Best papers

published in CHINA FOUNDRY 2004–2013

Twelve papers in the following were published in CHINA FOUNDRY from Vol. No.1, 2004 to Vol. No.4, 2013. All of which were the award-winning best papers from the Foundry Institute of Chinese Mechanical Engineering Society and the best papers from the 69th World Foundry Congress. We hope that you will enjoy reading these specially selected papers. The full texts you can find in the Archive by entering our website link foundryworld.com/english/foundry/index.asp?leib=2

1. Feasibility and practice of nodular iron casting feeder-less production

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Abstract: The volumetric changes of castings and dimension changes of mould cavity occurring during liquid cooling and solidification of nodular iron castings were described. The feasibility and prerequisites to realize feeder-less production of nodular iron castings was analyzed and proved with practical examples. It was pointed out that the feeder-less foundry method is by no means a feeding-less method, and it was emphasized that adopting high carbon equivalent, high rigidity mould, simultaneous and synchronous solidification, and intensifying cooling capacity of the mould to increase feeding effect of the gating system are important to success fully realize feeder-less production of nodular iron castings.

Key words: nodular iron; shrinkage; feeder-less; feeding
Vol.3 No.1, Feb. 2006; Start page: 1, End page: 9

2. Study on interfacial heat transfer coefficient at metal/die interface during high pressure die casting process of AZ91D alloy

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Abstract: The high pressure die casting (HPDC) process is one of the fastest growing and most efficient methods for the production of complex shape castings of magnesium and aluminum alloys in today's manufacturing industry. In this study, a high pressure die casting experiment using AZ91D magnesium alloy was conducted, and the temperature profiles inside the die were measured. By using a computer program based on solving the inverse heat problem, the metal/die interfacial heat transfer coefficient (IHTC) was calculated and studied. The results show that the IHTC between the metal and die increases right after the liquid metal is brought into the cavity by the plunger, and decreases as the solidification process of the liquid metal proceeds until the liquid metal is completely solidified, when the IHTC tends to be stable. The interfacial heat transfer coefficient shows different characteristics under different casting wall thicknesses and varies with the change of solidification behavior.

Key words: high pressure die casting (HPDC); magnesium alloy; interfacial heat transfer coefficient (IHTC)
Vol.4 No.1, 2007; Start page: 5, End page: 9

3. The forty years of vermicular graphite cast iron development in China

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Abstract: In China, the research and development of vermicular graphite cast iron (VGCI) as a new type of engineering material, were started in the same period as in other developed countries; however, its actual industrial application was even earlier. In China, the deep and intensive studies on VGCI began as early as the 1960s. According to the incomplete statistics to date, more than 600 papers on VGCI have been published by Chinese researchers and scholars at national and international conferences, and in technical journals. More than ten types of production methods and more than thirty types of treatment alloys have been studied. Formulae for calculating the critical addition of treatment alloys require producing VGCI have been put forward, and mechanisms for explaining the formation of dross during treatment were brought forward. The casting properties, metallographic structure, mechanical and physical properties and machining performance of VGCI, as well as the relationships between them, have all been studied in detail. The Chinese Standards for VGCI and VGCI metallographic structure have been issued. In China, the primary crystallization of VGCI has been studied by many researchers and scholars. The properties of VGCI can be improved by heat treatment and addition of alloying elements enabling its applications to be further expanded. Hundreds of kinds of VGCI castings have been produced and used in vehicles, engines, mining equipment, metallurgical products servicing under

alternating thermal load, machinery, hydraulic components, textile machine parts and military applications. The heaviest VGCI casting produced is 38 tons and the lightest is only 1 kg. Currently, the annual production of the VGCI in China is about 200,000 tons. The majority of castings are made from cupola iron without pre-treatment; however, they are also produced from electric furnaces and by duplex melting from cupola electric furnaces or blast furnace-electric furnace. Examples of typical applications for VGCI castings are introduced in this paper. In China, the technologies such as rapid testing of the molten metal and non-destructive testing of casting microstructure still need to be improved. Several proposals are put forward in this paper in order to improve the production of VGCI. Generally speaking, in China, the research, production, and application of vermicular graphite cast iron are at the same level as in other developed countries and in some fields China even takes lead. (332 references and 5 Tables)

Key words: vermicular graphite cast iron; China; review
(Part I) Vol.4 No.2, 2007; Start page: 091, End page: 098
(Part II) Vol.4 No.3, 2007; Start page: 175, End page: 181
(Part III) Vol.4 No.4, 2007; Start page: 261, End page: 269

4. Influences of pulse electric current treatment on solidification microstructures and mechanical properties of Al-Si piston alloys

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Abstract: Three kinds of Al-Si piston alloys were prepared and subjected to pulse electric current treatment (PECT) at different pouring temperatures. Some aspects of the solidification microstructures were examined including the morphology and the distribution of the matrix and the secondary phases by using of optical microscopy (OM), SEM and EDS methods. Results indicate that PECT can refine α-Al grains in the alloys as effectively as chemical modification by sodium salt. The processing parameters of PECT on the multi-component Al-Si alloys were then optimized through the testing of tensile strength, elongation and microhardness of the prepared alloys. A new theory was put forward to explain the mechanism of PECT.

Key words: pulse electric current; Al-Si piston alloys; solidification
Vol.6 No.1, 2009; Start page: 024, End page: 031

5. Advanced manufacturing technologies of large martensitic stainless steel castings with ultra low carbon and high cleanliness

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Abstract: The key manufacturing technologies associated with composition, microstructure, mechanical properties, casting quality and key process control for large martensitic stainless steel castings are involved in this paper. The achievements fully satisfied the technical requirements of the large 700 MW stainless steel hydraulic turbine runner for the Three Gorges Hydropower Station, and become the major technical support for the design and manufacture of the largest 700 MW hydraulic turbine generator unit in the world developed through our own efforts. The characteristics of a new high yield to tensile strength ($R_{p0.2}/R_m$) ratio and high obdurability martensitic stainless steel with ultra low carbon and high cleanliness are also described. Over the next ten years, the large martensitic stainless steel castings and advanced manufacturing technologies will see a huge demand in clean energy industry such as nuclear power, hydraulic power at home and abroad. Therefore, the new high yield o tensile strength ($R_{p0.2}/R_m$) ratio and high obdurability martensitic stainless steel materials, the fast and flexible manufacturing technologies of large size castings, and new environment friendly sustainable process will face new challenges and opportunities.

Key words: large martensitic stainless steel castings; ultra low carbon and high cleanliness; turbine runner and blade
Vol.7 No.4, 2010; Start page: 383, End page: 391

6. What do we do next; to survive, grow and be distinguished

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Abstract: In a new world era, where financial systems are being restructured, manufacturing insight reconsidered and ways of doing business is changing, the foundry industry has to adapt herself to the winds of change by placing all her inputs onto the table and reevaluate them to fit into this new era. The inherent strengths of the foundry industry alone would not be enough to fit in this change process, where careful and intelligent operation of the back office and the front office of the foundry should come into the picture.

The recent global crisis and previous ones have had positive effects on the improvement of foundry competitiveness by opening opportunities to change and "clean the house". The survival strategies, as well as what actions to be taken for growth and maintaining a strong foot print in this complicated atmosphere, is discussed in several headlines.

In the long run, survival of individual foundries depends on well managed orchestration by the "decision makers" of each individual component of the foundry. Sustainability of the whole is the sum of survival capabilities of its components and the management of their harmonization.

Key words: competitive power; sustainability; survival; operational excellence
Vol.7 No.4, 2010; Start page: 412, End page: 418

7. The mystery of molten metal

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Abstract: Recent advances in scientific understanding of high-temperature materials processing using novel experimental methodologies have shed light on the complex role of surface and interface phenomena. New in-situ studies on molten metal/solid ceramic interactions using a unique experimental complex at the Foundry Research Institute, Krakow, have revealed a number of unusual observations in materials processing at high temperatures. We present some such unusual observations and their explanation with reference to liquid metal processing of Al, Ni, and Ti, and their alloys in contact with oxide ceramics. In particular, we focus on the following aspects: primary oxidation of Al from residual water vapor or oxygen, capillary purification to remove surface oxide, substrate protection by CVD carbon, roughening due to spinel whisker formation, inclusions in castings due to mechanical detachment, floatation due to buoyancy forces, and

segregation due to directional solidification, modification of the solid surface morphology by metal vapor ahead of the liquid, and the complication due to multi-component alloys melted in crucibles made from complex oxide-based ceramics. In the case of Ti, rapid reactions with oxides result in undesirable volumetric changes that create difficulty in casting high-quality Ti parts, particularly by investment casting. Nanoscale (e.g., colloidal) coatings based on Y_2O_3 protect crucibles and hold ladles against such attack. Practical insights and recommendations for materials processing emerging from the fundamental studies on high temperature interfacial phenomena have been described.

Key words: molten metal; high-temperature phenomena; in-situ observation; casting defects
Vol.7 No.4, 2010; Start page: 425, End page: 437

8. Casting of microstructured shark skin surfaces and possible applications on aluminum casting part

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Abstract: Within the project "Functional Surfaces via Micro- and Nanoscaled Structures" which is part of the Cluster of Excellence "Integrative Production Technology" established and financed by the German Research Foundation (DFG), an investment casting process to produce 3-dimensional functional surfaces down to a structural size of 1 μm on near-net-shape-casting parts has been developed. The common way to realize functional microstructures on metallic surfaces is to use laser ablation, electro discharge machining or micro milling. The handicap of these processes is their limited productivity. The approach of this project to raise the efficiency is to use the investment casting process to replicate microstructured surfaces by moulding from a laser-microstructured grand master pattern. The main research objective deals with the investigation of the single process steps of the investment casting process with regard to the moulding accuracy. Actual results concerning making of the wax pattern, suitability of ceramic mould and core materials for casting of an AlSi7Mg0.3 alloy as well as the knock-out behavior of the shells are presented. By using of the example of an intake manifold of a gasoline race car engine, a technical shark skin surface has been realized to reduce the drag of the intake air. The intake manifold consists of an air-restrictor with a defined inner diameter which is microstructured with technical shark skin riblets. For this reason the inner diameter cannot be drilled after casting and demands a very high accuracy of the casting part. A technology for the fabrication and demoulding of accurate microstructured castings are shown. Shrinkage factors of different moulding steps of the macroscopic casting part as well as the microscopic riblet structure have been examined as well.

Key words: investment casting; microstructured surfaces; shark skin
Vol.8 No.1, 2011; Start page: 62, End page: 65

9. Effect of Mg-Zn-Nd spherical quasi-crystals on microstructure and mechanical properties of ZK60 alloy

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Abstract: To improve the strength, toughness, heat-resistance and deformability of magnesium alloy, the microstructure and mechanical properties of ZK60 alloy strengthened by Mg-Zn-Nd spherical quasi-crystal phase (I-phase) particles were investigated. $Mg_{40}Zn_{55}Nd_5$ (I-phase) particles in addition to α-Mg, MgZn phase and $MgZn_2$ phases can be obtained in ZK60-based composites under normal casting condition by the addition of quasi-crystal containing Mg-Zn-Nd master alloy. The experimental results show that the introduction of Mg-Zn-Nd spherical quasi-crystal phase into ZK60 alloy makes a great contribution to the refinement of the matrix microstructures and the improvement of mechanical properties. While adding Mg-Zn-Nd spherical quasi-crystal master alloy of 4.0wt.%, the ultimate tensile strength and yield strength of ZK60-based composite at ambient temperature reach their peak values of 256.7 MPa and 150.4 MPa, which are about 17.8% and 24.1% higher respectively than those of the ZK60 alloy. The improved mechanical properties are mainly attributed to the pinning effect of the quasi-crystal particles (I-phase) at the grain boundaries. These research results provide a new way for strengthening and toughening of magnesium alloys as well as a new application of Mg-based spherical quasi-crystals.

Key words: spherical quasi-crystal; ZK60 alloy; quasi-crystal-reinforced composites; microstructure; mechanical properties
Vol.8 No.3, 2011; Start page: 305, End page: 212

10. High Cr white cast iron/carbon steel bimetal liner by lost foam casting with liquid-liquid composite process

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Abstract: Liners in wet ball mill for mineral processing industry must bear abrasive wear and corrosive wear, and consequently, the service life of the liner made from traditional materials, such as Hadfield steel and alloyed steels, is typically less than ten months. Bimetal liner, made from high Cr white cast iron and carbon steel, has been successfully developed by using liquid-liquid composite lost foam casting process. The microstructure and interface of the composite were analyzed using optical microscope, SEM, EDX and XRD. Micrographs indicate that the boundary of bimetal combination regions is staggered like dogtooth, two liquid metals are not mixed, and the interface presents excellent metallurgical bonding state. After heat treatment, the composite liner specimens have shown excellent properties, including hardness > 61 HRC, fracture toughness α_k>16.5 J·cm^{-2} and bending strength >1,600 MPa. Wear comparison was made between the bimetal composite liner and alloyed steel liner in an industrial hematite ball mill of WISCO, and the results of eight-month test in wet grinding environment have proved that the service life of the bimetal composite liner is three times as long as that of the alloyed steel liner.

Key words: bimetal liner; liquid-liquid composite process; lost foam casting; high Cr white cast iron
Vol.9 No.2, 2012; Start page: 136, End page: 142

11. Microstructure and mechanical properties of a new type of austempered boron alloyed high silicon cast steel

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Abstract: In the present paper, a new type of austempered boron alloyed high silicon cast steel has been developed, and its microstructures and mechanical properties at different temperatures were investigated. The experimental results indicate that the boron alloyed high silicon cast steel comprises a dendritic matrix and interdendritic eutectic borides in as-cast condition. The dendritic matrix is made up of pearlite, ferrite, and the interdendritic eutectic boride is with a chemical formula of M_2B (M represents Fe, Cr, Mn or Mo) which is much like that of carbide in high chromium white cast iron. Pure ausferrite structure that consists of bainitic ferrite and retained austenite can be obtained in the matrix by austempering treatment to the cast steel. No carbides precipitate in the ausferrite structure and the morphology of borides remains almost unchanged after austempering treatments. Secondary boride particles precipitate during the course of austenitizing. The hardness and tensile strength of the austempered cast steel decrease with the increase of the austempering temperature, from 250 °C to 400 °C. The impact toughness is 4–11 $J \cdot m^{-2}$ at room temperature and the impact fracture fractogragh indicates that the fracture is caused by the brittle fracture of the borides.

Key words: boron alloyed; high silicon cast steel; austempering treatment; ausferrite structure; boride
Vol.10 No.3, 2013, Start page: 155, End page: 161

12. Colour Metallography of Cast Iron

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Abstract: Cast iron, as a traditional metal material, has advantages of low total cost, good castability and machinability, good wear resistance and low notch sensitivity, and is still facing tough challenge in quality, property and variety of types etc. Experts and engineers studying and producing iron castings all around world extremely concern this serious challenge. Over more than 30 years, a great of research work has been carried out on how to further improve its property, expand its application and combine cast iron technology with some hi-techs (for example, computer technology). Nevertheless, cast iron is a multi-element and multi-phase alloy and has complex and variety of structures and still has great development potential in structure and property. For further studying and developing cast iron, theoretical research work is important promise, and the study on solidification process and control mechanism of graphite morphology is fundamental for improving properties of cast iron and developing new type of cast iron. Metallography of cast iron normally includes two sections: liquid phase transformation and solid phase transformation.

The book, Colour Metallography of Cast Iron, uses colour metallography technique to study solidification structures of cast irons: graphite, carbides, austenite and eutectics; and focuses on solidification processes. With progress of modern solidification theory, the control of material solidification process becomes important measure for improving traditional materials and developing new materials. Solidification structure not only influences mechanical and physical properties of cast iron, but also affects its internal quality. The book uses a large amount of colour photos to describe the formation of solidification structures and their relations. Crystallization phenomena, which cannot be displayed with traditional metallography, are presented and more phase transformation information is obtained from these colour metallographic photos.

Except for focusing on the effect of high carbon phases in cast iron, in this book, special attention is also paid to the effect of austenite on solidification, graphite morphology, and quality of cast iron; at the same time, the study on the solidification behaviours in the region around eutectic cells and its effects on mechanical properties of cast iron, are also emphasized.

Key words: colour metallography; cast iron

This book consists of five sections: Chapter 1: Introduction, Chapter 2: Grey Iron, Chapter 3: Ductile Iron, Chapter 4: Vermicular Cast Iron, and Chapter 5: White Cast Iron.

CHINA FOUNDRY serially published this book in several parts, starting from Vol.6 No.1 (page 57–69), the first issue of 2009, to the end Vol.8 No.4 (page 447–462), the fourth issue of 2011.