube free condition). As noted by the P.I. during this project, "this is the largest number of die castings ever produced without the application of any die lube.

Project #215: High Pressure Die Casting Process Simulation Development for the Shop Floor was completed by John Moreland at Purdue University Northwest. This project developed an interactive virtual simulator for high pressure die casting process simulation for the shop floor. The resulting simulator, titled "Virtual Die Casting Simulator," enables die casters to raise the high pressure die casting process knowledge of shop floor workers to improve process decision-making at the machine, speed up attainment of proficiency by shop floor workers. The simulator is designed to be used with a VR headset or on a PC with mouse and keyboard. It includes sections for the die cast machine (DCM), two types of melter furnaces, education and testing, and tutorial sections. The DCM section includes activities for Orientation, Start-up Procedure, Operation, Troubleshooting, and Shot Parameters. The Melter Furnaces section of the simulator has two furnaces, a stack melter furnace and a reverb melter furnace. Each furnace includes activities for Orientation, Charging, Tapping, and Cleaning.

Project #220: Effect of Duplex PVD Coated H13 Steel on Thermal Fatigue Cracking was completed by Dr James McGuffin-Cawley at Case Western Reserve University. This project examined the effects of the application of a duplex PVD coating to H13 specimens subjected to molten aluminum. Several H13 specimens were coated with an ion nitrite base coating and then various PVD coatings were applied. The specimens were repeatedly dipped in molten aluminum and then sprayed with a release agent to simulate the die cast process. Every 5000 cycles the specimens were examined for thermal cracks. Each specimen was cycled 20,000 times. At the end of trials, the PVD coated specimens outperformed an H13 uncoated specimen for total number of cracks and for total crack length for thermal fatigue cracks that were formed on the surface of each specimen. (This data is available on the NADCA website)

Project #223: Die Lube Splash Test Development was completed by Dr Charles Monroe of the University of Alabama. This project used a heated plate to 400° C to evaluate metal flow based on die lube application and type. Also, this project focused on evaluating how well these water-based lubricants cooled the plate and modified the amount of heat being transferred into the plate by looking at the temperature graphs during the spray of lubricant and the splash of the aluminum. Simulations were also conducted to determine the stresses endured by the plate with different heat transfer coefficients during aluminum solidification as well as during the application of lubricants.

Project #226: Die Casting Manufacturability Analysis Tool – CastView completed by Dr. Charles Monroe at the University of Alabama. CastView is a design visualization tool that presents die casting specific information in 3-dimensional graphical form. CastView provides a very fast "quick and dirty" analysis of die casting part designs without the need for extensive input data or significant experience. The project was to rewrite the software so future updates to operating systems do not cause the current revision to be obsolete. The software was rewritten so it does not require a user interface associated with a given operating system like Windows 11.

Project #228: SPR joint quality for HPDC was completed by Dr. Xuzhe Zhao from the Bollhoff Technical Center. This project was sponsored by Ryobi Die Cast as a corporate member project. SPR riveting is known as Self-Piercing Riveting. This project looked at the joint quality of the rivet and all the process parameters and alloy chemistry to determine what is the best process. From this study it was found that the alloy chemistry was a large factor in joint quality. Also, the heat treatment of the material has a significant role in the optimal quality of the rivet. (for further information, this data is available on the NADCA website)

Project #231: Failure Analysis of Additively Manufactured (AM) Components was completed by Peter Ried of Reid and Associates. This project examined AM components after they had been run in a die cast operation and had failed. Failures were examined and from these it could be seen that printing defects and cracking were some of the failures that were examined. The cracking failures showed that the cracks formed in the internal cooling lines of the AM inserts and propagated to the outside of the insert. These cracks often formed on the roughest areas of the cooling lines. This project demonstrated that one reason for crack formation was the rough surface formed from the PBF Printing process of the AM inserts.

Project #232: Corrosion and Crack Resistance of Die Internal Cooling Lines for Different Tool Material, Manufacturing Processes, and Water Quality was completed by Dr. Yeou-Li Chu. This project studied the water corrosion behavior using a combination of different tool materials, cooling line manufacturing processes, and water qualities. The objective was to find an optimal combination of different parameters to reduce the corrosion attack from residual corrosion build-up and corrosion stress crack inside cooling lines. The project studied different die steels, various fabrication processes and various water quality levels. (This comprehensive study is available on the NADCA website)

Project #236: Virtual Reality – Fire Safety was completed by John Moreland of Purdue University Northwest. The VR Fire safety was funded by the Harvill Foundation. This project developed a virtual reality (VR) simulator and library of scenarios for fire safety training in the die casting industry. The simulator teaches users how to operate a fire extinguisher, how to make appropriate safety choices for different types of fires and enables them to practice putting out various types of fires in aluminum, magnesium, and zinc die casting facilities. This VR program is available to corporate members and runs on an Oculus or a Meta Quest VR Headset. Please contact NADCA for more information.

The 2024 Research & Development Strategic Plan and Roadmap Overview was published in the July 2023 issue of the Die Cast Engineer

GOVERNMENT RELATIONS

THE FRANKLIN PARTNERSHIP

410 First Street SE
Suite 200
Washington, D.C. 20001

P: 202.393.8250 | F: 866.876.9163
franklinpartnership.com

REPRESENTING NADCA MEMBERS

- Providing timely information on federal legislation, laws and regulations that impact die casting operations.
- Advocating on die casting issues before Congress and key federal agencies.
- Educating Congress and federal agencies of the impact their decision-making has on the die casting industry.
- Arranging for lawmakers to tour die casting plants.
- Host the annual Government Affairs Briefing in Washington, D.C., arranging for die casters to directly lobby members of Congress on critical issues.
- Alerting members on important Emerging Issues and Opportunities.
- Writing columns and articles regularly in Die Casting Engineer magazine and contribute to Video News & Information on industry matters, federal issues and programs.

GOVERNMENT AFFAIRS

NADCA'S VOICE IN WASHINGTON

In 2023, NADCA continued its relationship with The Franklin Partnership (TFP) to act as NADCA's representation in Washington, D.C. They are tasked developing Congressional connections for NADCA members among other items, and a section in Die Casting Engineer magazine presented by Omar Nashashibi.

The Franklin Partnership (TFP) is a bipartisan, Washington, D.C.-based government affairs consulting firm specializing in representing small, medium-sized, and middle market manufacturers before Congress, the White House, and Federal Agencies. You can read more about The Franklin Partnership by visiting http://www.franklinpartnership.com.

NADCA's views and positions are most important in the direction being taken by OSHA and EPA on a host of topics which directly and indirectly impact our industry. Webinars continue to be a popular way for NADCA to communicate with and educate its members and the industry as a whole. Information can be found under the Government Affairs tab of the NADCA website.

NADCA continues to report about the current administration, so members can expect to see updates in NADCA's Government Affairs section over the course of any given year. Top policy areas identified by NADCA through its surveys include: regulatory oversight (EPA, OSHA, NLRB, SEC), energy and raw material costs, tax policy, workforce recruitment/development, and more.

NADCA has been historically successful in obtaining funds for pre-competitive technology development that has resulted in changing the die casting industry. More research is needed and NADCA continues to educate the administration's offices on how die casting technology development would help advance the goals of the nation.

Look for more of this activity on EPA monitoring, OSHA reporting and research needs being conducted in 2024. NADCA needs good stories from the industry and the people in industry to come to Washington, D.C. to tell their stories.

NADCA spends almost 10% of the member dollar on Washington activities. This is a large percentage of your dues. Make that expense pay dividends - get involved in our Washington efforts!

RESOURCES

DCE & ENEWSLETTERS

Die Casting Engineer (DCE) magazine is distributed to all Individual Members, Corporate Members and subscribers. In 2023, more than 12,000 copies of Die Casting Engineer were in circulation, with an average of 1,800 people receiving each issue.

The magazine is a means to promote the die casting industry. It does so by featuring technical articles submitted by the industry's leading educators, scientists, engineers and suppliers. Upcoming educational courses, conferences and industry news are featured monthly. The past year featured numerous technical articles throughout the six bi-monthly issues. The themes for 2023 included furnaces/energy, metal melting & holding, cast materials (Al, Mg, Zn), additive manufacturing, advanced technologies, computer modeling & simulation, defects, design, high integrity processes & alloys, die coatings & surface treatments, process control & automation, and quality control.

DCE online is located at www.diecasting.org/dce. The site is also accessible through NADCA's main web site through a link under the Communications tab at the top of the page.

NADCA continues to host its digital edition in its current format. The digital edition features an interactive layout with a page view, content view, a list of advertisers, as well as searchable content. The digital edition has been positively received by readers of Die Casting Engineer magazine. Its features continue to evolve as its hosting service adds innovative functions.

NADCA also regularly sends out weekly eNewsletters. The NADCA Update eNewsletter continues to be sent to over 13,000 different emails. The eNewsletter updates its recipients on news in the industry, news from NADCA, upcoming conferences and meetings, and new products and publications. It is a great way to easily stay connected to the die casting industry.

PUBLICATIONS

IMPROVING THE INDUSTRY'S KNOWLEDGE

Publications play a pivotal role in enhancing the knowledge base of the die casting industry. Whether through research findings, insightful articles, or in-depth analyses, publications contribute to the continual growth and advancement of knowledge. They serve as a platform for sharing best practices, innovative ideas, and the latest developments, fostering a culture of learning and improvement. In 2023, NADCA released three publications.

Pub-432 Die Casting Opportunities in Energy Storage Batteries

In the past two years, the Technology Consulting Group (TCG) explored die casting opportunities in Battery Energy Storage Systems (BESS), spurred by prior NADCA initiatives in renewable energy and non-automotive OEM die casting trends. These efforts revealed strong interest from renewable energy engineers in die casting, suggesting its increasing importance in their products compared to other manufacturing technologies. TCG's market analysis forecasts significant growth potential, estimating a rise from 30 million to 200 million pounds of die castings in the US BESS market by 2030, with insights into battery construction and strategic recommendations provided in their report.

Pub-919 Ergonomics Solutions & Best Practices Guide for Die Casting

This document contains ergonomics "best practice" solutions of various companies involved in die casting operations, as well as ergonomics-based improvements that have been implemented in other industries that can benefit die casting as well. These are workplace enhancements that have been feasibly implemented, indicating their effectiveness at both improving the work process and being accepted by employees.

Pub-852 Wage & Benefit Survey – 2022

The survey report provides a comprehensive look at over 14 different job classifications of hourly wage earners, how they are compensated, what benefits they receive and how practices vary by company size and location. By partnering with Harbour Results Inc. to conduct the survey and report on the results, data from other industries is included for additional points of comparison.

The 2022 survey represents 19 die casting companies, nationwide, as well as 476 companies across tool building, plastics processing, and metal stamping. Information is shown as "die casters only" and "multi-process" which represents consolidated data for die casting, tool building, plastics processing, and metal stamping.

BOTTOM LINE

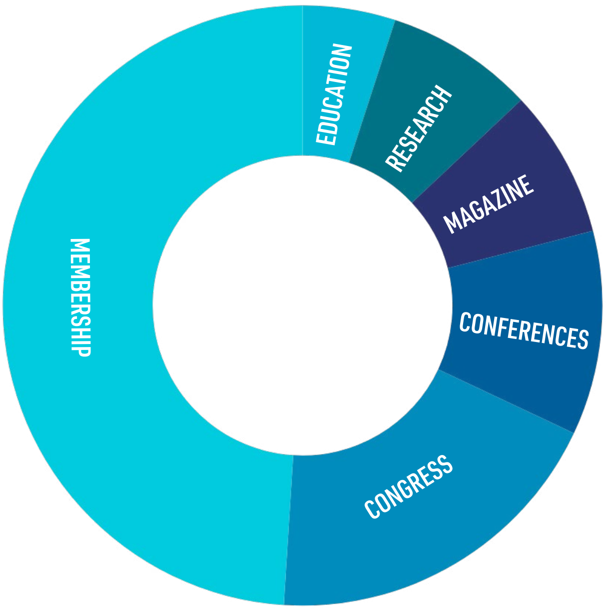
FINANCIAL STANDING

"NADCA IS COMMITTED TO VISITING EVERY CHAPTER IN 2024."

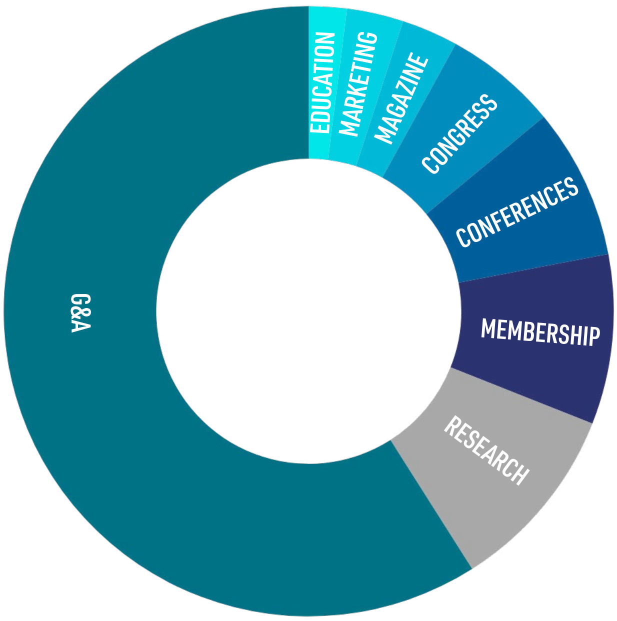
Overall, a solid year for the organization, as revenue came in at 98% of budget. Membership revenue was at 102%, and conference revenue came in at 108%. Many positive comments about the Grand Rapids area where we held our Die Casting Congress & Tabletop. Expenses came in under budget at 93%, which illustrates NADCA's commitment to being financially responsible. We spent nearly $200,000 on Research and Development projects in 2023, as advancing our industry technology is critical to our continued growth.

Our 2024 budget illustrates strong financial growth. We are predicting solid attendance for our "big" show in Indianapolis this fall. We also have plans to grow our membership base as well. We are committed to visiting every chapter this year and looking forward to connecting with as many members as possible. To date, our visits have been very rewarding. It's important for us to understand your needs, so that we can better serve you. Additionally, we have budgeted almost $300,000 for R&D projects in 2024. If have a project you'd like us to know about, please reach out to us!

2023 NADCA REVENUE



2023 NADCA EXPENSE



LOOKING FORWARD TO 2024

PLANT MANAGEMENT CONFERENCE
APRIL 30-MAY 2, 2024
FREMONT, CA

GOVERNMENT AFFAIRS BRIEFING
JUNE 10-11, 2024
WASHINGTON, D.C.

DIE CASTING CONGRESS & EXPOSITION
SEPTEMBER 30-OCTOBER 2, 2024
INDIANAPOLIS, IN

YOUNG PROFESSIONALS ORGANIZATION & EVENTS

MANY CHAPTER VISITS

IMPROVED MARKETING PLAN

CAPABILITIES & SUPPLIERS DIRECTORY UPDATES

ENGAGING PODCASTS

NEW WEBINAR TOPICS

Exhibitor Spotlight

Absolute Haitian Die Casting Systems 909

33 Southgate Street
Worcester, MA 01610
United States
P: (508) 792.4305
www.absolutehaitian.com

Allied Metal Company 708

4528 West Division Street
Chicago, IL 60651-1605
United States
P: (312) 225-2800
www.alliedmetalcompany.com

Allied Metal Company, a U.S.A. producer of aluminum and zinc alloys, supplies die casting and foundry operations that serve the appliance, automotive, electronics, furniture, hardware, housewares, sporting goods and toy industries, to name a few. Celebrating over 70 years in business, Allied Metal's innovation and expansion have shown our ongoing commitment to provide quality metals and superior service. A 4th generation family owned and operated business, Allied Metal Company has grown into one of most respected smelting companies in the United States.

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United States
P: (419) 467-5727
www.asddayton.com

B&L Information Systems Inc 806

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United States
P: (269) 465-6207
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B&L Information Systems is the global leader in cloud-based Enterprise Resource Planning (ERP) software for foundries, die casters and investment casters. Since 1976, B&L has implemented their unique ERP solutions at over 500 metalcasting operations, making their cloud-based Odyssey ERP match how metalcasters operate. With Odyssey, metalcasters maximize their resources, minimize costs, and make better decisions faster.

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Brach Machine is a full-service machine shop manufacturing parts for the die casting industry. We offer a variety of machined shot-end components for all makes and models of zinc and aluminum casting machines. Goosenecks, nozzles, noses, plungers, plunger couplings, shot rods, and shot couplings can be made to your specifications. We specialize in replacement parts for use in Techmire® and other miniature machines. Other services include refurbishing and re-sleeving goosenecks and deep hole gun drilling.

Brondolin North America 918

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World leader in HPDC injection tools since 1968, enthusiastically opened Brondolin NA division in 2021 to better support NA customers and share the best solutions for injection systems necessary to produce complex aluminum castings

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Die Casting Machines and systems made by BuhlerPrince are ideal for the most varied processes. Whether you are interested in aluminum, magnesium, zinc, vacuum, structural or engine block processes – BuhlerPrince has the right solution. BuhlerPrince supports customers throughout the life-cycle of their equipment with global services including process optimization, flow simulations, remanufacturing, retrofits and upgrades.

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Canada
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www.castool.com

Die casting is a complex and demanding process that requires precision, efficiency, and quality. No single component of the die cast production process should be examined or evaluated individually. Each interacts with at least one other complementary element of the process. If the interacting elements are equally efficient, they will reinforce and enhance the function of each other.

Castool is a global leader in providing innovative and customized solutions for the die cast industry. Castool offers a range of products and services that can optimize your die cast production process and improve your product quality, productivity, and profitability.

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United States
P: (517) 302-2962
www.chemtrend.com

Chem-Trend provides specialized solutions and expertise in release agents and lubricants for the die cast industry. We offer a comprehensive portfolio of die cast solutions and services. Products include die lubricants, plunger lubricants, hydraulic fluids, ladle coatings, die maintenance products, technical support and expertise. Chem-Trend aims to help customers improve operational efficiency, productivity, and part quality while ensuring the longevity and performance of dies and equipment.

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Flushing, NY 11374
United States
P: (954) 600-7379
www.conticast.com

Diehl Tool Steel 1013

3475 Spring Grove Ave
Cincinnati, OH 45217
United States
P: (513) 242-8900
www.diehlsteel.com

Diehl Tool Steel is a fully integrated distributor of specialty tool steels, powder metals, aluminum, carbon and stainless alloys. Diehl Tool Steel is the largest distributor of Yasugi® Specialy Steel proprietary grades in North America and a wholly owned division of Proterial Business Group. Diehl Tool Steel processes orders to exact customer specifications.

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Seto, Aichi 489-0984
Japan
P: +81 561 88 1071
www.dynamoinc.us/

We are a top Japanese manufacturer specializing in jet-cooled core pins and mold components for high-pressure die-casting. We serve users globally. Our die-cast die components include jet-cooled core pins, cascades, inserts, bore cores, and water jackets. We also offer complete molds and additive manufacturing products made from HTC45 die steel powder, providing benefits like SKD61 equivalence, high thermal conductivity, low expansion, and improved component life through conformal cooling.

Eastern Alloys Inc — 311

11 Henry Hennig Dr.
Maybrook, NY 12543-0316
United States
P: (845) 427-2151
www.eazall.com

Eastern Alloys manufactures world-class zinc alloys for the die casting industry using state-of-the-art processing technologies. Zinc alloys are manufactured in Eastern's 100,000-square-foot plant in Maybrook, New York, and as well as our Henderson, Kentucky plant. Eastern Alloys' competitive advantage is our combination of exceptional quality products and unique customer service programs (including defect analysis consultation, training and marketing) to ensure our customers have all the tools needed to manufacture high quality products.

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37682 Enterprise Court
Farmington Hills, MI 48331-3440
United States
P: (248) 624-9957
www.ekkinc.com

EKK Inc. is a global supplier of Casting Simulation Software and Consulting Services. The EKKcapcast software suite provides the ability to seamlessly setup and simulate a comprehensive set of casting processes. Finite Element Method (FEM) meshes of your part and mold are automatically created for you for the simulation of the entire process. EKK Inc. also provides engineering consulting services using EKKcapcast. Our experienced engineers help identify problems before they arise and optimize existing processes.

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United States
P: (800) 932-2188
www.ess.elwd.com

Fisa North America Inc. — 814

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Elk Grove Village, IL 60007
United States
P: (847) 299-8400
www.fisa.com

Flow Science — 508

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Santa Fe, NM 87505
United States
P: (505) 982-0088
www.flow3d.com/products/flow-3d-cast

FLOW-3D CAST is a state-of-the-art metal casting simulation modeling platform that combines extraordinarily accurate modeling with versatility, ease of use, and high performance cloud computing capabilities. For every metal casting process, FLOW-3D CAST has a workspace ready to put you on a quick, intuitive path to modeling success. With 11 process workspaces, powerful post-processing, pioneering filling and solidification and defect analysis, FLOW-3D CAST delivers both the tools and roadmap for designing optimal casting solutions.

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www.frechusa.com

Die casting systems by the Frech Group of companies offer customers improved productivity with the smart application of the die casting industry's leading technologies. Die casting cells are built to last and simple to operate with intuitive controls and flexible interfaces. Frech Group also includes important market brands like Robamat, Meltec, VDS, Spesima and FrechZPF.

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P: (330) 562-1440
www.godfreywing.com

Established in 1948, Godfrey & Wing is the longest-serving and largest vacuum impregnation equipment provider in the world. We manufacture and supply equipment, sealants, and services to seal casting porosity. Our systems are engineered to maximize productivity, economize sealant usage, and conserve resources. Godfrey & Wing maintains an extensive network of vacuum impregnation service centers and strategic partners. Global automotive, aerospace, defense, medical, and industrial companies trust Godfrey & Wing to seal their castings.

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www.hansoninternational.com

Hanson International excels in precision mold and high-pressure die cast die design, build, sampling, and inspection, primarily serving the automotive industry. Situated in Saint Joseph, Michigan, Hanson's campus features an office/engineering group, a manufacturing facility, and a die testing facility. Using modern equipment and engineering software, Hanson's experienced workforce ensures top-quality tooling. Hanson's rigorous inspections follow ISO 9001:2015 standards, ensuring excellence from design to delivery with a single-source, single-point-of-contact approach.

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United States
P: (866) 332-7024

HERCO, LLC 518

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Auburn Hills, MI 48326
United States
P: (248) 656-5900

High Temperature Systems Inc 309

16755 Park Circle Dr
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United States
P: (440) 543-8271
www.hitemp.com

With over 50 years of industry experience, High Temperature Systems, Inc. is a world leader in the innovative design of molten metal circulation, transfer, treatment, and chip submergence solutions. Our standard solutions target the aluminum, zinc, tin, and lead industries while our R&D resources develop unique solutions for specialty high-temperature liquid metal and mineral applications. We take the time to understand your unique challenges and design a solution that provides maximum value.

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United States
P: (865) 382-5601
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United States
P: 00390306850370
www.iecionline.com

Inductotherm Corp. 913

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Rancocas, NJ 08073
United States
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Induction can heat and melt aluminum at very high efficiency rates with very low metal losses as compared to gas or oil-fueled furnaces, which can emit a tremendous amount of carbon dioxide. As we go green, we help our customers meet their decarbonization initiatives through our induction furnaces. With over 70 years of experience, we can be your answer to reducing your carbon footprint. Visit Inductotherm.com to learn more.

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International Mold Steel 603

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Hebron, KY 41048
United States
P: (859) 342-6000
www.imsteel.com

J&S Chemical Corp 802

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www.jschemical.com

USA-based J&S Chemical is a leading manufacturer of specialty lubricants for the die casting industry. J&S Chemical's business philosophy is to create value for their customers by developing high quality, high performing, value added products. Substantial investment in R&D as well as their Technical Service Team, working on-site with their customers, is driving new product developments. Many of their brands are product leaders in the industry such as, TurboCast® (die release agents and liquid plunger lubricants), ShotBeads® (solid plunger lubricants) and TurboTrim™ (trimming fluids).

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Rogers, MN 55374-9361
United States
P: (763) 428-4229
www.lethiguelusa.com

LK World 332

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Edinburgh, IN 46124
United States
P: (616) 796-0777
www.lkadvantage.com

MAGMA Foundry Technologies Inc. 702

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Schaumburg, IL 60173
United States
P: (847) 252-1668
magmasoft.com

MAGMA's product and service portfolio includes the powerful, modular software MAGMASOFT®, with the newest release MAGMASOFT®, as well as engineering services for casting design and optimization. Today, MAGMASOFT® is used throughout the metal casting industry, especially for the robust design and optimization of cast components in automotive and heavy industry applications.

NovaCast USA Inc. 817

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United States
P: (630) 450-1647
www.novacastusa.com

OEE Companies 318

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United States
P: (612) 440-5714
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OEE Companies supplies custom inserts, tooling and advanced simulations to high pressure die casters including: custom core pins, chill vents, vacuum systems, jet cool systems, sub-inserts, ejection pins, parting line locks, guide pins and bushings, jet cooled pins and cascades, electric furnaces, multi-slide dies and open close dies.

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Phygen is the exclusive provider of FortiPhy XVD, a revolutionary surface enhancement process that far exceeds the performance characteristics of even the best conventional PVD coatings. Tool life and productivity can be increased 3x to 80x due to FortiPhy XVD's nanoperfection process, which eliminates up to 90% of the macro particle defects found in PVD coatings. Benefits include dramatic reductions in soldering, erosive wear, and heat checking. Phygen offers tailored ultra-endurance solutions to meet your most demanding needs and is a proven leader in research and advances in die casting.

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Progressive Components is a leading source of high-performing standard products for the die-cast industry. With today's plant managers working to reduce unscheduled production stoppages, Pro has engineered our die-cast line to maximize performance and longevity, and our Black Nitride products are proven to outperform others exponentially. Unlike standard additive process treatments, Pro's Black Nitride is a high-hardness diffusion that won't wear like DLC and other surface coatings and is available on our Pins, Sleeves, Bushings, and more.

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United States
P: 00393348108947
www.sappgroup.com

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P: (262) 347-0845

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Swiss Steel USA / Canada, part of Swiss Steel Group, is a leading distributor of quality tooling materials for the Die Casting tooling industry with a wide range of specialty tool, die and mold steels. Hot Work Die Steels include Thermodur® 2344, 2367, E40K, and DC Superior all remelted materials manufactured to the latest Die Casting specifications. Value added services include Vacuum Heat Treatment, full Lab services, CNC machining, and Custom saw cutting at six service centers in North America.

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Frank W. Schaefer, Inc (FWS) started business as a refractory contractor in 1930, and began designing and manufacturing industrial furnaces in 1945. In the early 1970's, FWS's aluminum furnace business grew large enough that it became necessary to form two divisions within the company: A Refractory Sales and Service Division and an Industrial Furnace Division. In 1998, the Industrial Furnace Division was separated from FWS, Inc to form a new company, Schaefer Furnaces, Inc (SFI). A combining of these two related companies took place in late 2002, forming The Schaefer Group, Inc. Two strong traditions are recombined, with the FWS Division providing exceptional refractory sales and service work and the SFI Division providing the best aluminum furnaces and molten metal delivery systems available.

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Uddeholm specializes in innovative die-casting solutions, prioritizing our clients' productivity. Our flagship product, Uddeholm Dievar, is now available as AM powder or a fully 3D printed insert, boasting exceptional toughness and ductility. Our comprehensive offerings encompass tool and die Steels, PVD coatings, Powders for AM, and 3D Printing, coupled with trusted Technical and Engineering Support. Focal steel options include Uddeholm Dievar® (≥18.4 ft-lbs. toughness value) and Uddeholm Orvar Supreme® (≥12 ft-lbs. toughness value), complemented by advanced PVD Coatings (Duplex-TIGRAL®) and innovative Additive Manufacturing solutions.

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Valor Alloys, LLC is a secondary smelter located in Houston Texas producing prime equivalent alloys and secondary alloys that meet or exceed customer specifications for the die casting industry. Valor possesses a rotary furnace and reverb furnace and is capable of making ingots and SOWs. Valor Is ISO 9001 Certified and a Tier 1 Automotive Supplier. Address 11280 Charles Rd. Houston, TX 77041: sales@valorerenewables.com 713-896-8585

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VERSEVO is a provider to the cast metals industry, with a focus on product diversity, and mission to become the premier supplier to the metal casting and cast products industries. Offerings include process development engineering, part design, tool design, prototype & production tooling, low pressure aluminum castings, production machining, and foam molding, for High Pressure & Low-Pressure Casting, Trimming, Lost Foam Casting, Permanent & Semi-Permanent Mold Casting, and Vertical & Horizontally parted Sand Casting.

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voestalpine Additive Manufacturing Centers (vAMC) are your premier destination for comprehensive Additive Manufacturing (AM) services specializing in die-cast tooling. We collaborate closely with clients to deliver personalized solutions, employing our optimized design, powder, and printing methods complemented by enhanced services like heat treatment and coating. Merging cutting-edge AM expertise with a wealth of die-casting experience, we offer the optimal tooling solution. Our services encompass conformal cooling design, process simulation & consultation, turn-key tooling manufacturing, and efficient spare management.

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voestalpine eifeler Coatings offer PVD coating Services to the North American Die Casting Industry. Our Duplex-TIGRAL® coating, with its high hot hardness characteristics, is a great solution for wear protection, as well as, both chemical resistance and oxidation. Additionally, when subjected to shear loads, the nanostructure properties help to prevent crack propagation, resulting in more production and less downtime. Visit us at www.eifeler.com/northamerica. PVD Coatings: SUBLIME®, Duplex-TIGRAL®, Duplex-VARIANTIC®

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voestalpine High Performance Metals is part of voestalpine AG, a leading steel and technology group. Based in Linz Austria, voestalpine is a global partner to the automotive, white goods, and energy industries. Through our various brands, we service the North American Die Casting Industry and global OEM's with tool steel, PVD Coatings, Heat Treatment and Additive Manufacturing. Brands and business units: Uddeholm, BOHLER, eifeler, voestalpine Additive Manufacturing Centers

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United States
P: (740) 382-5600
www.yizumi-hpm.com

Chapter News & New Members

Chapter 3 - Michigan

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Wayne Ding, Carlos Lv, Bart Mei, all with Dalite; Peter Duggan, Techman Sales; Peter Cell, Ital-PresseGauss*

Chapter 5 - Chicago

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Katie Hensley, Cottingham & Butler*

Chapter 6 - Cleveland

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Matthew H. Burch, General Die Casters Inc.; Shaun Higgins, Rochester Aluminum Smelting Canada Ltd.*

Chapter 7 - New York

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Mark Cook, Sun Metalon; Christopher Macey, Shimadzu*

Chapter 10 - Ontario

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Jerome L. Golden, Simon Golden, both from Rochester Aluminum Smelting Canada; Parth A. Savaliya, Sheridan College Institute of Technology and Advanced Learning*

Chapter 12 - Wisconsin

On February 1st, Chapter 12 hosted the NADCA's President, Mr. Mike Meyer, to provide a State of the Industry update to chapter members at Delafield Brewhaus in Delafield, WI. Mike gave an engaging talk covering multiple topics the die casting industry is facing. From the economy to OSHA regulation and Congressional performance to new technologies – the information provided had members attentively listening to learn what may lay ahead for 2024.

More than 60 people attended the event. It was a huge gathering for the chapter, extremely well attended. Ahead of Mike's talk was a networking, socializing, and dinner, which allowed chapter members from both foundries and suppliers to connect. Overall, it was a successful chapter meeting where members took away much to think about. It was a great way to start a new year!

Looking ahead, the Spring Education Seminar is right around the corner. On March 6, from 12:30-5:00 at Waukesha County Technical College, the topic of Process Design will be presented. Speakers for this event include Pat LaDuke (retired industry expert) along with Sean Frank and Clay Rasmussen (Mercury Marine). Registration for this event can be found at Chapter 12's website.

***Chapter 12** – Members had an opportunity to network before and after the talk.*

***Chapter 12** – The room was packed with 60+ members ready to hear the State of the Industry talk at Chapter 12's Feb 1st meeting.*

Chapter 12 *– Mike Meyer, President of NADCA, delivered an engaging talk on the challenges and opportunities the die cast industry has for 2024.*

Additionally, a Spring Member Meeting is planned for April 10th, and the Annual Dave William Classic Golf Outing is on June 14th. More information and registration for any of these events can be found at the Chapter 12 website: www.nadca12.org

Chapter 14 - S. Ohio

Chapter 14 kicked-off their 2024 season On Tuesday January 16 at Smith's Boathouse Restaurant.

Chapter 14 *– David giving the audience what they came for.*

David White educated the full house on Ways to "Reduce your Carbon Footprint in the Melt Shop". David educated the attendees with ways to produce their own electricity from plant exhaust gases, the pros and cons hydrogen burner options, electromagnetic stirring and more.

Chapter 14 *– 20+ filled the room at Smith's Boathouse for David's talk.*

David is no stranger to the Chapter 14 area. He is a great man who retired in 2020 after 41 years with The Schaefer Group, Inc. David is staying active in the industry via as the Co-Owner of D and S Consulting LLC, a consulting group that helps companies choose furnaces, refractories, combustion systems, how to implement industry 4.0 into the melt room.

Chapter 14 *– Good networking took place before and after the meeting.*

Chapter 14 looks forward to seeing you at their next two meetings!

Chapter 14 NADCA 2024 Schedule

- **January 16th –** David White- D+D Consulting "Reduce your Carbon Footprint in the Melt Shop"
- **February 13th –** "Cleaning furnaces and molten non-ferrous alloys with fluxes and the benefits" "
- **March 12th –** Mike Myer- State of the Die Casting Industry
- **April 9th –** TBD
- **June 1st** - Golf Outing at Pipestone

Your Chapter 14 executive staff looks forward to working with our members as we head into the 2024 season and beyond. Please feel free to contact myself or any of our executive team with your ideas on how we can become an even more effective chapter for you, your workmates, and your respective companies in this coming year.

Your Chapter 14 Executive Staff

- Monte Swigart- RYOEI USA
- Scott Frens- Fort Recovery Industries
- Bryan Dahms- HA International

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Ethan Hearty, Honda Development Manufacturing of America - Anna Engine Plant: ALDC*

Chapter 15 - Southeastern

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Sandy Calabrese, DISA Group; Leanne Lally, Norican Group; Alex Perry, Schaeffler Group, U.S.A.; Brian Potter, Institute for Progress*

Chapter 16 - Minnesota

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Matthew John Kleidon, Suzanne Lajoie, both from Water Gremlin Company*

Chapter 17 - St. Louis

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *David Heslop, Toyota Motor Manufacturing Tennessee (TMMTN) Carlos Leonardo Mezquitic Melendez, TESLA Motors - GigaTexas*

Chapter 25 - Indiana

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *George Umeda, Ryobi Die Casting USA Inc.*

Chapter 30 - Los Angeles

Please visit www.diecasting.org and click on Chapters under the Become a Member tab for details on upcoming events.

New Members: *Toshiro Aoki, Ahresty Mexicana, S.A. De C.V. Takahiko Nakamura, Ahresty Mexicana, S.A. De C.V. Venkat Nara*

International Members: *Fabian Esparza Sánchez, Ahresty Mexicana; Bojan Cesto, Volvo Car Sverige AB; Ram Karan Gupta, Haryana Plastics LLP; Ioannis Katsaoras, Vioral Castings SRL*

Student Members: *Keaton R. Allen; Xander Bowen; Brett Callow; Dakota J. Carter; Sean Daily; Trace Edmondson; Logan Ehrhardt; Andrew Findley; Chloey Grisez; Alexander Loeffelman; Logan Manross; Lauren E. Miller; Brennan Neitzel; Janae T. Spears; James M. Twomey*

NEMAK'S $18M EXPANSION PROJECT ON TRACK TO FINISH BY FALL 2024

Sheboygan, WI - Construction on an estimated $18 million expansion at a Nemak facility is on track to finish this fall. The automotive lightweight diecast manufacturer is building a 49,500-square-foot addition on the north side of its Sheboygan Business Park facility, 4243 Gateway Drive. There will be 35,300 square feet dedicated to diecasting production and storage with two 4,500-ton diecast machines and equipment.

The additional space will also have an electrical building, compressor room, dock area and offices.

The new diecast machines will be connected to the existing facility's furnaces to move molten aluminum, the conditional use permit application said.

The project could be finished by September, after breaking ground last summer.

The expansion will help "ensure long-term sustainability and future growth" for Nemak in Sheboygan, as the automotive industry transitions to electric vehicles and calls for larger diecast equipment, according to the application.

An estimated 900 people are employed at the facility, and the expansion is expected to add new hires. A company spokesperson said that number is undetermined at this time.

HOUSE PASSES CRITICAL TAX BILL

Washington, DC - On January 31, 2024, the House of Representatives has passed a critical bipartisan tax bill restoring critical tax provisions used by NADCA members such as modifications to Section 174 R&D expenditures, Bonus Depreciation, the Section 163(j) deduction, and Section 179. Addressing these tax issues will restore a significant amount of capital to the bottom lines of small and medium-sized manufacturers, allowing them to invest in and grow their businesses.

The Tax Relief for American Families and Workers Act of 2024, which the House passed by a vote of 357-70 delays until 2026 the R&D amortization provision and reinstates full expensing, restores full expensing for capital investments, reinstates the EBITDA standard for interest deductibility, and raises the maximum Section 179 expending deduction to $2.5 million.

Thanks to the work of NADCA and our coalition partners this vital bill heads to the Senate and is one step closer to becoming law. However, there is still work to be done. Make your voice heard by joining NADCA's coalition partners in telling the Senate that they must act now to immediately pass this tax bill which is critical to the die-casting industry.

NETA AND LK TECHNOLOGY TO JOINTLY DEVELOP 'WORLD'S LARGEST' DIE CASTING MACHINE

China - Neta, a brand of Hozon Auto, announced today that it signed a strategic cooperation agreement with Hong Kong-listed integrated die casting machine maker LK Technology on December 15 to jointly develop die-casting equipment in the 20,000-ton class.

The equipment will be the most powerful in the field globally, surpassing the 12,000-ton die casting machine currently used by Xpeng (NYSE: XPEV), the 9,000-ton die-casting machine used by Tesla (NASDAQ: TSLA) and Aito, and the 7,200-ton die casting machine used by Zeekr, Neta said.

With the help of this equipment, the integrated die-casting technology will be used for larger-sized parts, including B-class vehicle chassis, allowing a skateboard chassis to be made in 1-2 minutes, Neta said.

Neta will also purchase several large die casting machines from LK Technology and will form a joint venture to build a die-casting demonstration manufacturing base in Anhui province in eastern China.

Integrated die casting equipment can integrate otherwise dispersed components, significantly reducing the number of parts in a vehicle and lowering manufacturing costs compared to traditional manufacturing methods, Neta's press release noted.

The technology can reduce the manufacturing time for a vehicle chassis from the traditional 1-2 hours to 1 to 2 minutes, and help reduce the weight and improve the comfort of the vehicle, Neta said.

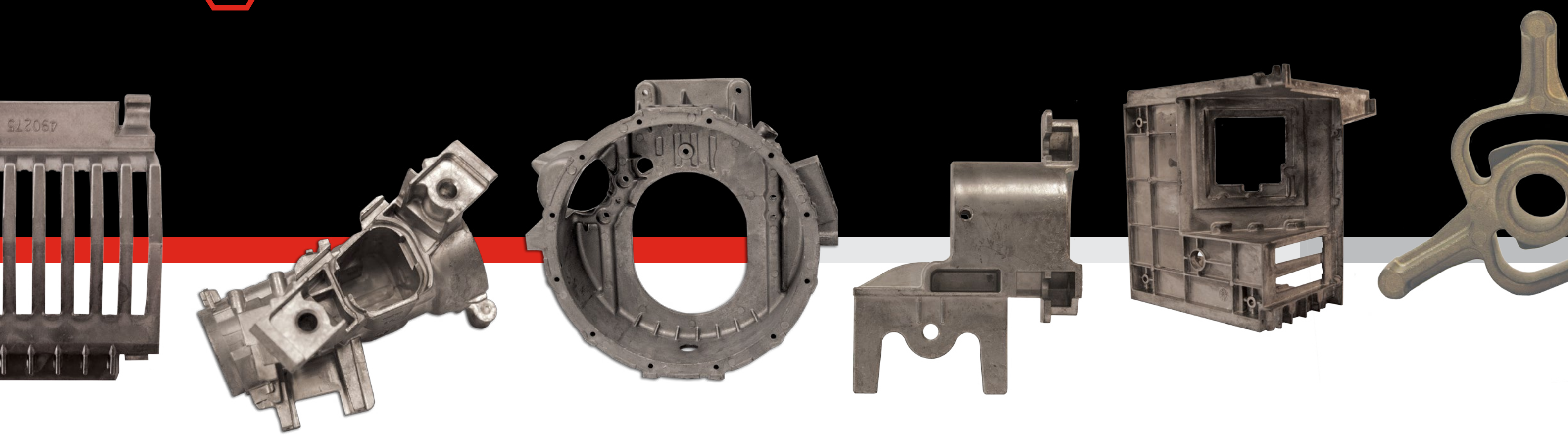
Creating a 20,000-ton die casting facility is significant in scaling down costs and will help the company achieve its goal of selling more than 1 million vehicles globally by 2026, Neta said.

ALUPRESS, LLC EXPANDING OPERATIONS IN LAURENS COUNTY

Columbia, SC - Alupress, LLC (Alupress), a manufacturer of automotive die casting components, today announced plans to expand operations in Laurens County. The company's $25.98 million investment will create 64 new jobs.

Founded in 1965, Alupress offers full-service system solutions to its customers by providing in-house development, project management and production. Located at 114 Hunter Industrial Park Road in Laurens, Alupress' expansion will add approximately 3,000 square feet to its existing facility, enabling the company to service a growing customer base.

The expansion is expected to be complete in the fourth quarter of 2028. Individuals interested in joining the Alupress team should visit the company's careers page. The Coordinating Council for Economic Development approved job development credits related to the project.



NADCA

NORTH AMERICAN DIE CASTING ASSOCIATION

CORPORATE DIE CASTER MEMBERSHIP APPLICATION

Please Type or Print All Information Below

KEY CONTACT'S NAME (FIRST NAME, MIDDLE INITIAL, LAST NAME) TODAY'S DATE

TITLE DEPARTMENT/DIVISION

COMPANY'S NAME

COMPANY'S MAILING ADDRESS (INCLUDES P.O. BOXES AND/OR MAIL DROPS)

CITY STATE OR PROVINCE ZIP OR POSTAL CODE & COUNTRY

COMPANY'S BUSINESS PHONE (WITH AREA OR COUNTRY CODE) COMPANY'S BUSINESS FAX (WITH AREA OR COUNTRY CODE)

COMPANY WEBSITE COMPANY'S EMAIL ADDRESS

CORPORATE DIE CASTER DUES CALCULATION

Base Membership:				$1000
Machines 65 tons or less:	_______	x $50	=	+
Machines 66 tons -399 tons:	_______	x $100	=	+
Machines 400 tons or more:	_______	x $200	=	+
Total Yearly Dues:				

- *Complimentary members are allocated to your record based on your dues level. All corporate members receive 3 complimentary individual members plus one for each $1000 of corporate dues over $3000.*
- *The maximum yearly dues are $16,000.*
- *Count all machines operating in North America. Must have a North American location.*

Payment Information *(U.S. Dollars Drawn on a U.S. Bank ONLY)*

☐ Check *(payable to NADCA - US Dollars only)*

☐ ACH *(Routing Number: 071000013 Account Number: 510019620)*

☐ Credit Card* ☐ VISA® ☐ MASTERCARD® ☐ AMERICAN EXPRESS®

Payment using Check or ACH saves NADCA on credit card fees. Please consider paying via Check or ACH.

Total Payment Amount* CSV Code

Credit Card # Expiration Date

Cardholder's Name *(as it appears on the card)*

Please complete and return this application, along with your remittance to:

North American Die Casting Association
3250 N. Arlington Heights Rd., Ste. 101
Arlington Heights, IL 60004

P: 847.279.0001
F: 847.279.0002
E: corporate@diecasting.org
W: www.diecasting.org

NOTE: *NADCA dues are not deductible as charitable contributions for federal income tax purposes, but may be deductible as a business expense.*

**Credit Card Convenience Fee = 3% of invoice amount*

People in Die Casting

RCM Industries Announces Staffing Changes

Dan Twarog

Chief Executive Officer
RCM Industries

Dan Twarog was promoted from President & Chief Operating Officer to Chief Executive Officer (CEO) reporting to RCM's Chairman, Robert C. Marconi.

In this role, Dan will focus on the macro, long-term direction of the company by analyzing business and industry trends, developing technology and operational strategies, and working closely with RCM's executive team on implementing those strategies within each operation.

Ethan Hamblen

President
RCM Industries

Ethan Hamblen has been promoted from Executive Vice President to President reporting to RCM's CEO, Dan Twarog.

As President, Ethan will have executive management responsibility over all four plants; he will work closely with each division's Plant Operations Manager and their key staff on implementing the technology and operational strategies developed by RCM.

Billy Spivey

Chief Operating Officer
RCM Industries

Billy Spivey has been promoted from Vice President of Operations to Chief Operating Officer (COO) reporting to RCM's CEO, Dan Twarog.

Although Billy will continue his role as Plant Operations Manager for AFP, he will also provide equipment, technology and other die casting operational support to the other RCM plants as needed.

Jim Mock

Information Technology Director
RCM Industries

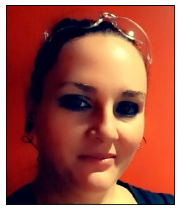
Jim Mock, who is RCM's Information Technology Administrator, will now report to Robert McFarlin, RCM's Chief Financial Officer (CFO).

Jim will continue his important role of leading RCM's Information Technology Team which provides computer hardware, software, data and security support to all RCM plants.

NADCA Level I - Certified Die Casting Technician

Toni Saxman

Process Engineering Technician
Cosma Casting



Toni Saxman recently completed the NADCA Level I - Certified Die Casting Technician program. Toni has been in die casting for 3 years. She started as an operator (3 months), spent a year and a half as a Die Set Team lead, and has been a Process Technician since.

What Toni likes about die casting is that she learns something new every day. Be it in Die Set, Tooling or Process. Toni enjoy the challenges that come with all aspects of die casting. Continued education helps Cosma make better parts and run more efficiently.

DIE CASTING ENGINEER

CLASSIFIEDS

Classified advertisements are accepted for publication in *DIE CASTING ENGINEER* for sale of equipment and notice of services and employment available or wanted. The net rate is $60 per inch or fraction thereof (for NADCA members, individual and corporate) and $70 per inch for all others, in the 2 1/8 in. wide column, payable with order. Please make remittance payable to *DIE CASTING ENGINEER*, and send with copy to: NADCA, 3250 N. Arlington Heights Rd., Ste. 101, Arlington Heights, IL 60004. Contact Athena Catlett at 847.808.3153 or email catlett@diecasting.org

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HELP WANTED

TWIN CITY DIE CASTINGS COMPANY SEEKS DIRECTOR OF BUSINESS DEVELOPMENT

Twin City Die Castings Company (TCDC), an employee-owned company with over a century of excellence and three locations, is seeking a dynamic Director of Business Development to shape our sales and marketing team for the future. Why TCDC? Because we highly value our employee-owners who are integral to our track record of delivering top-notch precision aluminum and magnesium die castings.

Join us in our exciting new era as you lead new business initiatives and devise strategies for enhanced customer satisfaction. As the primary liaison for our major customers, you will nurture relationships through travel, employing your strategic foresight to accurately forecast product demand using advanced methodologies. Your responsibilities will extend to overseeing marketing strategies and managing the department budget effectively.

We're looking for someone with technical expertise, engineering understanding and proficiency in blueprint reading. The ideal candidate will have 10 years in contract machining sales, preferably in a die-cast environment, with strong leadership, communication, and negotiation skills. The role involves a substantial amount of travel - up to 50% of your time – spanning both domestic and international locations.

See our careers page at www.tcdcinc.com for more information and seize the opportunity to apply TODAY to get started inspiring, leading, and mentoring a talented team to success! Take ownership of your career at TCDC and let's shape the future together!

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Bob McClintic, Die Casting Consultant

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