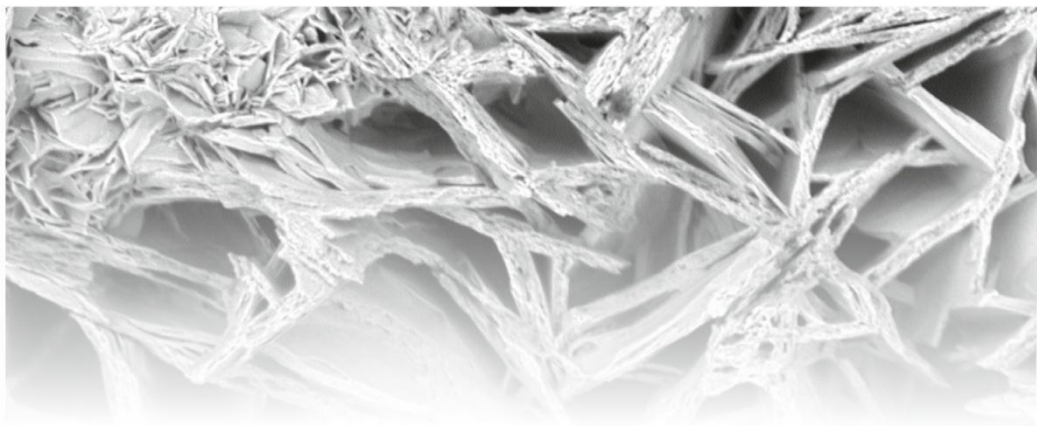




SOLIDIFICATION & CRYSTALLIZATION OF METALS

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Book of abstracts

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Verification of the suitability of secondary aluminum for decorative castings

The increasing demand for aluminum and the need for more sustainable production routes are driving the foundry industry towards greater use of secondary aluminum. Although recycling requires only about 5% of the energy of primary production, secondary alloys contain higher levels of impurities and inclusions, limiting their use in demanding applications. This is particularly challenging for decorative castings, where AlMg alloys are anodized to obtain a consistent shiny and coloured surface, as even minor compositional variations can cause visible colour deviations and surface defects. This project investigates the suitability of AlMg scrap from the offshore sector for producing anodized door handles by gravity die casting. The main goal is to get a specification for the chemical composition and inclusion content required to achieve sufficient anodizing quality. The work demonstrates the potential this kind of scrap for high-quality decorative castings and highlights the importance of controlling material and process parameters.

Effect of alloying additions on the properties of aluminium bronzes cast into molds manufactured using 3D binder jetting technology

Aluminum bronzes are copper-based alloys characterized by high mechanical strength, corrosion resistance, cavitation erosion resistance, and wear resistance. These properties enable their widespread use in marine applications, including propellers, valves, pumps, and offshore components. This study aimed to assess the effect of the chemical composition of selected aluminum bronzes on their mechanical and tribological properties. The alloys were produced by melting and casting into sand molds manufactured using 3D Binder Jetting technology. The results showed that CuAl9Ni5Fe3Mn2 exhibited the most favorable mechanical properties and the highest wear resistance among the investigated alloys. The beneficial effects of Al, Ni, and Fe additions on the functional properties of aluminum bronzes were confirmed, demonstrating their high potential for applications in marine environments.

Dilatometric evaluation of ausferritic transformation kinetics using Avrami diagram

The evaluation of the process window limits for isothermal quenching in the production of cast iron castings with an ausferritic structure for a selected ausferritization temperature is most often performed based on tests of the properties and microstructure of specimens. The materials for such analysis should be obtained by processing at low-temperature stage with varying duration. Increasing the accuracy of the assessment of the start and end times of the process window may require preparing a larger number of sample batches for such tests. Recording changes in sample dimensions during dilatometric tests allows for a basically continuous assessment of the kinetics of ausferrite formation. This article presents the theoretical foundations for analyzing the kinetics of the isothermal “austenite > ausferrite” transformation based on continuous dilatometric measurements using the Avram equation. It was noted that the results of such an assessment can serve as a kind of “fingerprint” of the behavior of alloys with different chemical compositions under selected process conditions. The results obtained in this way may be useful in evaluating the boundaries of the process window.

This research was funded by the Excellence Initiative - Research University (IDUB) programme at AGH University of Krakow.

The bifilm concept - revolutions for casting technology and metallurgical science

The bifilm is a recently discovered concept of such simplicity it seems sometimes difficult to understand and difficult to realise its awesome potential. However, it explains the causes of most foundry scrap, which can, for the first time, be eliminated, revolutionizing both foundry achievements and profits. Metal failure by fatigue can now be eliminated by good foundry practice. The bifilm concept has also led to the understanding of the dangers of the vacuum induction melting (VIM) process, necessarily pouring vacuum castings with great turbulence, which are therefore seriously damaged by a dense population of thin (effectively invisible) bifilms. The use of such VIM electrodes for vacuum arc remelting (VAR) will be explained to have been one of the greatest metallurgical mistakes of all time, leading to repeated aircraft tragedies over the years, especially tragic helicopter failures because of their reliance on defective VAR steels for their single drive train. Improved VAR is now predictable, using lower cost air melted metal, with total reliability to eliminate metal failures. Foundry and metallurgical revolutions are already at our door. The world of engineering will be happy to receive, for the first time, metals it can trust.

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The influence of mould-making technology using furfuryl resin-bonded moulding sands on the microstructure of high-grade cast iron castings — a comparison of the traditional method and Binder Jetting

This paper presents the influence of mould manufacturing technology and conformal cooling on the microstructure of castings made from high-quality ductile iron. Three mould variants were investigated: a traditional mould made from furfuryl resin-bonded moulding sand, an additively manufactured Binder Jetting mould without cooling, and an additively manufactured mould with active conformal cooling. The aim of the study was to determine how the mould preparation method and controlled heat extraction affect metal solidification, graphite morphology, and the metallic matrix of the casting. The use of Binder Jetting enabled the production of cooling channels adapted to the geometry of the mould cavity. The results indicate that conformal cooling intensifies heat extraction, promoting finer and more uniform spheroidal graphite as well as a more favourable microstructure of the casting surface layer. This technology can be used not only to produce moulds with complex geometries, but also to actively control casting properties.

This research was funded by the Excellence Initiative - Research University (IDUB) programme at AGH University of Krakow.

Estimating toughness limit of cast aluminum alloys with Reduced Pressure Test

Defect free casting begins with melt cleanliness and mould filling (i.e. well-designed runner systems). Failure of one of these main components has a significant negative impact on the quality of cast part. Three different mould designs were investigated where 10 cylindrical bars were cast by using A356 alloy. The reliability of the results was evaluated using Weibull analysis and survivability plots. It was found that the highest reliability and reproducible results with the highest elongation at fracture was obtained when tilt casting was used compared to the gravity casting with counter-gravity filling. A direct correlation between Reduced Pressure Test results, bifilm index and mechanical properties were proposed.

Ex-situ A356/SiCp cast composites – production method, microstructure, properties

Cast aluminium–silicon alloy matrix composites (AlMMCs) reinforced with hard silicon carbide particles (AlSi/SiCp) exhibit a favourable combination of properties, making them suitable for demanding structural applications, including pistons, cylinder liners, and brake discs. A new research direction, investigated in the present study, involves the potential use of AlMMCs as a material for the manufacture of lightweight automotive wheel rims. It should be emphasised that the ex-situ fabrication of AlSi/SiCp composite suspensions requires several critical conditions to be satisfied. These are primarily related to achieving a stable and durable bond at the matrix–reinforcement interface, minimising the tendency of ceramic particles to agglomerate and sediment, and ensuring sufficient fluidity of the composite suspension to enable complete filling of the mould cavity during solidification. The present study focused on evaluating the effect of selected alloying additions (Mg, Sr, Ti, and B) on the fluidity and gas absorption tendency of a composite suspension containing 10 vol.% SiCp. These characteristics are of particular importance as they directly affect the quality and mechanical performance of the resulting castings.

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Non-destructive testing and reverse engineering techniques for the characterization of medieval bell-casting technology

The subject of the research was a comprehensive technological and material analysis of a set of medieval bells. Given the unique historical, cultural and functional value of the objects, the research procedure was carried out using exclusively non-destructive analytical methods and advanced reverse engineering tools. Energy-dispersive X-ray fluorescence spectroscopy (ED-XRF) was used to determine the chemical composition. The results showed that the objects under investigation were cast from tin bronzes characterised by varying contents of alloying elements and the presence of natural impurities, such as lead, antimony, iron, nickel and arsenic. This elemental distribution indicates a lack of standardisation in the foundry alloys of the time and the use of remelted raw materials. An assessment of the structure, carried out using non-destructive ultrasonic testing (UT), enabled the identification of material discontinuities, including microstructural porosity and shrinkage voids concentrated mainly in the uppermost parts of the bell's crown and the thickest sections of the castings. An important element of the work was the mapping of the bells' actual geometry using 3D scanning, on the basis of which detailed CAD models were developed. These models, together with data obtained from analytical studies and thermodynamic modelling carried out using the Thermo-Calc system, served as the basis for advanced numerical simulations of the mould filling and alloy solidification processes, carried out in the MAGMASOFT computational environments. This enabled the analysis of molten metal flow dynamics, the identification of heat accumulation zones, and the determination of areas particularly prone to the formation of casting defects. The high correlation between the results of the numerical simulations and the defects identified empirically confirmed the validity of the analytical assumptions made and the effectiveness of the combined research methodology. The digital twins of the objects developed and the detailed technical documentation represent a significant contribution to the development of archaeometallurgy and research into the history of foundry work. These results can directly support the planning of conservation work and will also be used for long-term digital archiving within the international research infrastructure ERIHS.

Research project supported/partly supported by program „Excellence initiative – research university” for the AGH University of Krakow.

The role of the protective coating thickness in the process of moisture migration from the protective coating into the sand mould surface layer

This paper presents the results of measurements of moisture migration in the top layer of a sand mould during the sorption and desorption of moisture from the protective coating. The tests were carried out on a test rig for measuring the resistance of a porous medium. The change in the medium's resistance occurs because of moisture sorption from the protective coating into the medium, followed by moisture desorption. The tests utilised an alcohol-based zirconium coating, the viscosity of which was determined using a Ford cup with a 4 mm orifice. The conventional viscosity of the coating was 20 s. The protective coating was applied by pouring onto the test cores. The cores were made from a furan matrix on a matrix of medium-grain quartz sand with a mean grain size of $d_l = 0.25$ mm. The thickness of the coating applied to the core varied, ranging from 0.6 mm to 1.2 mm. Investigations into changes in the resistivity of the porous medium were carried out at depths of 2, 3, 4, 5, 8, 12, 16 and 20 mm. Based on the results obtained, the course and kinetics of the moisture migration process in the top layer of the core following the application of a protective coating were determined, as well as the effect of the coating thickness on the mechanism of moisture migration. The tests were carried out in a climatic chamber at a constant air temperature of $T = 25$ °C and humidity of $W = 40$ per cent. The studies demonstrated how moisture migrates from the coating into the top layer of the moulding sand, how deep this process extends and how long it lasts, as well as how the thickness of the coating applied to the moulding sand affects this process.

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Porosity of carbon materials used in foundry practice for the carburization of molten cast iron

The process of smelting cast iron in electric furnaces can be conducted using pig iron or steel scrap. Various carbon materials are used to compensate for the carbon deficiency. These include anthracite, natural graphite, synthetic graphite, pitch coke, or petroleum coke. Petroleum cokes and synthetic graphites are most commonly used in foundry processes. These materials should be characterized by the highest possible carbon content, low sulfur content, low ash, and low nitrogen and moisture content.

This article presents the results of tests on the most commonly used carburizers in foundry: synthetic graphites (SG), petroleum cokes (PC), and pitch coke. Specific resistivity, apparent density, porosity, and microstructural analysis using an optical microscope were tested. The obtained measurement and calculation results are presented in tables, graphs, and microstructure photographs. Based on the measurements and calculations, it was determined that synthetic graphites, sulfur-free petroleum coke, and petroleum cokes had the highest predicted carburization efficiency, while pitch coke had the lowest. It was also noted that samples with higher apparent density had fewer open pores, which directly translated into a lower capacity for water absorption. Low-density materials, on the other hand, had a complex porous structure, which dramatically increased their water absorption. It was also found that the tested carburizers were characterized by numerous pores of varying thickness and length, arranged in parallel or in a swirling pattern. This arrangement is referred to as a fibrous or streaky texture. Images of these structures obtained at various magnifications are included in the article. These studies also confirmed the high usefulness of resistivity measurements for determining predicted efficiency. Lower resistivity of the carburizer translates into higher efficiency. These studies aimed to determine the effect of various parameters on the degree of carbon assimilation achieved by the liquid metal.

Optimization of tool geometry as an element of sustainable development in manufacturing processes

Modern manufacturing increasingly requires combining high productivity with efficient use of raw materials, making resource efficiency a key aspect of sustainable development. One promising approach to reducing material consumption is the optimization of tool geometry used in sheet metal forming processes. Properly designed tools can maintain the required product quality while reducing material usage and minimizing process-related defects. This paper presents a case study involving the modification of a forming process for thin-walled aluminum components, where changes in tool geometry and the implementation of a multi-stage forming strategy enabled the use of thinner sheet material without compromising product functionality. The role of numerical simulations as a tool supporting the development of material-efficient manufacturing solutions is also discussed.

This research was funded by the Excellence Initiative - Research University (IDUB) programme at AGH University of Krakow.

Structural and material optimization of cast components for solid-fuel heating devices

The paper presents the results of the structural and material conversion of cast grates used in solid-fuel heating devices. A multi-variant geometric optimization based on finite element analysis (FEA) was carried out to reduce component weight while minimizing thermal stresses and deformations. The optimized designs achieved up to 16% weight reduction and up to 40% lower thermal deformation without compromising their functional performance. In parallel, the alloy composition was modified by reducing chromium content and increasing the silicon level. The experimental results showed that decreasing the chromium content from approximately 1.0% to 0.3% increased thermal fatigue resistance from 26 to 88 cycles while eliminating technological issues associated with high chromium content. The obtained results confirm that the combined structural and material optimization approach significantly improves the durability and manufacturability of cast heating device components.

Small-data-driven models in manufacturing. Application to a sustainable aluminum secondary smelting process

The presentation addresses the use of the Small Data approach in modelling industrial processes, with particular reference to aluminium casting. The theoretical part systematizes the sources of small datasets in industry and discusses methods for their analysis, validation and technological interpretation. The application part presents a case study related to the start-up of a new technology for remelting 6xxx-series aluminium alloys with approximately 90% scrap content, including unstable post-consumer scrap. Since the target foundry was being developed in parallel with the research work, no historical production-line data were available. Therefore, 42 controlled semi-industrial melts were used to build predictive models of melting yield. The results show that a properly prepared small dataset can effectively support technological decision-making in a complex process of significant ecological, economic and energy importance.

Analysis of the knockout performance of ceramic moulds for patterns with different geometries in investment casting

This paper presents an innovative method for the production of ceramic moulds, developed with the aim of improving the demouldability of castings with complex geometries. The essence of the proposed solution lies in the use of a multi-layered, hybrid ceramic mould design. Within its inner zone, layers are placed which are characterised by a deliberately reduced strength following the sintering process. An organic binder is used to produce these layers. Layers with reduced strength can be applied either over the entire surface of the casting or locally. The research utilised models in the form of sleeves with varying internal cross-sectional shapes. The studies carried out demonstrated that the use of the developed technology leads to a marked improvement in the demouldability of ceramic moulds, particularly in the case of castings characterised by complex geometry.

Research project supported/partly supported by program „Excellence initiative – research university” for the AGH University of Krakow.

Shaping the structure and functional properties of chromium cast iron

Chromium cast irons, classified as white cast irons, are used in mining, energy and construction industries due to their high hardness, abrasive wear resistance and operational durability. Their main technological issue is the tendency to hot cracking and porosity, which reduces casting reliability. The study presents melt inoculation and heat-treatment procedures enabling the production of defect-free castings with improved wear resistance and acceptable impact strength. The research involved the Althoff-Radtke test, hardness and impact measurements, abrasive wear tests, thermal analysis and microstructural examinations (LM, SEM, TEM, EBSD). Special attention was given to Fe-Ti and Fe-Nb inoculiers and their effect on crystallization. Small additions of these inoculiers refine primary grains, reduce undercooling and limit hot cracking and shrinkage defects. Inoculation improves structural homogeneity and wear resistance, while lowering heat-treatment temperature does not deteriorate properties and reduces energy consumption.

This research was funded by the Excellence Initiative - Research University (IDUB) programme at AGH University of Krakow.

Mechanism of B2 phase crystallization in Cu-Zr-Al bulk metallic glass matrix composites

Bulk metallic glasses (BMGs) exhibit outstanding mechanical properties, including high strength, large elastic strain, and excellent corrosion and wear resistance. However, their practical application is limited by their intrinsic brittleness at room temperature caused by shear band localization. This limitation can be overcome by developing bulk metallic glass matrix composites (BMGMCs), in which ductile crystalline phases are embedded within the amorphous matrix. Among them, Cu-Zr-Al BMGMCs containing an in situ formed B2 CuZr phase are of particular interest because the stress-induced martensitic transformation of the cubic B2 phase into the monoclinic B19' phase enhances both strength and ductility. While the literature attributes the formation of the B2 phase to a polymorphous (massive) transformation from the liquid, this presentation proposes an alternative formation mechanism based on the ternary phase diagram and experimental results.

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From FEA to foundry: optimization and production of an integrated spindle mount for CNC milling machines

This article presents the optimization process and manufacturing of an integrated spindle mount for a CNC milling machine. Three design variants were analyzed using a Finite Element Method (FEM) in ANSYS software to optimize the component in terms of mechanical strength and mass reduction. The selected geometry was evaluated through casting process simulation in MAGMASOFT Software. The analysis included mold filling and solidification processes, prediction of casting defects, and its microstructure. To produce the casting in a sand mold, an FDM 3D printed casting model was manufactured. Finally, a microstructure analysis and porosity was conducted at selected areas of the casting. As a result of this research, a new, stronger, and lighter integrated spindle mount was obtained.

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Development of a technology for manufacturing products from ecological silicon brass including material recycling

The implementation of the Drinking Water Directive 2020/2184/EU, which restricts the use of lead-containing materials in drinking water installations, necessitates the development and implementation of new, lead-free fitting materials. Silicon brass CuZnSi is a particularly promising group, offering an alternative to currently used lead-containing copper alloys. The work aims to develop a technology for manufacturing rods and pipes from eco-friendly silicon brass using continuous casting, maximizing the use of recycled materials. The scope of work includes the preparation of recycled materials and the optimization of the melting and casting processes, ensuring the production of uniform, high-quality products with the required properties. The developed technology will enable the production eco-friendly fittings that meet legal and market requirements while simultaneously reducing the consumption of primary raw materials.

3D Binder Jetting printing technology to produce elements with the required functional properties

The most widely used 3D printing method in the foundry industry is Binder Jetting (BJ), which involves the selective deposition of a binder onto layers of sand to produce a casting mold or core. Compared with conventional manufacturing, this technology offers significant economic advantages. BJ is currently used for casting iron and Al alloys. Limited information on its application to Cu alloys has created new research opportunities. In this study, a casting mold was designed and manufactured using Bindr Jetting metod, and a propeller was cast from Cu6328 alloy. The propeller characterised high quality and accurately reproduced the designed geometry. Non-destructive testing confirmed a homogeneous structure and the absence of significant internal defects. The identified defects were limited to the propeller surface, which characterised the typical roughness associated with this type of mold. This roughness was considered acceptable for real applications, provided that final machining of the casting is performed.

Quantitative multiscale characterization of reinforcement distribution anisotropy in cast composites with aluminum and A3XX-Series aluminum alloy matrices

The spatial distribution of reinforcing phases in cast composites with aluminum and A3xx-series aluminum alloy matrices (e.g., A356 and A339) results from complex interactions during solidification, in situ synthesis, and subsequent processing. Particle segregation, particle pushing by the solidification front, and agglomeration of ceramic reinforcements such as SiC or TiC can produce pronounced local heterogeneity that reinforcement volume fraction alone fails to capture. This contribution presents a quantitative framework for characterizing such composite microstructures across the micro-, meso-, and macroscales, integrating digital image analysis, statistical methods, Fourier analysis, and analytical representative volume element (aRVE) theory. Structural information extracted from micrographs is expressed through local phase concentration, structural sums, and parameters describing the magnitude and orientation of anisotropy. This enables identification of structurally representative regions, detection of subtle variations in reinforcement distribution, and quantitative links between microstructural geometry and effective properties such as thermal conductivity. The approach is applied to composites obtained through both ex situ (e.g., friction stir processing) and in situ (e.g., self-propagating high-temperature synthesis) routes. Spatial mapping and unsupervised clustering of the anisotropy coefficient reveal the coexistence of isotropic and anisotropic regions within a single sample, even where the reinforcement concentration remains nearly uniform—indicating that particle arrangement, not concentration alone, governs local anisotropy. The framework provides a basis for comparing manufacturing routes, assessing process stability, and studying how processing parameters influence reinforcement redistribution, contributing to data-driven microstructure classification and closer integration of experimental and numerical approaches.

Effect of rapid cooling and ultrasonic treatment on the functional properties of casted SnSb11Cu6 bearing alloy

The SnSb11Cu6 alloy is widely used for manufacturing the sliding layer of bearing shells. The good sliding properties of this alloy result from its microstructure, which consists of a soft tin matrix, hard Sn-Sb phases acting as a load-bearing skeleton, and Cu-Sn phases. Conventional gravity and centrifugal casting methods lead to the formation of large, angular Sn-Sb phase particles, which limits ductility and reduces the fatigue strength of sliding layers. This study presents the results of investigations into the effects of rapid cooling and ultrasonic treatment during the gravity casting process on the morphology of the Sn-Sb phase and the functional properties of the SnSb11Cu6 alloy. It was demonstrated that, compared with the alloy cast under conditions involving slower heat removal, the alloy produced using this method exhibited more than 10% higher strength properties and over 60% lower wear.

Effect of acidity (pH) of fresh and reclaimed sands on the curing rate of furan moulding sands monitored by ultrasonic technique

This study investigates the effect of sand matrix type (quartz, reclaimed quartz, zircon, chromite, corundum, synthetic, and olivine) on the curing kinetics of self-hardening moulding sands bound with Kalthartz U404 urea-furan resin and Activator 100 T3 acid hardener (hardener-to-resin ratio: 50 %, resin content: 1.00 pbw). All measurements were conducted in a climate chamber at a constant ambient temperature of 20 °C (moulding sand temperature: 20 ± 1 °C). The experimental methodology comprised: • sieve analysis of the tested base sands; • matrix pH determination via a modified protocol by N. Matonis and D.M. Halejcio (based on the BN-81/4021-02 standard); • Fourier-transform infrared spectroscopy (FTIR); • ultrasonic monitoring of curing kinetics, based on wave velocity (CL), degree of hardening (Sx), and their respective rates of change (dCL/dt and dSx/dt). The results indicate that sand acidity (particularly in reclaimed sand) is a primary, though not exclusive, governing factor in the hardening rate of furan resin-bound moulding sand.

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The influence of convection on the microstructure of AlSiMg alloys during slow solidification

The presence of gravity during pouring, causes the flow of the alloy in the gating system and the mold cavity, as well as the phenomenon of natural convection at the stage of solidification of the casting. However, the developed casting technologies also use the phenomenon of forced convection, which can be generated by mechanical or electromagnetic mixers. The effect of stirring with electromagnetic coils on the microstructure of Al-Si-Mg alloys was analyzed, based on slowly solidifying small cylindrical samples. In tested Al-Si-Mg alloys, melt flow led to microstructure modification: changed amount, dimension, and location of magnesium-rich Mg₂Si precipitates, secondary dendrite arm spacing SDAS, specific surface and grain size of α -Al phase and finally modified eutectic spacing for observed binary and ternary eutectics. Flow produced more and larger blocky shaped and Chinese script phases and significantly reduced amount and dimension of dispersed Mg₂Si in the alloy where Mg₂Si grow as first phase. By co-precipitation of α -Al and Mg₂Si with a basically dendritic shape and internal form of Mg₂Si, forced flow increased its SDAS, produced globular forms, whilst did not change the internal spacing. In the alloy where α -Al and Si crystals co-precipitate, stirring caused formation of characteristic eutectic-enriched regions separated from α -Al rich regions. In the alloy where Mg₂Si and Si co-precipitate before eutectic growth, stirring caused distinct appearance of dendritic Mg₂Si and α -Al. The observed structural modifications are new and can help in assessing of convection effect on microstructure of industrial alloys and support the design of casting processes in which mechanical or electromagnetic stirring is the main phenomena determining microstructure and mechanical properties of cast parts.

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Formation of local WC composite reinforcements in Fe–C-based alloy castings using in situ synthesis

The work presents the potential of in situ synthesis reactions for the local fabrication of tungsten-carbide-reinforced composite layers and zones in Fe–C alloy castings. Two technological routes are discussed: reactive coatings applied to the mould surface and local reactive systems placed inside the mould cavity to produce thicker composite zones. The effects of selected technological and material parameters on the reaction course, microstructure and morphology of the resulting zones are presented. The experimental results are discussed in relation to the thermodynamic conditions governing the formation and stability of carbide phases in the Fe–W–C system. The possibility of controlling the local structure of castings through an appropriate selection of the reactive system and processing conditions is highlighted.

The influence of chromium on the microstructure of low-pressure castings from the EN AC-42000 alloy obtained with increased scrap content

The need to increase the scrap content increases the content of various impurities, the worst of which is iron. To neutralize its negative impact, alloying additives with similar crystallographic parameters are introduced, of which manganese is a common one. However, substitutes are sought. Research results concern the effect of chromium on the microstructure, particularly the porosity, of low-pressure castings (LPC) made of ENAC-42000 alloy (AlSi7Mg) with scrap content ranging from 60 to 90%. Increasing scrap content resulted in an increase from 0.12 wt.% to 0.49 wt.% Fe. The chromium content was adjusted to maintain a Fe/Cr ratio of 1/3. Based on microstructural studies, it was determined that the addition of chromium causes the transformation of the acicular Al₅FeSi phase to the Al₁₃(Fe,Cr)₄Si₄ phase. For iron contents up to approximately 0.39 wt.% and chromium contents up to approximately 0.13 wt.%, the Al₁₃(Fe,Cr)₄Si₄ phase adopts a dendritic morphology. Exceeding these values causes the morphology of the Al₁₃(Fe,Cr)₄Si₄ phase to change from dendritic to polygonal. These solids then constitute sludge particles, which significantly increase the porosity of EN AC-42000 alloy castings.

Porosity and mechanical properties of rheocast gearbox housings compared to HPDC

A rheocasting technology trial was conducted on an electric motor gearbox housing under conditions close to serial production, covering a total of 15 production shifts and more than 700 castings made from the AlSi9Cu3(Fe) alloy. The objective was to evaluate process stability, required clamping force, casting quality in terms of porosity and mechanical properties, as well as the impact of the technology on cavitation and potential die wear. The results confirmed the stability of the rheocasting process, while indicating the need for enhanced process parameter control. A significant advantage was the possibility of reducing the required clamping force by approximately 20-30%. Leak-tightness testing demonstrated improved performance compared to conventional high-pressure die casting, with lower average leakage values. Further assessment is required for the tensile test results, as specimens taken from the gate area did not meet the minimum acceptance criteria.

Effect of casting conditions on high-chromium steel working layer properties in layered castings

The aim of the conducted research was to determine the possibility of integrating the manufacturing process of layered castings in the X46Cr13 steel (working layer) – grey cast iron (supporting layer) material system with the hardening process of the steel carried out directly under mould conditions. As part of the research, a series of layered castings was produced using the mould cavity preparation method, in which a monolithic X46Cr13 steel insert was poured with liquid grey cast iron containing flake graphite. The influence of selected technological parameters of the casting process was analysed, including pouring temperature, the thickness of the supporting part of the casting, and the intensity of heat extraction from the mould, which depended on the type of moulding material used. The obtained results confirmed that an appropriate selection of technological parameters of the casting process enables effective control of the fraction of structural phases and, consequently, the shaping of the functional properties of layered castings. At the same time, within the investigated range of technological parameters, conditions enabling the complete elimination of pearlite from the microstructure of the working layer made of X46Cr13 steel were not achieved.

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Effect of laser remelting on the abrasive wear resistance of WC coatings in a ball-on-disc test

This study presents the results of an investigation into the effect of laser remelting of a coating based on tungsten carbide (IV) (WC) powder on the surface properties of S355 structural steel. The coating, prepared in the form of a WC powder-based paste, was applied to the surface of S355 steel specimens and subsequently remelted using a diode laser with beam powers of 300, 400, and 500 W. The microstructure, microhardness, and tribological wear resistance of the resulting layers were investigated. Tribological tests were conducted using the ball-on-disc method under a load of 10 N and over a sliding distance of 1000 m. The results showed that increasing the laser power increased the depth of the remelted zone from approximately 356 µm at 300 W to approximately 427 µm at 500 W, while maintaining a similar microstructural character of the layers. The application of a laser-remelted WC-based layer resulted in a significant increase in surface microhardness, reaching approximately 770–800 HV0.5, compared with approximately 150–160 HV0.5 for the S355 steel substrate. At the same time, a substantial improvement in abrasive wear resistance was observed. The maximum wear depth decreased from approximately 260 µm for unmodified S355 steel to approximately 24 µm for the surface with the laser-remelted WC-based layer. The obtained results confirm the beneficial effect of laser remelting of a WC-based coating on improving the service durability of S355 steel components, particularly those operating under conditions of intensive abrasive wear.

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Low-pressure casting technology for sanitary fitting components made from next-generation brass alloys

This publication focuses on the development and optimization of low-pressure die casting (LPDC) technology for sanitary fitting components made of new-generation, low-lead brasses, addressing stricter environmental regulations in the drinking water sector. Based on thermal-derivative analysis (TDA), dilatometry, and dezincification resistance testing, the influence of alloying additives on casting shrinkage kinetics and the microstructural formation of lead-free alloys was determined. Numerical process simulations were employed to validate thermophysical properties and ensure the precise selection of pouring and solidification parameters, enabling the minimization of porosity and shrinkage defects in castings with complex geometries. The research findings were verified under industrial conditions, ultimately leading to the successful implementation of the technology for casting fitting bodies and inserts that meet stringent requirements for tightness and surface quality.

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Simulation of bifilm defects in aluminum alloys using the finite element method to evaluate mechanical properties

During the casting of aluminum alloys, several metallographic defects can occur in the microstructure of the material as a consequence of the manufacturing process. Especially detrimental for the macroscopic operational strength of a mechanical component are voids, inclusions of other materials and bifilms. Whilst the occurrence and severity of void formation can be reduced by special manufacturing techniques, such as e.g. pressure die casting, the appearance of bifilms and their effect to fatigue performance can typically not be detected due to the nature of the defect with zero volume. Moreover, bifilms behave like pre-existing cracks already in the liquid metal prior to the casting procedure which then further expand during the solidification stage. Commonly, analysis of defects and their effect to the load-bearing performance is studied from the metallographic point of view. On the contrary, this study analyses the defects from an engineering point of view. Specifically, the influence of both a void and a bifilm is presented with respect to fatigue performance of a simple cantilever beam with a rectangular cross-section. A structural finite element method is used to carry out the simulations. The void is modelled as a geometric cavity in the bulk material of the cantilever beam and the bifilm is modelled using a cohesive contact. Whilst the cantilever beam is subjected to either tensile, bending or torsional load or their combination, the local stress-strain field is observed and the stress concentration factors are determined. The severity of voids and bifilms is then ranked with respect to fatigue performance of the alloy.

Effect of tempering temperature on the volume fraction and hardness of retained austenite in cast GX70CrMnSiNiMo2 alloyed tool steel

The abrasive wear resistance of cast steel strictly depends on its hardness, microstructural constituents and homogeneity. Commonly used in heavy industry for thick-walled castings, cast GX70CrMnSiNiMo2 steel after heat treatment has a martensitic structure with a certain content of retained austenite (RA), which depends on the carbon content and the content of alloying elements. It is generally believed that, being the cause of accelerated wear of components, retained austenite is not a favourable constituent of the structure, and one of the methods to reduce its amount is tempering after hardening. In this study, the results of research on the changes in hardness and volume fraction of RA and martensite as a function of the tempering temperature are presented.

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Effect of alloying additions on the wear resistance of high-chromium cast iron

The article reports the results of a study on the effect of Ti, Nb, and B alloying additions on the abrasive wear behaviour of high-chromium cast iron. Wear resistance was evaluated using two complementary methods: the Miller test in accordance with ASTM G75 and a pin-on-disc test performed using the Tribotester 3-POD apparatus developed at the Department of Foundry Engineering, Silesian University of Technology. The results demonstrated improved abrasion resistance of the alloyed materials compared with the reference alloy. To establish the relationship between chemical composition, microstructure, and tribological properties, metallographic observations were carried out using reflected-light microscopy. The microstructural characterization was supplemented by scanning electron microscopy (SEM) coupled with energy-dispersive X-ray spectroscopy (EDS). Phase identification in the investigated cast irons was performed by X-ray diffraction (XRD)

The research was funded by the Ministry of Science and Higher Education as part of the VI edition of the "Implementation Doctorate" program conducted at the Doctoral School of the Silesian University of Technology in the Department of Foundry Engineering.

Quantitative characterization of irregular Al–Si eutectic microstructures using image-based descriptors

Irregular eutectic microstructures are difficult to quantify owing to their fragmented, branched, and non-uniform morphology. Conventional characterization methods mainly focus on local interlamellar spacing measurements and therefore provide only limited information about the overall structure. In the present work, a quantitative image-analysis framework was developed for the characterization and comparison of irregular Al–Si eutectics. The method integrates four complementary descriptors: eutectic ratio (ER), characteristic lamella-length (CLL), average lamella distance (ALD), and eutectic lamella orientation (ELO). The approach was demonstrated on directionally solidified Al–12.6Si and Al–18Si alloys produced in a four-zone vertical Bridgman furnace under controlled solidification conditions. High-resolution optical micrographs were processed using automated image analysis, enabling the extraction of geometric parameters from large populations of eutectic Si lamellae. The results revealed significant longitudinal variations in the microstructure that correlated with changes in eutectic front velocity. In the initial regions of the samples, ALD values were 13.1 μm for Al–12.6Si and 7.4 μm for Al–18Si, while both alloys converged toward approximately 3 μm at higher solidification velocities. The CLL descriptor showed a pronounced increase from 31.59 to 84.63 mm^{-1} in Al–12.6Si, indicating progressive refinement of the eutectic lamellae, whereas Al–18Si exhibited a comparatively stable range of 44–55 mm^{-1} . Orientation analysis demonstrated a dominant growth direction of 15–25° in the eutectic alloy, while the hypereutectic alloy displayed a broader angular distribution. The proposed framework provides a reproducible and statistically robust tool for evaluating irregular eutectic structures. Combining multiple morphology descriptors enables detailed comparison of microstructures formed under different solidification conditions and offers potential applicability to a wider range of irregular eutectic systems.

Analysis of upper and lower ausferrite growth kinetics based on dilatometric measurements

A dilatometric analysis was conducted to investigate the phase transformations occurring in nodular cast iron specimens intended for obtaining an ausferritic structure. Following austenitization at 875°C, the specimens were quenched at temperatures of 350°C and 250°C. The entire heat treatment process was monitored by measuring the changes in specimen length. The transformation fraction was determined using the following equation: $f = (L - L_{min}) / (L_{max} - L_{min})$ where L represents the specimen length, while L_{min} and L_{max} denote the minimum and maximum values of this parameter during the test, respectively. The dilatometric measurement data were analyzed using the Avrami equation: $\ln(-\ln(1 - f)) = k + n \cdot \ln(t)$ where t is the austempering time, k and n are kinetic rate constant and Avrami exponent, respectively. The obtained results indicate that both the mechanism and kinetics of ausferrite growth alter during isothermal quenching. Microstructural investigations and final microhardness measurements of the examined specimens were performed.

This research was funded by the Excellence Initiative - Research University (IDUB) programme at AGH University of Krakow.

Mechanical and corrosion properties of Al_2O_3 fiber reinforced aluminum alloy matrix composites

Composites based on the AlSi12 aluminum alloy reinforced with alumina fibers (Composite I) and with both alumina fibers and nickel-coated graphite flakes (Composite II) were developed using the squeeze casting method in the fabrication process. The objective of this work was to evaluate the influence of the employed reinforcements on the mechanical properties, dry sliding wear, and corrosion behavior of the obtained materials. To achieve this, investigations were conducted, including SEM analysis, flexural strength testing, Brinell hardness testing, linear sweep voltammetry (LSV), electrochemical impedance spectroscopy (EIS), and pin-on-disc wear testing under varying loads at a constant sliding speed of 1 m/s. Mechanical investigations revealed a significant increase in flexural strength and hardness for Composite I compared to the plain matrix alloy. In contrast, Composite II's flexural strength was reduced by the weakening effect of graphite flakes, though performance under bending still improved by 46% for Composite I and 25% for Composite II compared to the AlSi12. Tribological tests yielded ambiguous results; the addition of graphite did not significantly improve wear resistance, nor did it notably influence the friction coefficient. The corrosion resistance of the tested materials followed the order AlSi12 > Composite I > Composite II. The LSV and EIS results indicate that the explanation for this may be differences in the properties of the protective oxide/hydroxide layer, while SEM images showed a weak bond between nickel and graphite.

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Corrosion performance research of simulation and experimental for aircraft motor shafts (30CrMnSiA) under high humidity and high salinity

To guarantee the durability of aviation motors under marine conditions and meet diverse working requirements, this study conducts wet-heat and salt-spray tests to simulate the corrosion of 30CrMnSiA aviation motor shafts, uses electrochemical experiments to evaluate coating protection performance, and adopts first-principles calculations to analyze the material's work function, energy band and electronic structure, and explore the corrosion mechanism of 30CrMnSiA aviation motor shafts. Experimental results confirm that surface coatings can effectively block corrosive media invasion and delay their diffusion from the adhesion layer to the substrate. However, excessive surface roughness easily causes condensation during salt-spray tests, attracts more Cl^- ions and intensifies surface corrosion. Simulation results show that the material's energy band and density of states indicate active electron transition regions within -2 to 2 eV. The work function and adsorption energy results confirm that 30CrMnSiA has strong water molecule adsorption capacity. Under high humidity, after Fe adsorbs Cr charges, the Cr-O covalent bond in the generated Cr_2O_3 will break via reaction with water vapor and NaCl salt film, forming a large amount of loose porous Fe_2O_3 layer and accelerating material corrosion. Electrochemical Impedance Spectroscopy (EIS) and Potentiodynamic Polarization (PDP) results verify the protective effectiveness of the coating for 30CrMnSiA. Atomic-level simulation reveals the corrosion failure mechanism of Cr atoms under high-salt and high-humidity conditions, providing effective reference for subsequent production and processing, and ensuring the operational reliability of aviation motors.

Functional surface layers of medium- and large-sized cast iron castings produced using in situ technology

Castings serving as components in various devices, machines, and vehicles often operate under conditions where it is advantageous for the surface layer to possess mechanical, physical, and chemical properties distinctly different from those of the rest of the casting wall. Based on these characteristics, the author proposes terming this region a "functional surface layer" (FSL). A wide range of castings operate under conditions of intense conventional wear (abrasive wear). Other examples include layers designed for enhanced corrosion resistance or low thermal conductivity. There are also castings where the thermal conductivity of the near-surface layer is modified to mitigate thermal shock. Given these attributes, such layers are designated as "functional," featuring a structure that imparts the specific physical properties required for the casting's operating conditions. This paper presents research findings on the production of functional layers over large surface areas of cast iron and cast steel components. It describes the author's proprietary technology for producing ceramic-metal preforms based on a framework of fine-weave, thin-filament metal mesh, which is shaped into a 3D structure. This method enables the creation of functional layers with precisely controlled thickness. Materials are deposited onto the mesh framework to form a ceramic-metal composite layer of controlled thickness, or to introduce alloying additives into the layer that alter the alloy's metallographic structure and properties. Once placed in the mold, the preform is infiltrated with molten metal, forming a functional layer "in situ". The paper presents examples of the technology's application to large-scale castings, as well as directions for further work on the development and implementation of the solution

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The problem of veining defects in the mass production of cast iron castings – a new testing method, formation mechanism, and causes

This paper analyzes the mechanism behind vein formation in cast iron castings and describes a novel technological test designed to assess how processing factors influence the tendency for vein formation. Veining manifests as irregular, lamellar protrusions extending from the casting surface. Although classified as a "repairable" defect, it often renders the product unusable—for instance, in the case of ventilated brake discs. The incidence of this defect increased following the adoption of the "cold-box" process, a technology widely used for mass-producing small cores on automated production lines. While various core sand additives have been developed to mitigate veining, no standardized technological test has yet been established to evaluate new additives or investigate the impact of processing variables. The authors propose a new solution for assessing veining susceptibility: a novel technological test described in this paper. The article presents the results of research into how the core sand matrix, binder type, sand compaction degree, and the use of protective coatings affect vein formation. This research provides a deeper understanding and a more comprehensive explanation of the defect's formation mechanism, potentially facilitating efforts to minimize or eliminate it.

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Evaluation of the effectiveness of selected modifiers for EN GJL-200 gray cast iron for thin-wall castings

This paper presents an evaluation of the effectiveness of three commercial modifiers: Superseed 75, Inolate 30, and Zincinoc, used to modify eutectic gray cast iron of the EN GJL-200 grade, intended for castings with a wall thickness of 5–15 mm. Modification effectiveness was analyzed based on microstructural studies, mechanical property measurements, and thermal analysis (ATD). It was found that, of the modifiers tested, Superseed 75 had the strongest effect on the solidification process and microstructural properties of eutectic cast iron. This modifier significantly reduces sensitivity to cooling rate, ensures uniform distribution of graphite precipitates, and prevents carbide formation in thin-walled sections. Another effective modifier, intended for castings with thicker walls, is INOLATE 30. The modification procedures significantly increase the tensile strength of the cast iron. As a result of the fragmentation of eutectic grains, R_m increases by approximately 20%, while the optimal dosage of modifiers should be approximately 0.2%.