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Volume of structural castings produced by high pressure vacuum die casting is predicted to grow fivefold from 2015 to 2020. Alloys and tempers mechanical properties such as yield strength and elongation play an important role in automotive part design. However, part failure is often linked to fatigue crack growth. Fatigue strength and fatigue life is therefore a critical aspect in the design of castings. Fatigue life can be affected by various parameters such as chemistry, temper and defects. In this paper, the low-cycle and high-cycle fatigue life of three Aural™ alloys were evaluated to study the impact of the silicon and magnesium content, as well as the impact of temper and defects. Strain controlled fatigue testing was used to obtain a complete strain-cycle curve in both the low and high cycle regime. Each samples fractured surface was analyzed to determine the crack initiation site. Moreover, the samples microstructure and crack propagation route were analyzed to determine the key microstructural aspects to obtain good fatigue life.

**Effect of Temper and Defects on Fatigue Life in High Pressure Vacuum Die Casting Alloys**

F. Breton (Rio Tinto)

Selecting for this study to have all alloys with the 0.50% magnesium content for a good T5 aging response clearly place alloys 367, B360, 362 in the same basket figuratively, because a 0.50% Mg is at the top of Mg range for 367, in the middle of the Mg range for B360 and at the bottom of the Mg range for 362. The inclusion of F380 and 368 in the same Mg group is justified at the 0.30% Mg value [i.e., the upper value in the 0.10-0.30% Mg range for F380 and 368] because generally over the 0.30-0.50% Mg range in such alloys as 367 the aging response for UTS and for elongation is essential nearly constant. The handling of the magnesium content, as cited above, is certainly valid when the UTS values and elongations values obtained for both the as-cast condition, and T5 aged condition at 170°C, 180°C and 190°C for up to 7 hours, are used to calculate the quality index, as defined by Drouzy, Richard and Jacob as, UTS + 150 log(elongation), and plotted on graphs of UTS vs log(elongation) to the base ten. In this plot for T6 mechanical properties, lines of constant quality index are basically perpendicular constant yield strength lines, and the quality index values are unaffected by “the quench”, “the aging” and “the Mg content”. Thus, in principle, the expectation is the quality index for the above cited alloys should have the same quality index if the T6 heat treatment process was used to measure the UTS and elongation. However, this study is about alloys having a manganese range of 0.25-0.35%, which means the max Mn is 0.35%, which means the iron has to be below 0.45% Fe to avoid the primary precipitation of intermetallics. Thus, all alloys are structural aluminum die casting alloys, and not in the class of conventional die casting alloys that are high in iron. This has produced a first; a constant quality index value has been demonstrated for either a high iron or low iron die casting alloy for a given T5 aging treatment at either 170°C, 180°C or 190°C for up to 7 hours of aging. The four new rules discovered from these plots are (1) T5 QI [low Fe] >> T5 QI [high Fe], (2) as-cast QI [low Fe] >> as-cast QI [high Fe], (3) T5 QI [low Fe] = as-cast QI [low Fe] and (4) T5 QI [high Fe] < as-cast QI [high Fe]. More specifically, T5 QI [of 0.27 Fe alloy] was not statistically different from T5 QI [of 0.45 Fe alloy], but quite significant different from the lower QI of the 0.99 Fe alloy. And finally, the T5 quality index of alloys 367, B360, 362, F380 and 368 is calculated at 433 MPa, exactly equal surprisingly to the T6 quality index of A356 [also equal to 433 MPa], which means die casters using the cited alloys 367, B360, 362, F380 and 368 in the low cost T5 heat treated condition [which increases the yield strength 60-70% over the as-cast yield strength] can compete with casters using a higher cost casting process [the PM process] and a higher cost heat treating process [the T6 heat treatment], which can be associated with distortion problems due to the quench.

**Reanalyzing Effects of Iron and Manganese on T5 Mechanical Properties of 367, B360, 362, F380 & 368**

R. Donahue (Mercury Marine); S Midson (The Midson Group); J. Brennan (Global Mold Tech Management)

Many high performance HPDC alloys, such as EZCast™ alloy (C611, C60K, C448), Aural™-2, Aural™-5, A365 and Mercalloy, are being widely used for automotive structural applications for weight reduction. Silicon content in these alloys varies from about 6 wt% to 11 wt%. What is the impact of silicon content on mechanical properties and product performance, and also how to choose alloys based on silicon content for different applications? To answer...
these questions, a systematic study has been performed using a 1200-ton vacuum-assisted high pressure die casting machine for four different alloys at different silicon content varying from 6.5wt% to 11.0wt%. Mechanical properties at various tempers, as-cast, T4, T5, T6 and T7, were measured. Aging curves for all four alloys were also generated.

**Computer Modeling I**

9:45 am - 11:15 am

Session Chair: Robert Mcinerney

**Thermal Stress Analysis of Spot Cooling Line in Die Casting Die**

J. Huang (Exco Engineering)

With different analytical and numerical approaches this paper thoroughly investigated the thermal stress of different types of cooling lines of high pressure die casting dies, which includes cooling line in circular core, conformal cooling line in metal saver, loop cooling line in main insert and spot cooling line in main insert. The thermal stress on the inner surface of the cooling hole in each case is studied under a typical die casting manufacturing process condition. The thermal stress results showed that the thermal stress of cooling line in circular core is low. It is why the residual wall thickness in a cooled circular core can be very thin without thermal cracking failure. But the thermal stress of cooling line in irregular metal saver or main insert could be very high, which puts a limit how close the cooling line can be placed to the cavity surface. Through these analyses the optimal cooling line placement strategies are recommended to achieve the maximum cooling efficiency and the acceptable tooling service life.

**Thermal Dynamic Prediction of Phase Evolution in Die Casting Alloys**

M. Yasin, D. Sun, Q. Han (Purdue University)

Mathematical modelling of various physical processes and simulation thereof have become a necessity for the development of high-quality die casting alloy. The present work focuses on the thermodynamic simulation for phase evolution prediction of aluminium based die casting alloys. The simulation allows important issues to be studied, such as the control of morphology and optimization of the solidification range in the alloy design. The modelling can also be utilized to describe the solubility limit of the components in the alloy system. Advanced simulation software, Pandat and PanAluminum database are used as the tools to do the modelling. The proposed model is developed for predicting solidification path of the die casting alloy. The simulations are primarily based on the solidification profiles and the quaternary phase diagram of aluminium alloys. The results of the numerical thermodynamics simulations of solidification performed on aluminium based alloys are presented and compared with available experimental data. Based on the overall developments, it appears that the proposed approach is a viable basis for the development of an effective computational tool to be used in the simulation of solidification of die casting aluminum alloy.

**A Framework for Virtually-Guided Certification of Die Cast Manufacturing Processes**

S. Shahane, S. Mujumdar, N. Kim, N. Aluru, S. Kapoor, P. Ferreira, S. Vanka (University of Illinois at Urbana–Champaign)

Die casting is an important process of metal manufacturing used in automotive, housing and other industries. The need of simulations to understand the physics and estimate the product quality in manufacturing is growing. It is convenient and financially viable to use computer simulations as replacements to real life experiments. There are uncertainties in the inputs like shot sleeve temperature, incoming metal speed and temperature, thermal boundary conditions (coolant flow rate and temperature, die temperature) etc. which affect the product quality. In this project, we aim to analyze the impact of these uncertainties with simulations using verification, validation, sensitivity analysis and uncertainty quantification. The framework consists of high speed numerical simulations, micro-structure characterization, experimental inputs, sensitivity analysis and uncertainty propagation from stochastically varying inputs to casting quality. As a first step, we are developing a three-dimensional finite volume based Navier-Stokes solver running on an unstructured mesh. Unstructured mesh helps to represent complex geometries with less number of control volumes maintaining good accuracy. The solver includes fluid flow, natural convection, heat transfer and solidification physics. Multigrid methods are used to accelerate the convergence and GPU is used to reduce the solution time. The temperature gradient, rate of cooling, velocities and other flow parameters are used to estimate the micro-structure parameters like dendrite arm spacing. Micro-structure parameters govern the final casting quality. The empirical models used are calibrated using experimental results including the effects of uncertainty. The overall approach is rigorously verified using published numerical results and validated using experimental results. There is significant amount of uncertainty in the process parameters and it is practically difficult to tightly control all the parameters. Hence, sensitivity analysis is performed to judge which parameters are important as far as the casting quality is concerned. Uncertainty analysis quantifies the impact of variation of each process parameter on the casting quality. This overall framework will help in assessing the importance of each process parameter, its effect on the casting quality and the amount of variation in the input that can be allowed with a constraint of maintaining the quality within given bounds.
Die Materials & Coatings

2:00 pm - 3:30 pm
Session Chair: Dr. Stephen Midson

Plunger Design Meets Caster Requirements

L. Chien, P Robbins (Castool)

The demand on high-pressure die casting quality has never been higher. High quality cast requires a good control of the clearance between plunger OD and shot sleeve ID. The active clearance must be maintained at 0.004” at all times to prevent aluminum blow-by and excessive wear, therefore generating consistent shot velocity for quality casting. Typically, a die caster can only choose two categories of plunger tips:

1 - a copper alloy plunger with high thermal conductivity. The temperature of the plunger tip doesn't fluctuate much from beginning to the end of die cast cycle. Therefore, the dimensions of the plunger do not fluctuate much. The wear and strength of the copper alloy tips are lower than steel. Also beryllium copper alloy is a health hazardous material. The cast quality is good and high productivity but the initial cost of tip and cost on health is prohibitive.

2 – a steel plunger with low thermal conductivity. The tip temperature and dimensions cannot be controlled. The cast quality is inferior and the productivity but the initial cost of tip and cost on health is prohibitive.

A new plunger tip material with better toughness and thermal conductivity is presented. The new robust plunger profile face eliminates the impact stress. The torus plunger tip face can save a significant amount the aluminum from the biscuit.

Extending Life of Shot Sleeves in Demanding Die Casting Applications

D. Schwam (Case Western Reserve University); D. Bell (Phygen)

As new, low-iron aluminum alloys are making inroads into die casting of parts for structural applications, the demands on shot sleeves are increasing, especially accelerated washout under the pour hole. This paper describes a few methods of extending shot sleeve life. Application of an AlCrN coating on the ID has promise as a relatively simple method to improve performance of shot sleeves. This coating has been extensively evaluated under laboratory condition with the rotating pin experiment. The results, especially the long-term washout protection it provides to H13 pins have been very favorable, often reducing washout by an order of magnitude. This AlCrN coating was applied on the area across from the pour hole of a H13 shot sleeve and evaluated in production. Another approach to extend life of shot sleeves is to clad the ID with a layer of washout resistant alloy. Performance of shot sleeves cladded with a maraging steel and Daido DHW is described.

Lessons Learned Heat Treating High Pressure Die Casting Tools

R. Simons, T. Mohr (Paulo)

Years of processing high pressure die casting tools has provided lessons regarding processing and tool performance. These lessons can be helpful to tool designers and manufacturers. Emphasis has been put on quench rates with respect to heat checking and gross cracking. Quench rates can be misleading as there is significant measurement uncertainty in obtaining this number. Studies conducted with a 16” cube have found that dramatically different furnace designs result in similar quench rate outcomes. From these studies, the focus on quench rate from 1885°F to 1000°F may not be as important or reliable as the relationship between tool cross section and quench pressure. It is also notable that in order to see a measurable improvement in Charpy impact values a significant increase is needed in quench rate. As quench rates are increased, special precautions are needed in both tool design and process execution. We will review practical risk management techniques that will help mitigate cracking risk during processing of these highly hardenable alloys. This includes precautions to help eliminate the potential for decarburization, and minimize stress concentrators of the roughed out tool. Extra precautions can also be taken on surfaces that are not exposed to hot metal. These techniques are often low cost measures that can be quickly implemented for any shop to reduce the high cost of a cracked tool.

Process Engineering

3:45 pm - 5:15 pm
Session Chair: Peter Ried

Hot Cup Die Casting: A New Process for Al Alloys

G. Wilson (Hotflo Diecasting); E. Herman (Creative Concepts); E. Buckley (O.E. Products)

Hot Cup Die Casting is a new form of high pressure Die Casting which overcomes all the shortcomings inherent in the traditional Cold Chamber process. Instead of a ‘cold chamber’, it uses a ‘hot cup’, hence the name. The alloy remains molten in the cup at all times, so there is no pre-solidified material to end up in the gates or in the casting. The hot cup process enables parts to be made with better properties, thinner wall sections, faster production rates and lower costs.
Slide Wedge-Locks as Leaf Springs Addressing an Unrecognized Problem

E. Herman (Creative Concepts)

Die casting dies are often operated colder and with longer cycles than otherwise necessary to keep slides operating properly. Differential thermal expansions of slide, cover and ejector can cause the slide lock to be too tight or let the slide flash if the die members are not maintained at nearly the same temperature. Keeping the die at nearly the same temperature, does not allow adjusting temperature to maximize filling time, cycle time or die life. The problem can be accommodated by making the slide wedge-lock as a spring.

Challenges and Innovations in Die Cast Tooling

M. Hartlieb (Viami International); M. Schnur, G. Whealy (Delaware Dynamics); P. Mussler (AHP Merkle)

With die castings getting larger, more complex and with ever rising requirements, dies are also getting bigger, heavier (and therefore more and more difficult to transport and manipulate), and more expensive. They increasingly need to incorporate complex thermal management, vacuum valves, etc. while being perfectly leak tight. The trend is towards larger die casting machines that can handle larger parts and bigger dies, but this does not mean it is getting any easier to transport and handle giant, complex dies, let alone justify the increased prices. One challenge is therefore how to reduce the footprint and weight of the dies without compromising their robustness and life expectancy. Less weight means less steel, which is obviously one of the major cost items in die casting dies. With larger parts that integrate more components and functions and the trend to minimize part weight through thinnest possible walls we are often faced with no alternative to extensive heating/cooling systems, vacuum valves, several slides, squeeze pins, etc. Those add to the complexity and costs of our dies. To some extent certain European designs are therefore becoming more and more prevalent in North America.

The focus of this paper will be to illustrate current and future designs both in North America and Europe and technologies available and under investigation/development to minimize the footprint, weight, complexity and costs of large and complex die casting molds; and how to develop and build long lasting high-tech die casting dies that will require minimum maintenance.
Global Trends Spotlight

8:00 am - 9:30 am
Session Chair: Dr. Raymond Donahue

State of the Art and the Role of Innovation in the Recovery of the Die Casting Industry in the European and Italian System

New Trends for Aluminium Alloys for Die Casting

Digital HPDC New Platforms for Monitoring and Forecasting Quality and Costs

An Innovative Experience: HPDC & LPDC School in Brescia

Aluminium in Alfa Romeo’s Giulia, R&S in Low Pressure Casting at OMR Group

Structural

9:45 am - 11:15 am
Session Chair: Hal Gerber

Impact of HPVDC Process Parameters on Microstructure and Mechanical Properties of Aural™ 2 in the F and T5 Conditions

D. Levasseur, F. Chiesa (Centre de métallurgie du Québec); F. Breton (Rio Tinto)

Structural aluminium High Pressure Vacuum Die Casting (HPVDC) is the fastest growing foundry sector in North America. This growth is mainly due to the automotive sector which increasingly replace steel assembly by one-piece aluminium HPVDC parts (shock tower, cross members, rear door panel, etc.). The choice of a structural alloy is based on the published mechanical properties from each supplier, however these mechanical properties are rarely met everywhere in the casting. Moreover, the effect of HPVDC process parameters on the solidification structure and mechanical properties are not well known and must be studied in order to assist foundries in developing their process, meet specifications and optimize their cost efficiency. This study aims at determining the effect of alloy pouring temperature, die temperature and gate velocity on the mechanical properties of Rio Tinto’s Aural™ 2 alloy in the F and T5 conditions. Yield strength, tensile strength and elongation were measured for the 12 combinations of casting parameters and statistically analysed using 3-way ANOVA. The effects of single factors and interactions were highlighted by this technique. The microstructure of the castings was studied in order to establish the relationship between process parameters, microstructure and tensile properties of HPDC parts.

Effect of Cooling Rate on the Micro-Constituents of the Structural HPDC Aluminum Alloy Silafont 36

I. McAdams, Q. Han (Purdue University)

Structural HPDC is becoming a more prevalent subcategory of HPDC over the last 25 years due to the desire to convert automotive structural components from steel to aluminum. However, there is a lack of fundamental microstructure research on the current alloy. The current paper performed experiments on Silafont 36 under different cooling conditions in order to investigate phase formation with particular attention to the SDAS. The results show that the phase formations were refined yet consistent from slow cooling to rapid cooling. Also, the Al-Mg-Si intermetallic was identified within the microstructure for both slow and fast cooling conditions. Finally, curves were presented for the SDAS as a function of solidification time and cooling rate.

New Developments in Die Casting Alloys for Structural Castings

S. Wiesner, R. Klos (Rheinfelden Alloys); V. Anthony (Nikkei MC)

This paper is about two alloys recently developed by RHEINFELDEN ALLOYS dedicated for high pressure die cast structural parts for automotive car bodies. The first having a AlMg4Fe2 composition (Castaduct-42) relies on a completely different eutectic composition formed by a combination of around 4,2 % Mg and around 1,6 % Fe. This guarantees very good castability which is similar to eutectic Al-Si alloys. Si is at a minimum level. In basically all existing foundry alloys Fe is an impurity that reduces mechanical properties and castability through Fe containing needles in the microstructure. In this new alloy Fe is an alloying element and does not negatively impact the properties. The achievable mechanical properties in the as cast state are comparable to typical Al-Si-Mg type alloys with full T7 heat treatment.

The second is AlMg6Si2MnZr (Magsimal-plus) which is a further development of the Rheinfelden’s well-known high strength alloy AlMg5Si2Mn (Magsimal-59). This new alloy Magsimal-plus provides even higher strength at a similarly high ductility making it the highest strength HP-DC alloy for structural parts actually available. AlMg6Si2MnZr (Magsimal-plus) due to dispersoid hardening with Mo and Zr in the Magsimal type alloy is offering yield strength values up to 200-240 MPa (29-35 ksi) in F and T5 temper while still having 10% elongation.
Initial Development of Machine Learning Algorithms to Predict Casting Defects in High-Pressure Die Casting

D. Blondheim, Jr. (Mercury Marine)

Data giants like IBM, Google, Amazon, and Facebook have been using big data and machine learning algorithms for years and, in some cases, decades to help drive extraordinary results and insight for their companies and customers. The high-pressure die cast industry lives in a data-rich world. A review of the die casting process reveals hundreds to thousands of variables that may affect the process or equipment, and therefore, the quality of a casting. Some of these variables are easily measured, while others are technically difficult.

This purpose of this paper is to review the approach used at Mercury Marine’s Casting Business Unit (a division of Brunswick Corporation) to experiment with big data from the high-pressure die casting process and then test its application in machine learning algorithms to improve the understanding of the casting process. Data sources for the analysis include thermal images of die steel after spray and shot end process parameters collected during the production cycle. The results of these initial algorithms will be reviewed to show the effectiveness of utilizing the data to help predict casting defects and what future areas of development, data collection, and improvement are needed.

Optimizing Die Cooling Using Pulsed Spray & Lube Residuals on Die Surface Using Lube Spray Methods

K. Blowers (Purdue University & FCA); M. Rakita, A. Koehler, D. Lee, M. Landa, Q. Han (Purdue University); D. Gettinger, A. Hughes, C. Daugherty (FCA)

In high pressure die casting (HPDC), it is necessary to apply a lubricant onto the surface of the die to prevent soldering and to decrease the cycle time of the casting process. Traditional methods use a continuous spraying method to apply the lubricant; this can be wasteful. This research examines the ability of a pulse spray application process to apply die lubricant onto the die surface. A previous study at Purdue University concluded that the pulsed spray method of die lubricant application could result in a significant reduction of the amount of spray runoff and consumption of die lubricant, leading to large cost reductions. This paper expands upon that research and presents findings for spray frequencies of 10Hz to 100Hz and increments of 10Hz.
Robotic Automation of 3D Scanning for Die Casting Quality Control

M. Kang, J. Hwang (ARIS Technology)

In this paper, we seek to provide a comprehensive overview of how 3D scanning can be utilized to provide die casting companies with an efficient and comprehensive quality control solution. We start by exploring the current state of 3D scanning and how robotic automation of 3D scanning can help overcome its perceived limitations in achieving this stated goal. We then use a reference system, equipped with a 6-axis robot and a 3D scanner and powered through ARIS’s QC automation software, to perform a case study on a die cast part, provided by one of the NADCA member companies. A full inspection report is generated for this part, with a range of annotations that are needed to ensure quality. Then, a gage R&R study is performed on the measurements, where the precision (repeatability and reproducibility) is tested and compared against well-accepted industry standards. This precision test seeks to inform whether automated 3D scanning systems can be deployed in-production, instead of in-lab, leading to significant cost savings. In addition, we test if automated 3D scanning solution leads to lower cycle time, higher inspection rate, and higher data quality, and therefore increased ROI compared to existing systems and processes.

Die Surface Engineering

3:30 pm - 5:15 pm

Session Chair: Peter Ried

Hot Isostatic Pressing of Core Pin coated with PVD Ceramic Coating

Y. Liu, Q. Han (Purdue University); Corey Vian, A Reiff (FCA); C. Chen, Z. Guo (University of Science and Technology Beijing)

This work examines the effect of Hot Isostatic Pressing (HIP) technology on the adhesion of PVD ceramic coating on H-13 steel matrix and on the service life of the core pins under the accelerated soldering testing conditions. Samples with a ceramic coating were heated up to various temperatures for 2 hours under argon protection. These samples were then characterized using an accelerated testing method for their service life in molten A380 alloy, and using Rockwell hardness tester for examining the toughness of the coatings. Experimental results obtained under the accelerated testing conditions suggest that the use of commercial coatings such as BALINIT® ALCRONE, BALINIT®D, BALINIT® FUTURA NANO, and BALINIT® LUMENA extend the service life of core pins by 12-150 times. Hipping of these PVD coating extends the service life of these coatings by another 20%. Rockwell hardness testing indicates that much less cracking is formed near the indentation dents on the coatings subject to HIP-

Additive Remanufacturing of Die Casting Dies by Applying Electron-Beam Deposit Welding with In Situ Heat Treatment

T. Schuchardt, S. Müller, K. Dilger (Braunschweig University of Technology)

High pressure die casting dies made of hot work tool steels like AISI H13 are cyclically exposed to severe thermal, mechanical, chemical and tribological loads during operation. These loads lead to different defects, hence degrading the quality of die surfaces and consequently the quality of cast surfaces. In case of an unexpected production stop caused by critical defects, a remanufacturing by deposit welding is often an appropriate method to make the tool operational again. Currently, TIG or plasma welding processes are mainly used for repair welding routines. However, these welding techniques often exhibit an insufficient process-reliability and poor metallurgical properties. Hence, the primary objective of this work is to enable electron-beam welding technology as a deposit welding technology for an economic regeneration of locally damaged die casting dies made of hot work tool steels. Using this production method enables to establish a flexible, adequate temperature control of the material, resulting in advanced metallurgical properties and improved mechanical properties of the hot work tool steel. The article provides an overview of the qualified filler materials and their achieved mechanical properties. Furthermore, different welding parameters and strategies for the generation of multi-layer systems and experimental limits of the parameters welding speed and wire feed speed are depicted. The article also shows the possibility of in situ pre- and postheat treatment by using different deflection techniques of the electron beam. The results form the basis for a continuous production chain for regenerating worn cavity surfaces. As an alternative repair welding technique, it is in direct competition with existing manual and semi-automatic welding processes. In order to establish this method, the focus for further analysis and research will be on a higher degree of automation.

AMC Results from a Series of Plant Trials to Evaluate the Impact of PVD Processed AlCrN Thin-Film Die Coatings to Minimize Die Lubrication

B. Wang, G. Bourne, J. Song, M Kaufman, S. Midson (Colorado School of Mines); A. Monroe (Mercury Marine); A Korenyi-Both (Tribologix)

A paper published at the NADCA 2016 Congress introduced the concept of using PDV thin-film coatings to reduce or eliminate die lubrication during the die casting process. Reducing die lubrication has the potential of
making significant improvements to the die casting process, including reducing residual porosity and entrapped gasses in the castings, lowering production costs, extending die life, and reducing housekeeping issues.

The results of laboratory testing and initial plant trials suggested that an AlCrN coating applied to the die has the potential for dramatically reducing die lubricant. The objective of this paper is to provide an update on plant trials performed to evaluate the ability of PVD coatings to minimize die lubrication during conventional die casting. To date, 11,652 shots have been produced using a die coated with AlCrN, with die spraying reduced by between 83-to-92% compared with the amount of spray used for an uncoated version of the same die. In addition to reducing spray, it has been possible to reduce the cycle time by about 12%, and T6 heat treating trials suggested that the reduction of spray decreased the amount of gasses entrapped in the castings. Additional details of the plant trials are presented.

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Modelling and Optimization of Part Ejection in Magnesium High Pressure Die Casting

S. Mitra, O. Koester, J. Ruckert, A Sholapurwalla (ESI); P. Uhl (Stihl)

One important process step in Magnesium HPDC (High Pressure Die Casting) is the ejection of part from the mold. Due to solidification and cooling down the part shrinks onto the mold. To overcome the strong forces that hold the part on the mold, ejection pins are used that push the part outside. Often the number of ejection pins is exaggerated since it is currently difficult to estimate if a reduced number could already be sufficient to eject the part without actually trying it. Reducing the number of ejection pins would decrease production costs and also give more flexibility to the mold maker to set cooling channels since these are occupying the same design space as the ejection pins. This article presents a novel modelling approach to virtually test the part ejection. The approach is a simulation chain built of two steps. In the first step a multi-physics modelling of the casting process, taking into account flow, thermal and mechanical aspects, is performed. Target of this simulation is to predict the stresses in the part that fix the part to the mold. This stress distribution is used as the initial state for the second part which represents the modelling of the ejection process taking into account all friction effects. Outcome of the modelling provides information if the stresses in the part during ejection will remain in the elastic range or if there are regions where plastic deformation occurs, which would indicate that the process parameters are not set well. Using this methodology will enable the virtual testing of different distribution and settings of ejections pins.

Runner Development for an Oil Pan Casting

M. Gondek (Magma Foundry Technologies); B. Fung (FCA)

Runner development prior to tool fabrication for a casting can significantly reduce air entrapment and local gas porosity. Filling simulations should be applied to identify potential problem area such as local heavy sections causing flow recirculation and air entrapment.

Various runner layouts can be simulated and properly ranked using the Autonomous Engineering feature of MAGMASOFT. Once the optimal design is found the selected runner layout goes through a proper CAD design for further refinement and complete filling and solidification analysis. This final version is tested through multiple process parameters to confirm there is a large process window.

This process has shown that a very high yield at first sampling can be achieved for the Oil Pan prototype die.
Ultrasonic Degassing That Lowers Porosity in Radiographs and Increases the Weight of Die Castings

R. Donahue, A. Monroe (Mercury Marine)

Because, die casters do not always see per se hydrogen porosity in high pressure die castings, many die casters do not degass their metal. However, as the small bubbles in rotary impeller degassing slowly rise in the melt, hydrogen enters these bubbles and are carried to the surface of the melt. As this process is going on, oxide films [the source for nucleation sites for porosity] attach themselves to the bubbles and float to the surface where they can be removed by skimming. This seemingly perfect world has a few nuances. The best operating rotary impeller degassing unit, in theory, still creates some oxides because of the effect of the impeller speed, even though it might be floating out more oxides than it is creating. However, in practice, under high speed rotation or high gas flow rates, the rotary impeller could be making the metal more dirty. And when rotary impeller degassing is done in a die casting plant, it is generally done at a degassing station for a 3,000 lb melt in a transfer ladle for 6 to 10 minutes. The benefits of this 6 to 10 minutes of degassing is generally substantial wiped out when the degassed melt in the transfer ladle is top poured into the holding furnace at the die casting machine. Thus, it is believable we degassing in high pressure die casting primarily to remove oxide films, the nuclei for porosity. With this theory, it is the ultrasonic vibrations that break up oxides into smaller oxides and effectively destroys the nucleation sites where porosity might nucleate. Further, we are not sure if destroying porosity nucleation sites is time related as lowering the hydrogen content is; it might be amplitude related. In our practice, described in the paper, we ran the ultrasonic degassing unit for six hours and refilled the holding furnace at the die casting machine and ran for another two hours, where the recovery [i.e. lowering of the hydrogen content] after refilling was faster than it was at the start of ultrasonic degassing. Unlike the rotary impeller degassing that was done at the degassing station for a 3,000 lb melt, before the degassed melt was top poured into the holding furnace at the die casting machine, ultrasonic degassing was done in the actual holding furnace at the die casting machine, with brackets on other die casting machines where the ultrasonic degassing unit could be move, in essences providing “On-Demand” ultrasonic degassing for other critical parts. The paper exhibits radiographs before and after ultrasonic degassing and show that, everywhere on the radiograph, there is an improvement as a result of ultrasonic degassing. In fact, at the critical site where the part is generally rejected, it was evident in radiographs before ultrasonic degassing why the part was rejected. After ultrasonic degassing the critical site where the part is generally rejected was so improved that
it was speculated that an ultrasonic degassed part might never again be rejected. Quantitively, a Student’s t-analysis on weights before and after ultrasonic degassing showed significant weight increases after ultrasonic degassing at the 0.1% level of significance [i.e., only one in every 1000 parts might not show the increase in weight].

Coating on Performance

D. Heumannkaemper, M. Pavoni (Morgan Advanced Materials)

Functional coatings have been developed to increase the performance of Graphite or SiC-Crucibles in specific applications. Typical areas of applications of such clay or carbon-bonded crucibles are in the melting, refining, among others, of non-ferrous metals such as aluminium, copper, precious metals, zinc and related alloys. The benefits of the coatings on the crucibles are increased purity of the melted metal, reduced dross adhesion and increased erosion resistance. These advantages were highlighted through case studies in this report.

Process & Quality Control

12:30 pm - 2:00pm
Session Chair: Rob Malarky

Casting Quality Comparison: Vertical vs. Horizontal HPDC

Q. Han (Purdue University); Jerry Good, Corey Vian (FCA); Jue Sun (Sanji Foundry Equipment)

Casting made using conventional horizontal HPDC and vertical HPDC are characterized in terms of porosity formation using optical microscopy, X-ray, and CT scan. It has been found that much less porosity is formed in castings made using the vertical HPDC than that using conventional horizontal HPDC process. Numerical simulation has been performed to investigate the behavior of molten metal in the shot sleeve for both processes. The simulation results suggest that comparing with the conventional horizontal HPDC process, the vertical HPDC 1) eliminates wave formation in the shot sleeve and thus reduces entrapped air in the molten metal, 2) has a smaller surface area of molten metal in the shot sleeve and thus reduces oxide formation over the melt surface, and 3) has a smaller temperature gradient in the melt that reduces the formation of cold flakes and pre-solidified materials in the shot sleeve. It is expected that the use of the vertical HPDC process has the potential of improving the pressure tightness of die castings.

Important Considerations for Laser Marking an Identifier on Die Casting Parts

A. Fraser, J. Maltais, X. Godmaire (Laserax); A. Monroe (Mercury Marine); M. Hartlieb (Viami International)

Traceability and individual part marking of castings is becoming increasingly important. Different marking technologies are available and have been presented and discussed in the previous paper (NADCA 2016). For die casting in most cases laser marking is clearly the most suitable technology – and sometimes actually the only viable and/or long term most economical one. This is due to the fast cycle time; harsh environment (lubricants and dust on parts, and their high temperature when marked); heat treatment and/or subsequent surface treatments (like shot blasting, e-coating, painting, etc.) of the parts which the marking needs to survive and remain readable not only for the human eye but also for automatic 2D bar code readers (otherwise a perfectly good casting has to be scrapped); and the often complex 3D shapes to be marked. Part marking should never be the bottleneck in the process or a contributor to scrap rate due to unreadable markings. And it is not just any laser marker that is capable of doing this complex job. It requires a dedicated system tuned for the specific application and process. In this paper we present and discuss laser safety (often a concern), and how a system might be designed and developed that is easy to install while guaranteeing Class 1 laser safety in any typical die casting environment. We also show the results of extensive research work that has been done since last year’s paper and the successful development of a completely suitable laser marking system for die casting, including pre-engineered solutions for easy retrofitting into existing die casting cells.

Investigation of the Effectiveness of Heat Pipes used in the Die for Magnesium High Pressure Die-Casting

M. Farrokhnejad, J. Weiler (Meridian Lightweight Technologies)

In high pressure die casting (HPDC), the geometry of parts, physical properties of alloys, feeding system design and process parameters all have their own influence on the overall thermal field of the die. However, proper die thermal management is a key factor that yields a high production rate and optimal quality parts. In HPDC, to assist with the die thermal management, cooling bars such as copper rods, heat pipes or isobars are used as heat transfer devices. However, very little information is available as a guideline to use these devices in the die. Previously, the authors of this paper reported on the effectiveness of copper rods in the die [1]. The analysis of some of the in-house experimental work for the heat pipes is reviewed and presented here.