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Book of Abstracts

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Additive Manufacturing / 1

Design and manufacture a cost-effective, high-performance plastic injection mould using a hybrid additive-subtractive manufacturing strategy

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Conformal cooling channels (CCC) are essential in plastic injection moulds to enhance cooling and reduce the cycle time. Recent advances in metal additive manufacturing (AM) make such fabrication possible. However, the utilisation of AM in modern mould-making is still low due to higher manufacturing costs. This article reports designing and manufacturing an 8-cavity plastic injection mould using a hybrid additive-subtractive manufacturing (HASM) strategy to complement an existing 4-cavity mould to meet increasing demand. Inserts in the new mould were designed with CCC, made of hybrid maraging 300 steel powder-wrought 17-4 PH stainless steel, fabricated using laser powder-bed-fusion and finished with conventional mould-making methods. From the cost analysis, the AM tooling cost incurred in building this new mould was about 10% of the total tooling cost. When equipped with conformally cooled hybrid-built inserts, the new 8-cavity mould ran with 56% shorter cooling time and 15% faster overall cycle time than the existing 4-cavity counterpart. Considering the additional tooling cost but faster moulding cycle time that reduced the moulded part cost by $0.01 per unit, the break-even point for this new mould was about 29 days of run time. The HASM strategy used in this project has proven to be a cost-effective solution for high-volume run injection moulds.

Speaker Country:

New Zealand

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Additive Manufacturing / 2

Multi-material steel assemblies by EB-PBF

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There is a growing interest in adapting various metal additive manufacturing (AM) technologies to produce multi-material components. This is particularly appealing in the tooling industry, where combining properties like hardness, corrosion resistance, and toughness from different alloys within a single tool can greatly enhance performance. Significant efforts have been made to adapt powder bed fusion (PBF) techniques for multi-material fabrication. In electron beam-based processes (PBF-EB), beam parameters can be precisely controlled at specific points in the build area. This layer-by-layer control allows for precise melting and solidification, enabling adaptive processes that incorporate powders of different compositions. In this study, two steel-based powders, X40CrMoV12-2

and X35CrMoV5-2 provided by Uddeholms AB, were used to create multi-material tooling assemblies. The process involves loading each hopper with a different metal feedstock, which is dispensed layer-by-layer into the powder bed. The result is crack-free, multi-material specimens with various assemblies. Tailored heat treatments were applied to optimize material properties, and their effects on microstructure and micromechanical performance were evaluated. Characterization of the specimens was conducted in both the as-built and heat-treated states using techniques such as optical microscopy (OM), scanning electron microscopy (SEM), SEM-EDX, and nanoindentation.

Speaker Country:

Sweden

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Materials, Properties & Microstructure / **3**

Effect of superfine pretreatment on carbides precipitation behavior of plastic S136 mould steel

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S136 steel is a kind of plastic mould steel with excellent corrosion resistance, which is often used for high polishing and high demand internal mould to produce products in medical and food industry. Due to the influence of component segregation and cooling after forging, the microstructure defects such as chain carbides are easy to appear after annealing. Adding superfine pretreatment process such as high temperature solid solution or high temperature solid solution and high temperature tempering after forging and annealing can solve the problem of uneven distribution of carbides. In this study, the distribution characteristics of chain carbides in the annealed structure of S136 steel were analyzed, and the effect of solution temperature on the dissolution of chain carbides of S136 steel was studied. The results show that after superfine pretreatment, a large number of chain carbides on the grain boundary in the annealed structure of S136 steel are redissolved, the state of ferrite is maintained in the crystal, the grain is refined as a whole, and the mechanical properties are better. The superfine pre-treatment process of high temperature solution and high temperature tempering can control the number and size of carbides precipitation in the annealing process, and the process can be manipulated, which is a practical means of S136 steel pretreatment.

Speaker Country:

China

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / **4**

Directed energy deposition - Arc vs. casting: Enhancements of

mechanical and thermal properties of hot-work tool steels through additive manufacturing

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The additive manufacturing of complex shapes and medium-sized parts by Directed Energy Deposition-Arc (DED Arc/M) presents a promising approach by eliminating the need for specific tooling and minimizing resource use. However, DED-Arc/M results in microstructures differing distinctly from those observed in conventionally processed, cast materials. This is attributed to the process immanent thermal conditions, which are characterized by high cooling rates and successive re-heating during DED-Arc/M processing. Whereas the mechanical properties of additively manufactured tool steels are documented reasonably well, the thermo-physical properties are highlighted insufficiently in previous works. Thus, the present study focusses on the investigation of DED Arc/M-induced microstructural effects on the mechanical and, additionally, thermo-physical properties of the hot-work tool steel AISI H13 (X40CrMoV5-1). Therefore, the DED-Arc/M processed material's properties are contrasted to those of cast material in this work. An innovative statistical approach that incorporates quantitative EDS data was employed to investigate the distribution of alloying elements within the material. Additionally, the mechanical properties were examined at elevated temperatures through hardness, tensile and compression testing. Moreover, the thermal conductivity was studied in the temperature range of RT to 500 ℃. This study thus facilitates a more comprehensive understanding of the DED Arc/M-induced effects on the microstructure, thereby providing insight into the material's enhanced mechanical and thermal properties. The findings indicate that DED-Arc/M-processing is a promising approach for manufacturing more efficient tools for hot-working applications.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Fatigue / 5

Influence of microstructure on fatigue life of cryogenically treated AISI H13 steel

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Cryogenic treatment is widely utilized for tool as well as die steels in order to enhance their performance. AISI H13 die steel is widely used in forging industries wherein fatigue loading conditions are frequently encountered leading to failure of the forging dies. This work involves heating AISI H13 specimens to 1020^{0}C for 20 minutes thereafter quenching in oil followed by double tempering at 525^{0}C. The specimens were subjected to cryogenic treatment at -185^{0}C for 16 hours cryosoaking period followed by soft tempering at 100^{0}C. Rotating bending fatigue test was performed at room temperature at constant amplitude loading conditions. Precipitation of fine carbides in the matrix of

tempered martensite assisted in refining the grain structure by inhibiting the grain growth. The fatigue life was reported to be enhanced by 17% on account of obstruction to the fatigue crack propagation due to fine grained structure in case of 16 hours cryogenically treated specimens in comparison with conventional heat treatment for AISI H13.

Speaker Country:

India

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Materials, Properties & Microstructure / 6

Effect of carbide precipitation along grain boundaries on the high-temperature service performance of 4Cr5Mo2V steel

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This study employed the electrical resistivity method to uncover the phenomenon of carbide precipitation along grain boundaries in 4Cr5Mo2V die casting die steel under specific quenching and cooling rates, and delved into the impact of this phenomenon on the high-temperature service performance. By comprehensively utilizing characterization techniques such as Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), and Transmission Electron Microscopy (TEM), this paper elucidated the precipitation patterns of carbides under different quenching processes, and established a connection between carbide precipitation along grain boundaries and the deterioration of high-temperature mechanical properties and thermal fatigue resistance. The research findings indicate that within the temperature range of 898 to 1022℃, MC-type carbides rich in V and Mo tend to precipitate along grain boundaries. As the quenching rate gradually decreases, the phenomenon of carbide precipitation along grain boundaries becomes more pronounced, exerting a significant negative influence on the resistance to temper softening and impact toughness of 4Cr5Mo2V steel. Notably, when the quenching rate is as low as 0.05 ℃/s, the hardness of the steel, after being held at 600℃ for 48 hours, decreases by 60% compared to oil-quenched samples. Furthermore, an analysis of impact fracture morphology reveals that under lower cooling conditions, the fractures exhibit reduced shear lips and diminished dimples, indicating an increase in material brittleness. Regarding thermal fatigue performance, the significant precipitation of carbides along grain boundaries accelerates the formation and propagation of thermal fatigue cracks, resulting in wider and deeper cracks, and even pronounced crazing at the macroscopic scale. During thermal fatigue cycling, the carbides precipitated along grain boundaries promote the aggregation and coarsening of M23C6-type carbides, weakening their pinning effect on dislocation movement, thereby leading to a substantial decrease in dislocation density and further compromising the thermal fatigue resistance of steel.

Speaker Country:

China

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Sustainability / 7

Sustainable advancements in component adjustment and sliding surface production

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It is widely known that working within the micrometer range is essential in the construction of machine tools. One of the most time-consuming processes in this field is the precise alignment of individual components. The DWH adjustment coating, an epoxy resin system, offers a highly effective solution to this challenge by significantly reducing the time and effort required for fine-tuning and alignment.

As an adjustment layer, DWH allows engineers to account for gaps between components during the design phase. These gaps can later be precisely adjusted using set screws, enabling quick and accurate alignment of parts. DWH is then applied to fill these gaps, ensuring a secure and durable connection. In addition to creating form- and force-locked bonds—proven through decades of industrial use—the epoxy resin system of DWH offers superior damping properties compared to traditional steel-to-steel connections. This not only enhances the stability of the assembly but also reduces vibrations, resulting in improved overall machine performance. Furthermore, DWH enables the exact replication of master forms, providing a highly accurate adjustment layer.

Another area where exact molding is crucial is the production of sliding surfaces. With the use of Moglice, also an epoxy resin system, sliding surfaces can be precisely manufactured through molding. Moglice extends this precision by offering self-lubricating sliding coatings. Like DWH, Moglice is applied via a molding process, ensuring exact surface replication for bearing surfaces and guideways, delivering optimal accuracy and smooth movement in machine tool assemblies.

Both materials, DWH and Moglice, contribute to sustainable manufacturing practices by increasing the lifespan of components, reducing material waste, and minimizing energy consumption through enhanced machine efficiency and reduced downtime.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Materials, Properties & Microstructure / 9

Influence of viscous dissipation on the wear behaviour of plastic mold steels in injection molding

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According to Polaris Market Research “Tool Steel Market Size, Share Global Analysis Report, 2023-2032” the plastic mold segment had the highest market penetration in 2022. It forecasts that this trend will persist until the end of the forecast period in 2032. Even slightly worn-out parts in polymer processing can lead to variations in the produced polymer parts, resulting in them being out of tolerance and rejected. Adjustments in process parameters can keep production going, but wear

will continue to happen and ultimately lead to a standstill in production and the necessity to replace the worn part. Reducing wear therefore leads to an extended operation time and a lifetime extension. The presented study shows the impact of an injection volume rate (IVR) of 100 cm^3/s versus an IVR of 300 cm^3/s on the wear behaviour of five different steels currently used as plastic mold steels using a Polyamide 66 filled with 50%wt. glass fibers in a platelet-wear-test. The process conditions of injection molding can lead to such a high degree of mechanical energy being turned into heat that the resulting temperature in small gaps or slit like sprues or screw flanks can reach a level where the steel loses surface hardness due to tempering effects. Hardness and resistance to abrasive wear are closely coupled, leading to a strong increase in wear when this dissipation effect is occurring. This effect was evident at an IVR of 300 cm^3/s but not with an IVR of 100 cm^3/s as was measured with near surface hardness measurements of the test specimens after wear testing. Besides an increase in wear the secondary hardening peak temperature has a significant effect on the wear behaviour under these conditions influencing the wear behaviour favourable with higher secondary hardening peak temperatures and therefore improve the lifetime.

Speaker Country:

Austria

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / 11

Additive manufacturing of hot-work tool steel by in-situ alloying using laser powder bed fusion and directed energy deposition – Strategies to improve chemical homogeneity

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The production of complexly shaped parts like molds with integrated cooling channels by additive manufacturing represents a promising approach by eliminating the need for specific tooling, reducing lead times, and minimizing the material footprint. Unfortunately, typical carbon-martensitic steels used to produce such components often suffer from crack formation during additive manufacturing processes associated with steep thermal gradients and fast heating and cooling cycles. To prevent cracking of parts additively manufactured from carbon-martensitic steel adjustments in alloy design can be made. A promising approach to modify the composition of available starting powders and to develop novel alloys is in-situ alloying. Thereby, the desired alloy is formed during the additive manufacturing process from a mixture of different precursor powders. This, however, often results in chemically inhomogeneous parts due to incomplete dissolution of powder particles and insufficient intermixing of alloying elements within the melt pool. Thus, the present work investigates the possibility of improving the chemical homogeneity of an in-situ alloyed hot-work steel powder mixture including ferrotungsten and ferromolybdenum as precursor materials since those have proven challenging to be homogenized using standard additive manufacturing process parameters. On this basis, both, the effect of re-melting in PBF-LB/M by applying double laser exposure and enlarged melt pools by DED-LB/M on chemical homogenization were analyzed with reference to single exposure PBF-LB/M processing. The chemical homogeneity is assessed statistically by calculating Gini coefficients based on large scale 2D-EDS data. Furthermore, the local hardness in heat-treated condition is compared and related to the chemical homogeneity. Thereby, this work gives a guideline to which extent chemical inhomogeneities resulting from in-situ alloying can be tolerated with regard to mechanical properties and local defect formation. The findings indicate that applying re-melting in PBF-LB/M is promising to produce parts of high geometric accuracy from powder mixtures containing even high-melting precursor materials.

Speaker Country:

Deutschland

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Surface Treatment & Coating / 12

Effect of aluminum content on ion nitriding and nitriding kinetics of new SDAH13 extrusion die steel

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This study investigates the ion nitriding process of a novel aluminium-extruded mould steel (SDAH13 steel) with four different aluminium contents (0.01 wt.%, 0.21 wt.%, 0.76 wt.%, and 1.33 wt.%) through orthogonal and univariate experiments. Optical microscopy, scanning electron microscopy (SEM), and X-ray diffraction (XRD) were employed to characterise the microstructure and phase composition of the nitrided layer's cross-section. A microhardness tester was used to measure the hardness gradient across the nitrided layer, while Rockwell hardness tests examined the brittleness of the samples post-nitriding. The findings indicate that the optimal ion nitriding parameters are a nitriding temperature of 540℃, an holding time of 14 hours, and a furnace pressure of 400 Pa, with the most effective aluminium content being 0.76 wt.%. Under these conditions, the nitrided layer depth reached 270–290 μm, with a white layer thickness of 4–5 μm and a surface hardness of 1150 HV0.2.

Based on the ion nitriding results, the diffusion behaviour of reactive nitrogen atoms in SDAH13 steel with varying aluminium content was investigated, and the activation energy for the diffusion of reactive nitrogen atoms in this steel was calculated. Subsequently, mathematical expressions were proposed to predict the nitrided layer depth for SDAH13 steel with different aluminium contents at varying ion nitriding temperatures. Using Fick's second law and the Arrhenius equation alongside linear fitting methods, mathematical expressions were derived for the nitrided layer thickness in H11 steel (0.01 wt.% Al) and SDAH13 steel with 0.76 wt.% Al concerning holding time. Additionally, a relationship was established for the nitrided layer depth of these two compositions in relation to nitriding time and temperature.

Speaker Country:

⊠

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Surface Treatment & Coating / 13

Decoating of cutting tools exploiting vacuum and liquid plasma technologies

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Diamond-Like Carbon (DLC) and Titanium Nitride (TiN) coatings are widely employed to increase the useful lifespan and performances of Hard Metal (HM) and High-Speed Steel (HSS) cutting tools, especially for harsh and severe service conditions. Then, at the end of the service life, tools will present damages and defects that lead to their decommissioning. For this reason, an effective procedure to remove DLC and TiN from the HM and HSS surfaces is required to allow for the substrates to be resharpened, recoated and reused. In the present research, vacuum and liquid plasma technologies are implemented to tackle the issue of cutting tools decoating, with an eye on avoiding the use of harmful chemicals in the process. Low-Energy High-Current Electron Beam (LEHCEB) [1] was employed to strip DLC coatings from WC-Co4 inserts while Plasma Electrolytic Polishing (PEP) [2] was used to remove TiN coatings from AISI M2 drill bits. LEHCEB is a vacuum plasma technique that is able to rapidly bring the DLC coating to sublimation, allowing for its complete removal within few tens of seconds. Different combinations of electron accelerating voltages (20-30 kV) and number of pulses were studied to assess the optimal decoating parameters. On the other hand, PEP is a liquid plasma technique in which the application of a high voltage (100-400 V) lead to the formation of vapour gas envelopes on the conductive surface of TiN, allowing to strip the coating in few minutes of DC polarization. Different combinations of diluted (1-6 wt.%) and eco-friendly electrolytes were investigated to determine the optimal time and temperature of decoating.

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[2] doi.org/10.1007/s00170-021-07012-7

Speaker Country:

Italy

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Materials, Properties & Microstructure / 14

Research on laser cladding Fe-based alloy coating to enhance high-temperature friction and wear properties of H13 die steel

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Hot stamping is a mature manufacturing process in the field of automobile manufacturing. The surface strengthening and toughening of mold steel play a very important role in improving the service life of hot stamping in high temperature and high stress environments. This work uses laser cladding to clad FeCrWSiV alloy onto the surface of H13 mold steel. The prepared coating has good metallurgical bonding with the substrate, and the coating structure is fine martensite and uniformly distributed carbides, which is the key to improving the high-temperature wear resistance of the surface. SEM was used to observe the surface structure morphology and carbide distribution and size of the prepared coating. High-temperature friction and wear is one of the many failure modes of molds. Wear will not only change the mold surface geometry but also the surface roughness, and normal stress will cause further wear between the wear debris and the mold surface. Reducing stamped product quality and resulting in more rework costs. Designed to simulate hot stamping environments at 200℃, 300℃, and 400℃ to conduct high-temperature hardness and high-temperature friction and wear experiments on the coating. Test the hardness changes at different high temperatures and maintain high hardness in high temperature environments. As the temperature rises, the friction and wear COF curve will also show a slight upward trend, mainly due to the formation of

oxide layers in high temperature environments. A white light diffractometer was used to observe the scratch depth after friction and wear to verify the adhesive wear and oxidative wear during high temperature friction.

Speaker Country:

China

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Surface Treatment & Coating / 15

The effect of ion nitriding temperature on the high-temperature wear resistance of austenitic die-casting mold steel SDHA

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Austenitic mold steels exhibit significant potential in the die-casting industry due to their excellent high-temperature mechanical properties. However, their susceptibility to wear, scratching, and relatively low hardness impairs their wear resistance, thus limiting the application of austenitic steels in die-casting. In this study, austenitic hot-work mold steel (SDHA) with varying surface hardness was produced via ion nitriding at different temperatures. High-frequency ball-on-flat dry sliding reciprocating high-temperature wear tests were performed. The results indicated that nitriding at 560℃ produced the highest surface hardness (1331.6 HV0.2), the greatest average nitride layer thickness (20.7 μm), and the lowest wear rate (11.0×10^{-8} m^2/N at 600℃). The average coefficient of friction (Cof) increased slightly, which was attributed to the increased surface roughness caused by plastic deformation from ion sputtering etching pores and the formation of γN. As the wear temperature increased (from 200℃ to 600℃), a glazed layer, primarily composed of sintered oxides and oxidized debris, formed on the contact surface, effectively reducing the contact area and lowering the Cof by 36.76% compared to low-temperature friction.

Speaker Country:

China

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Fatigue / 16

Fatigue and life-time prediction resistance of low-alloy mould steels

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Fatigue resistance is an essential property to consider in the design of a plastic injection mould. During plastic injection, certain parts of the mould can reach temperatures between 100 and 300℃ and be subjected to high pressures of around 300 – 600 bar during holding. Therefore, moulds must withstand a large number of injection cycles, from thousands to millions, depending on the required number of injected parts. For low-alloy steel, to ensure a great microcleanliness property is not sufficient to guarantee high fatigue resistance. The homogeneity of the steel grades in terms of microstructure and mechanical properties is also important. In this study, research work was carried out on 1.2714 steel and a proprietary grade to demonstrate how the service life of a mould can be improved. By proper selection of the steel fatigue resistance and the design of the parts, the right amount of steel can be adjusted to expected level of production runs and overall lifetime of the mould.

Speaker Country:

France

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Surface Treatment & Coating / 17

Effect of shot peening on plasma nitriding microstructure and properties of 4Cr5Mo2V steel

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Third-times shot peening(TSP) was conducted on 4Cr5Mo2V hot-stamping die steel prior to plasma nitriding(PN). The optical microscopy(OP), X-ray diffraction(XRD), white-light interferometer, microhardness tester and ball-on-disk wear tester were employed to investigate the microstructure and properties of plasma nitrided 4Cr5Mo2V steel coupled with TSP processing. The results show that, compared with the PN sample, the γ'-Fe4N phase content increased significantly, diffraction peak intensity of the sample increased by approximately 300% and the nitriding layer showed greater toughness after pre-TSP treatment. Meanwhile, the surface hardness, the thickness of the white bright layer and the effective hardened layer of the sample increased by approximately 5.9%, 37.5% and 10.7%, respectively. This could be attributed to an increase in the contact area of nitrogen atoms, dislocation density and subcrystal refinement. Additionally, Samples nitrided after TSP processing has the better wear resistance than PN sample, wear scar depth and wear rate decreased by 8.1% and 14.7%, respectively.

Speaker Country:

China

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Materials, Properties & Microstructure / 18

ASP®2008, a new PM-HSS for high performance forming tools with improved wear and chipping resistance

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Designing a powder metallurgical high speed steel (PM-HSS) means defining the best compromise between toughness, hardness at room or high temperature, wear resistance, grinding ability etc. The best compromise depends on final application. In this context, Erasteel developed a solution intended for tools that suffer mainly from mixed adhesive/abrasive wear and/or chipping/cracking together with high toughness requirements. This new grade named ASP®2008 is positioned between existing grades used for cold work tools or rolls.
During design of the new grade, computational thermo-dynamical simulation tools were used to fine tune alloying elements, V, Nb, Mo and W with the goal to obtain an extremely fine and even carbide distribution containing many but very small and hard MC-carbides. The theory behind was that the right balance of mainly Nb and V gives, according to the simulations, similar volume fractions of two MC carbide phases: one rich in Nb and one rich in V. Mo and W were adjusted to avoid presence of coarse M6C carbides while providing a good hardening response. The target chemical analysis was validated by examining the microstructure of test heats with scanning electron microscopy, which confirmed a very fine microstructure.
Thanks to this a unique combination of wear resistance, edge strength, toughness and hardness was obtained. The alloying theory to obtain the outstanding fine microstructure, results from mechanical tests, wear tests and some first performance tests of actual usage of the grade in tool application will be presented.

Speaker Country:

Sweden

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / 19

Sliding wear and nitriding behavior of HWTS 50 tool steel tailored for L-PBF process

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This manuscript investigates the properties and performance of Osprey® HWTS 50, a lean hot work tool steel with 0.22 mass % carbon, in contrast to standard AISI-H13 and H11 grades (˜0.4 mass %). The steel was manufactured using the laser powder bed fusion process (L-PBF) and subjected to

sliding wear tests as well as gas nitriding. Three different conditions were evaluated: as-built (AB), directly double tempered from AB (DT) at 50±2 HRC, and quenched and tempered (QT) at 50±2 HRC. The wear performance of HWTS 50 was compared with an additively manufactured maraging steel of 18Ni300 type in peak-aged condition (˜54 HRC) and a wrought H13 counterpart tempered to 50±2 HRC. The results indicated that the wear damage in HWTS 50 variants is comparable or slightly lower compared to the wrought H13 counterpart. Additionally, it was observed that all carbon-containing hot work tool steels outperformed the carbon-free 18Ni300 steel. Gas nitriding was carried out on AB, DT, and QT specimens. For comparison, gas nitriding was also performed on electro-slag remelted (ESR) H13 and H11 steels, which were tested under the same conditions. The results from the nitriding experiments showed that in all HWTS 50 variants, surface hardness was comparable to the wrought counterparts. However, the nitriding hardness depth (NHD) was significantly larger than that of ESR H11 and H13. This was attributed to the lower contents of elements Cr (˜3 mass%) and V (˜0.5 mass%) in HWTS 50, which enhance the diffusion of nitrogen, and the increased dislocation density inherent to the L-PBF- process, which may enhance the diffusion kinetics. Microscopic analysis revealed a more extensive compound layer (approximately 10 µm vs. 4 µm) and diffusion zone in HWTS 50 compared to other steels. XRD analysis on the nitrided surface demonstrated comparable phases, including Fe2N and Fe4N, in all alloys.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / 20

Direct energy deposition of chromium-molybdenum-vanadium LMD Vanadis 4 Extra© cold work tool steel

Authors: Dominic Bartels[1]; Aydin Selte[2]; Michael Schmidt[3]; Pavel Krakhmalev[4]

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For cold work tool steel applications, additive manufacturing is an attractive technology that provides opportunities to manufacture tools with complex geometries with minimal machining to the net shape. In the present work, a chromium-molybdenum-vanadium LMD Vanadis 4 Extra© cold work tool steel was manufactured using the direct energy deposition (DED) method. Process parameters were varied in a wide range to determine the influence of different build rates and cooling conditions on defect formation and resulting microstructure. The main parameter was the feed rate varied 400-800 mm/min, while laser power was maintained constant at 600W. Consequently, the powder mass flow was adjusted to result in an even layer thickness independent of the feed rate. Optical light microscopy proved a high relative part density above 99.5 % for different parameter combinations. Electron microscopy revealed dendritic microstructure with a developed network of V- and Mo-rich carbides. Interdendritic cracks or cracks between colonies were not observed in the DED build. Nevertheless, an increase in built height resulted in the formation of cracks between the substrate and the built. An increase in feed rate from 400 to 800 mm/min resulted in the formation of pores 100 µm and larger. At the same time, the microstructure looked finer in the material manufactured with higher feed rate, presumably due to higher cooling rates. The hardness of the build exceeded 900 HV1 and decreased to 700 HV1 in the dilution zone. The observed results confirm printability of chromium-molybdenum-vanadium Vanadis 4 Extra© cold work tool steel by DED. However, further optimization of process parameters and an investigation of the influence of the substrate material on crack formation in the dilution zone still need to be performed.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Surface Treatment & Coating / 21

Surface induction hardening of a hot work tool steel for aircraft applications

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Gears designed for power transmission in aircraft require increased surface hardness while maintaining the integrity of their core properties. This is typically achieved through conventional thermochemical treatments like case hardening or nitriding. However, these methods can be time-consuming and generate significant CO2 emissions, prompting the search for new processes to meet modern industrial needs.

Induction hardening emerges as a promising alternative, offering shorter processing times, improved control over distortion, and a reduced environmental impact. Hot work tool steels are known for their excellent mechanical properties. These high carbon steels have a strong hardening potential which makes them ideal candidates for surface induction treatments.

This collaborative research between Safran and IRT M2P aims to develop induction hardening for hot work tool steel in gearing applications. Our first experimental results demonstrate that this induction treatment can achieve surface hardness levels exceeding 750 HV.

The presentation will show how using simulation, the induction parameters can be adjusted to reach optimized microstructure, residual stress profile, and hardness profile. Additionally, the core heat treatment prior to induction is also being refined to achieve the best possible balance in mechanical strength, impact toughness, and grain size.

Speaker Country:

France

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Materials, Properties & Microstructure / 22

Investigation of factors influencing crack formation in cooling channels of injection moulds

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Cooling systems utilizing water are usually used for temperature control in injection moulding processes. To achieve short production cycle times and high surface quality of injection-moulded parts, cooling channels are designed to run close to the mould's cavity surface. While optimal cooling performance is achieved by conformal cooling channels using additive manufacturing techniques, conventional drilling methods remain a more economical option for creating these channels within moulds.
The corrosive effects of cooling water, as well as the plastic melt and its additives, place significant stress on the tooling used in these processes. Consequently, corrosion-resistant tool steels with a martensitic microstructure are frequently employed. However, in practical applications, damage occasionally due to cracks originating at cooling channels, attributed to a combination of corrosive effects and mechanical stress.
This study analyses such damage through optical microscopy and scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM/EDX). Following this analysis, corrosion tests - including aging tests and constant load tests - were conducted on a selected martensitic chromium steel under varying conditions. These tests aimed to evaluate the influence of factors such as chloride content in cooling water and the presence of brass components within the system.
The findings reveal that the observed damage stems from a form of stress corrosion cracking initiated by intergranular corrosion. The laboratory tests further indicate that the presence of copper from brass components and the chloride concentration in the cooling water significantly affect the initiation of cracks from the cooling channels.

Speaker Country:

AUSTRIA

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Materials, Properties & Microstructure / 23

Innovation in advanced and sustainable prehardened steels: introducing Toolox 46 for high performance hot work tooling applications

Authors: Hadi Torkamani[1]; Håkan Engström[1]

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Prehardened already heat-treated steels are commonly used in tooling applications. Most plastic moulds are for example produced from such steel products. The benefits are several compared to machining soft steel and do external heat treatment. Among those are shorter lead times, lower costs, and a better control of the product quality. Commercial prehardened steels have a limited maximum hardness, and Toolox 44 a product from Swedish special steel producer SSAB has been the market leader with 45 HRC. Also, in some tooling segments like hot work applications there has not been any prehardened steel available with sufficient performance.
SSAB has recently developed Toolox 46, a new steel grade that has been proven in application testing to fulfill this market need. Performing similar or even better than Electroslag Remelted (ESR) hot work steels commonly used. This product is designed as a medium carbon steel (in the lower carbon range) with relatively low alloying content. The alloy and process design for Toolox 46 results in a tempered martensite microstructure with combination of required properties for this type of applications, offering an excellent machinability given its hardness level. This product is produced via

continuous casting, rolling and heat treatment to deliver a ready to use product. As a result, no further heat treatments are required at local heat treatment facilities, which also potentially contributes to a lower environmental impact. As already one of the world's most carbon emission-efficient steel producers, together with partners and customers (i.e., within HYBRIT technology), SSAB is taking further significant steps toward reducing carbon emissions and creating a fossil free value chain from mine to end products.
This paper will present and discuss production characteristics, microstructure and properties along with several application cases of Toolox 46, which would explain the success and high performance of this product.

Speaker Country:

Sweden

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Die Casting / 24

Development of an active tool insert to improve the properties of aluminum parts in low-pressure die casting

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Highly stressed aluminum components, such as wheels and chassis parts, are often manufactured using low-pressure die casting. This is partly because the process results in a particularly low-oxide and low-porosity microstructure and therefore high strength and elongation at break. However, the increasing complexity of components and the desire to save weight also leads to challenges in low-pressure die casting. For example, thin walls of structural parts or rims can lead to cold runs and/or shrinkage porosity and thus result in an increased scrap rate or insufficient mechanical properties. To counteract filling and feeding difficulties, component areas are therefore often provided with greater wall thicknesses or feeder paths. The disadvantage of this approach is that it leads to higher melting costs (and a larger CO2 footprint), more post-processing work and longer cycle times. To meet these challenges, voestalpine is developing an active tool insert that supports the filling locally and produces a finer-grained solidification. This is made possible by an innovative combination of electric current and magnetic field, whereby the flow and solidification of the molten aluminum can be specifically influenced. Here, we demonstrate the benefit of the active tool insert in gravity die casting for a thin-walled test component made of AlSi7Mg. The results show a significant improvement in die filling as well as improved mechanical properties (higher tensile strength and elongation at break). According to the results to date, the technology enables scrap-reduced production of aluminum castings with thinner wall thicknesses and better mechanical properties. This technology can therefore lead to a significant improvement in the competitiveness and sustainability of low-pressure die casting.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Materials, Properties & Microstructure / 25

Evolution mechanism of Mo-rich, B2-NiAl, and Cu-rich particles under high temperature and its influence on thermal stability and thermal fatigue in a maraging hot work steel SDH88

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A novel maraging hot work steel designed for integrated die casting, SDH88, is developed to achieve a balance between ultimate tensile strength (UTS), yield strength (YS), and elongation by combining nanometer-scale precipitates of B2-NiAl, Cu-rich, and M2C carbide. Compared with H11 hot work steel, SDH88 steel exhibits an excellent hardenability and better tempering softening resistance (TSR, i.e., thermal stability). This means that SDH88 steel can avoid the deformation and cracking risk of traditional die casting mold during quenching and tempering process, as well as have a lower time cost. On the other hand, the TSR and thermal fatigue resistance are tested. The precipitation evolution of Mo-rich, B2-NiAl, and Cu-rich particles under 600℃ is systematically investigated, which is close to the service temperature. Compared with H11 steel, the fast rate of age hardening of SDH88 steel is attributed to the precipitation of NiAl nanoparticles. As the increasing of holding time under 600℃, the relative better TSR of SDH88 steel is related to the transformation of M2C and M6C to Laves phase. The results of thermal fatigue tests show that the thermal fatigue crack depth of SDH88 steel is smaller than that of H11 steel in the early stage of thermal fatigue. This is related to the higher tempering softening resistance of SDH88 steel, which can better resist the early thermal fatigue crack initiation. As the number of thermal fatigue cycles increases to 2000, the thermal fatigue properties of SDH88 steel are close to those of H11. Finally, this work aims at proposing a new approach for designing hot work die steel without quenching treatment during mold processing.

Speaker Country:

China

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Materials, Properties & Microstructure / 26

Mechanical properties and thermal fatigue behavior of a novel hot work tool steel SDH68 for die casting applications

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The production cost of aluminum die casting is largely influenced by the raw materials used in the die steel. Due to the high temperature and pressure conditions, die-casting moulds require frequent replacement. In this study, a novel hot work die steel, SDH68, was developed, offering lower raw material costs compared to conventional H11 steel. Thermal fatigue is the most prevalent failure mechanism in die casting, and the carbides precipitated in high-alloy tool steels have a significant impact on the thermal fatigue resistance of the die steel. The high-chromium H11 steel precipitates substantial amounts of Cr-rich M23C6 carbides during thermal fatigue testing. These precipitates coalesce and grow rapidly at elevated temperatures, leading to a reduction in the hardness of the die steel. Consequently, SDH68 steel has a lower Cr content to enhance thermal stability. By maintaining similar levels of Si and Mn, close to 1%, the strength of the die steel is improved. The reduced

carbon content and overall alloy composition contribute to good thermal conductivity and lower material costs. Niobium microalloying modifies the carbide type and enhances the thermal fatigue resistance of the die steel. The study found that SDH68 steel consistently maintained good thermal stability at high temperatures, which may be attributed to grain boundary strengthening and the nature of the carbides. The contributions of grain boundary strengthening and precipitation hardening to the strength of SDH68 and H11 steels were calculated and verified against experimental measurements. The carbide evolution of SDH68 steel at high temperatures was characterized and analyzed. Furthermore, SDH68 steel demonstrated superior performance in thermal fatigue testing compared to H11 steel.

Speaker Country:

China

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / 27

Microstructural analysis and wear resistance of Osprey® MAR 55 tool steel produced via Laser Powder Bed Fusion

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Based on the concept of combining the advantages of standard carbon martensite with those of maraging, carbide strengthened Ni-Co-Cr-Mo steels were introduced over 40 years ago. These steels contained up to 0.4 wt.% C in combination with Ni (up to 10 wt.%), Co (up 8 wt.%) and additions of Mo, Cr and V. This development stemmed from the need to combine high yield strength, and wear resistance due to refined martensite substructure, and carbide precipitation with good toughness and adequate weldability of the Fe-Ni lath martensite. With the emergence of laser-based additive manufacturing (AM) as a viable processing route for fabricating tools with complex geometries and near surface conformal cooling channels, revisiting such compositions which bridge the gap between high strength Fe-C martensite and weldable Fe-Ni martensite seem to be a promising route. This work presents the development of Osprey® MAR 55 steel powder, a new alloy designed by Sandvik, inspired by carbide strengthening Ni-Co-Cr-Mo steels.
The study focuses on the microstructural evolution, mechanical properties, tempering resistance, and wear behaviour of this novel steel processed by laser powder bed fusion (L-PBF). Through dilatometric and Energy Dispersive X-ray Spectroscopy (EDXS) analyses, key phase transformations during heating and tempering were identified, including the precipitation of molybdenum rich M2C phases and austenite reversion driven by nickel diffusion. These transformations significantly affect the alloy's temper resistance. Comparative wear tests show that MAR 55 demonstrates superior wear performance relative to the most commercially exploited L-PBF 18Ni300, which is attributed to its optimized microstructure (C-martensite) and enhanced carbide stability. This research further highlights field test results, showing the potential of MAR 55 in as built (˜50 HRC) and heat-treated condition (˜53 HRC), as a high-performance alternative in applications requiring improved wear resistance, exceptional toughness, and enhanced weldability, making it a promising material for advanced AM processes.

Speaker Country:

Italy

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Materials, Properties & Microstructure / 28

Impact of retained austenite on the corrosion behavior of Martensitic stainless steels.

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This paper (short communication) reports the impact of retained austenite on the corrosion behavior of plastic molding grades such as Vanax Super Clean, Tyrax ESR, Stavax ESR and Mirrax ESR. For each grade, austenitization at two different temperatures were carried out and samples in as-quenched condition was compared with as-quenched condition with deep cooling. Corrosion behavior was characterized using cyclic potentiodynamic polarization method in 0.1M NaCl solution, and retained austenite content was characterized using XRD. The corrosion behavior response corresponding to retained austenite content was discussed.

Speaker Country:

Sweden

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Materials, Properties & Microstructure / 29

Investigation of microscopic non-metallic inclusions in powder metallurgical high-speed steels

Author: Manuel Schickbichler[1]

Co-authors: Robert Musi [1]; Martin Hafok [2]; Christoph Turk [2]; Gerald Schneeberger [2]; Susanne Michelic [1]

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The production of high-speed steels using powder metallurgy (PM) frequently results in materials with superior characteristics in terms of wear resistance and mechanical properties. This is particularly the case when compared to conventionally produced steels. Cleanness is thereby a critical factor that influences the property profile of these steels. For this reason, non-metallic inclusions (NMI) are increasingly becoming the focus of product and process optimization investigations. Even

if macroscopic inclusions usually induce material failure, understanding the microscopic cleanness is essential for evaluating inclusion behavior during processing. Various methods are used in industry and research to assert the characteristics of steel cleanness, such as the composition, distribution, size and morphology of the inclusions.
The present work analyzes the micro cleanness of different powder metallurgical high-speed steels in detail. For this purpose, several samples were examined using automatic and manual scanning electron microscopy (SEM) combined with energy-dispersive X-ray spectroscopy (EDS) measurements. The measured data was then subjected to further analytical and statistical analysis, e.g., to predict the maximum inclusion size by applying the GPD (Generalized Pareto Distribution) method. The results regarding the inclusions' size, distribution and chemical composition were classified and compared. The obtained data is essential for describing reactions and interactions in the steel-slag-refractory system and allows a possible link to thermodynamic and kinetic considerations. This combination of different tools and methods enables a valuable and representative description of inclusion behavior in the investigated steels and helps to identify further optimization potentials.

Speaker Country:

Austria

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Fatigue / 30

Carbide-related effects on the fatigue behavior of high-strength tool steels in the field of cold work applications

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The requirements for tool steels have increased in recent years. For example, the trend in the automotive industry towards stronger sheet metal for the automotive industry is leading to higher tool loads in cold work applications, such as fine blanking, punching, and cold forming. A comprehensive understanding of the properties of these steels is therefore essential for the development of such steel grades. Besides high compressive strength, abrasive- and adhesive wear resistance as well as sufficient toughness, fatigue properties play a decisive role for improved tool life. All of these properties mentioned are often tested on tool steels, with the exception of fatigue behavior. Although some research has been carried out in the past, specific microstructural variations have not been tested so far. This paper will examine the effect of different microstructures on fatigue in more detail. In order to obtain a comparable basis, the microstructures were systematically altered by heat treatment so that a significant difference in primary carbide spacing and size could be studied at the same hardness level. Since in applications such as fine blanking and punching the temperature of the active elements can rise significantly during operation, additional fatigue tests were carried out at elevated temperatures. This makes it possible to study not only the influence of the microstructural parameters, but also the influence of the temperature on the fatigue properties.

Speaker Country:

Austria

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Fatigue / 31

Effect of surface condition on high-cycle fatigue behavior of PM-HIPed high-nitrogen martensitic tool steel

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This study focuses on a high-nitrogen martensitic tool steel, known for its excellent corrosion resistance, very high wear resistance, high compressive strength, and good hardening properties. Due to the presence of high nitrogen and other alloying elements, producing this alloy using conventional processes is challenging. As a result, it is manufactured using powder metallurgy (PM) and hot isostatic pressing (HIP). In the last step of PM-HIP process, the powder container must be removed, typically by pickling in an acid-leaching bath. However, this pickling process can lead to increase surface roughness and alter the outermost surface layer. The aim of this study is to investigate the impact of the pickling process on the high-cycle fatigue properties of the high-nitrogen tool steel. Two surface conditions, as-pickled and machined, were evaluated. Fatigue performance under high-cycle regimes was assessed using a four-point bending test. The fracture surfaces of failed samples were analyzed to identify fatigue failure defects. The influence of parameters such as surface roughness and residual stress was also discussed.

Speaker Country:

Sweden

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Additive Manufacturing / 32

High-quality refurbishing of high pressure die casting tools with Laser Metal Deposition of the hot-work tool steel Dievar

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Die casting tools are subject to extreme thermal and mechanical stresses which manifest themselves in a variety of wear mechanisms and often premature failure. The necessary repair and maintenance of the tools result in enormous costs for the foundries and place a heavy burden on the economic efficiency of the die casting process. This is exacerbated by the fact that the manual repair welding usually used is heavily dependent on the skills of the person carrying out the work and can only be reproduced to a limited extent. As a result, the service life of the new tool cannot usually be achieved after a repair. In addition, the labor-intensive manual welding process will become increasingly difficult to implement in the future simply due to the lack of personnel availability. One promising approach to tackling this problem is automated and digitalized tool refurbishment using Laser Metal

Deposition (LMD). Based on the detection and evaluation of the underlying failure mechanisms and the subsequent digitization of the tool, the combination of CNC machining and LMD enables a repair that would be impossible to carry out manually. This is done with the aim of generating economic benefits for the foundry through a reproducible and automated process by significantly extending the service life of the repaired tool.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Additive Manufacturing / 33

Increasing the service life of press hardening tools with the innovative EvolutionClad 58 coating solution using Laser Metal Deposition

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The service life of press hardening tools is a decisive factor for the efficiency of production processes, particularly in the hot forming of galvanized and AlSi-coated sheet metal. With the EvolutionClad 58 coating solution, which is applied by laser deposition welding, the service life is significantly increased compared to through-hardened variants. This approach to tool manufacturing is characterized by an optimal combination of a hard shell with a hardness of 56-58 HRC and a soft, tough core with a hardness of 30-34 HRC, which significantly reduces the tendency to crack, especially at the critical transitions from the cooling channel to the surface. EvolutionClad 58 offers excellent resistance to abrasive and adhesive wear and significantly extends tool life. The pre-tempered base material also offers numerous advantages. The high toughness (A5 18-20%) reduces the risk of cracking, while the very high thermal conductivity (33.5 W/m*K at 20°C) leads to a reduction in cycle time compared to through-hardened variants. Added to this is the possibility of efficient machining in the soft state, which is guaranteed with a hardness of 30-34 HRC. These properties contribute to excellent weldability, especially when reprocessing the coating. In addition, the base material offers good availability at comparatively low cost. These advantages make EvolutionClad 58 an excellent choice for the coating of press hardening tools, as it not only increases the service life of the tools, but also contributes to an improvement in process stability and efficiency.

Speaker Country:

Deutschland

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Surface Treatment & Coating / 34

Comparative study of conventional and nano-diamond coated wire drawing dies

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The wire drawing process enhances the material properties and dimensional accuracy of hot-rolled wire by pulling it through dies typically made of cemented tungsten carbide or diamond. Despite ethical and health concerns associated with cobalt, a key component of cemented carbide, it remains the most common choice due to its cost-effectiveness and durability. Recently, Nano Dies with nano-diamond coatings have gained attention, offering claims of lifespans 20 to 100 times longer than conventional dies. These dies have the potential to reduce cobalt dependence and improve the efficiency and sustainability of wire drawing. However, the price of these tools varies significantly, by up to a factor of 20, creating uncertainty about performance differences across price segments. This paper presents an in-depth comparison of a conventional die with two nano-diamond coated tools from different price ranges, focusing on mechanical properties such as hardness, surface roughness, and microstructure. Additionally, laboratory wire drawing experiments were conducted to assess the performance of these new tools compared to conventional dies.

Speaker Country:

Sweden

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Fatigue / 35

Fatigue strength in Additive Toolmaking: A study of Metal Binder Jetting and Electron Beam Melting for processing carbide-rich cold-work tool steels

Author: Frederik Tegeder[1]

Co-authors: Lennart Mirko Scholl [1]; Sandra Wieland [2]; Christian Weck [2]; Marie Franke-Jurisch [2]; Alexander Bezold [1]; Thomas Weißgärber [2]; Christoph Broeckmann [1]

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Additive Manufacturing (AM) offers numerous possibilities for toolmaking, such as the integration of internal cooling structures, easy fabrication of complex tool geometries or hybrid manufacturing. Another important aspect is the minimization of necessary post-processing steps through near-net-shape manufacturing, which enables considerable cost and effort savings, especially for difficult-to-machine, carbide-rich tool steels. Previous studies have investigated laser-based processes (LPBF). Due to locally high cooling rates and associated high residual stresses, hot cracking often occurs in laser-based AM of ultra-high-strength tool steels. In particular, steels with high carbon, vanadium or cobalt contents are difficult or not processible. This hot cracking tendencies are removed with Metal Binder Jetting (MBJ), as this process is cold and uses debinding / sintering. AM processing is also possible via Electron Beam Melting (EBM) with optimized printing parameters.
In this study AISI A11 (V10, X245VCrMo10-5-1) was successfully processed using MBJ and EBM. The resulting carbide and microstructures were characterized depending on the AM process and optional HIP application. Mechanical investigations enable appropriate microstructure-property-correlations for fatigue performances. For additively manufactured A11 with / without HIP (A11

AM) the High Cycle Fatigue (HCF, NG = 107) strengths are statistically evaluated under rotation bending tests (RBT). Those results are compared to conventional material (A11 PM) produced via HIP and subsequent Hot Working (HW). The critical defect types and sizes are exemplarily compared for each process.
The results show that AM toolmaking of high vanadium alloyed, carbide-rich tool steels is a promising alternative to conventional steelmaking. Emerging defect types and sizes are manufacturing-dependent, whereby fatigue strength is primarily determined by microstructural defect sizes. AM toolmaking obtains similar HCF strengths as conventional steelmaking when applying suitable HIP treatments, but without HIP fatigue strengths are clearly below those of conventional A11 PM due to increased porosity or lack of fusion.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Fatigue / 36

Influence of cleanliness, carbide size and hardness on HCF strength and fatigue mechanisms in carbide-rich cold-work tool steels

Author: Lennart Mirko Scholl[1]

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Wear-resistant tool steels with high carbide contents are essential to optimize performance and lifetimes of cutting, stamping and extrusion tools used for industrial massive cold forming applications. Tool service life is primarily constrained by wear resistance and fatigue strength. However, the complex connection between the steel manufacturing process and the fatigue strength has not yet been studied and understood profoundly. In addition, the impact of heat treatment (hardness) on fatigue performances of high vanadium alloyed tool steels has not been thoroughly investigated so far.
To investigate these influences on the High Cycle Fatigue (HCF, NG = 107) strength, rotating bending tests (RBT) were performed on AISI A11 (V10, X245VCrMo10-5-1) steel at four different, application-relevant hardness level. The raw materials were produced by three different industrial manufacturers using Hot Isostatic Pressing (HIP) of gas atomized powder with subsequent hot working (HW). The HW process and the HW degree φ were systematically changed during raw material fabrication to compare three differently hot worked conditions of the AISI A11 steel.
In accordance with prior findings by Murakami & Endo for low alloyed steels, which indicate that increasing hardness correlates with enhanced HCF strength, the results presented here show that this also holds for carbide-rich tool steels. Higher hardness can improve HCF strength and performance, but only at very high cleanliness and small carbide sizes (preventing carbide coarsening and clustering).
Noticably, it is not only the atomization process that significantly influences crack initiation and fatigue strength, but also the grain size distribution used for HIP as well as the technique (type) and degree φ used for HW. This phenomenon can be attributed to the direct manipulation and control of critical defect sizes (non-metallic inclusions or coarsened, primary vanadium carbides) within the steel microstructure.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Sustainability / **37**

Increased sustainability through additive manufacturing and laser hardening of emission free tool steel – a case study.

Authors: Hanna Nilsson Åhman[1]; Jaakko Korteniemi[1]; Jonas Gozzi[1]; Ulrika Fager[1]; Hugo Wärner[1]; Robert Larsson[1]; Jesper Vang[1]

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Additive manufacturing techniques such as Laser - Powder Bed Fusion (L-PBF) has great potential in reducing the CO2 footprint of many tooling solutions. By enabling complex internal cooling systems, and often a higher material hardness, increased tooling speeds and longer tool life is possible. Moreover, L-PBF enables in-house production, allowing for a more agile spare parts management. This reduces lead times and eliminates storing and shipping of spare parts.
Nevertheless, L-PBF parts often have larger CO2 footprints than traditionally manufactured parts due to the material used in the process. By combining the possible benefits of L-PBF with a material based on high-quality recycled scraps, a zero-emission component with longer service life can be produced.
Herein, the in-house production of a spare tool part for coil strapping illustrates the potential of increasing sustainability by L-PBF processing and laser hardening of a zero-emission steel. The tool is crucial in SSABs internal steel production. It is highly exposed to wear, resulting in a relatively short tool life. Moreover, SSAB has been suffering from supply issues with the original equipment manufacturer part. To resolve these issues, a copy of the tool was created by 3D-scanning, and parts were produced by L-PBF. The printed material is a low alloyed steel with tempered martensitic structure, having an as-built hardness of 450HV. Through laser hardening, a higher hardness was obtained in key areas of the tool.
Consequently, the tool life was increased by 3 times in comparison with original spare part, while also cutting the lead times in half. Moreover, the as-built hardness, combined with laser hardening, makes other heat treatments redundant, further reducing CO2 emissions. In conclusion, by using L-PBF and laser hardening, an increase in tool life was obtained, and a more agile spare parts management possible, resulting in a more sustainable tooling solution.

Speaker Country:

Sweden

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / **38**

The potentials of using directed energy deposition (DED) to process a cold work tool steel for repairing purposes

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Additive manufacturing (AM) using Directed Energy Deposition (DED) has emerged as a potential technique for repairing components of high-performance materials like K340 tool steel. K340 is a high-carbon, chromium-molybdenum-vanadium alloyed cold-work tool steel known for its exceptional mechanical properties, making it ideal for demanding applications such as forming and stamping tools and dies. This study explores the feasibility of using the DED process to repair K340 tool steel components. Initially, by depositing different double-tracks, process parameters such as laser power, gas flow rate, and travel speed were systematically varied and optimized to achieve optimum deposition dimensional accuracy, minimal porosity, desired penetration, and a proper surface quality. Cubic samples were then deposited on a platform made from the same material. Microstructural analysis, by using optical microscopy and scanning electron microscopy, revealed that the rapid solidification inherent to the DED process results in a fine cellular and dendritic structure with retained austenite and segregation of the alloying elements in inter dendritic regions in the as-built condition. Post-processing heat treatments were employed to homogenize the microstructure and improve hardness by transforming retained austenite into martensite, thereby enhancing the mechanical properties and wear resistance of the material. Mechanical testing showed that the hardness values of DED-processed K340 steel could be significantly improved after heat treatment, reaching up to 830 HV, comparable to conventionally produced materials. The results demonstrate that the DED process is a viable approach for processing K340 tool steel, offering tailored microstructures and mechanical properties through process optimization and subsequent heat treatments. This research provides valuable insights into the potential of DED for repairing high-performance tooling materials, reducing lead times, and minimizing material wastage, and paving the way for broader industrial adoption in the manufacturing sector.

Speaker Country:

Italy

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Sustainability / 39

Effect of heating agent on scale formation of tool steels

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In order to heat steel without CO2 emissions in the future, the burner technology of at least some of the furnaces used today will be converted from natural gas to hydrogen combustion. This poses a particular challenge for tool steel due to the more frequent heat treatments compared to engineering steel. The effect of the changed process gas on the furnace lining, temperature uniformity (TUS) and scale formation is being investigated in an EU-funded HYDREAMS project, among others.
A low-alloyed hot-work tool steel 1.2322, an alloyed hot-work tool steel 1.2344/H13, a ledeburitic cold-work tool steel 1.2379 and an aluminum-alloyed nitriding steel were each tested with natural gas/air and hydrogen/air heating.
Initial results from laboratory tests carried out at the University of Graz on tool steel samples from the Swiss Steel Group show that the qualitative formation of the scale layers does not change when the process gas is changed, but that there are significant differences in the kinetics. When steel is heated using hydrogen instead of natural gas, a significant increase in scaling is to be expected.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / 40

Short process chain by additive manufacturing

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When processing long products in particular, the process chain from steel production to the finished component is very long and generally optimized for large quantities. In contrast, the quantities for defense applications are extremely low compared to the automotive industry. Despite the high production costs, additive manufacturing of components can have advantages here because, for example, forging dies do not have to be produced over a long period of time and the high costs are not spread over a large number of units.
Additive manufacturing still focuses on relatively few materials such as 1.2709 and 1.4404. Common engineering steels such as 42CrMo4, 16MnCr6, 100Cr6 and tool steels such as 1.2344 are difficult to process additively. In the meantime, a number of new materials have been developed specifically for additive manufacturing that can substitute the above-mentioned materials. These new steels can also be produced conventionally as mass steel and then cover the entire spectrum from prototypes and spare parts production to mass production. A table of common construction materials and their substitutes suitable for additive manufacturing has been compiled.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Materials, Properties & Microstructure / 41

Research and development program as a solution for competitiveness of the Brazilian toolmaking sector

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Since 2019, the Brazilian government has been implementing programs to develop the automotive supply chain. One of these programs, entitled “More Competitive Brazilian Toolmakers”, seeks to

overcome the challenges faced by toolmakers with low productivity and technological lag. The main objective is to train the tooling chain for automotive products, seeking to achieve global competitiveness. Aligned with the government's commitment to neo-industrialization and innovation, the program focuses its initiatives on optimizing deadlines, costs, and quality throughout the various phases of the tooling production life cycle. In doing so, it seeks to prepare Brazilian toolmakers not only to meet the national demand in vehicle manufacturing but also to achieve a prominent position in the global market. The program also promotes research and development as complementary tools to create an ecosystem that favors collective efficiency through collaboration between the various actors in the chain, including toolmakers, assemblers, system suppliers, universities, and technology centers. This collaborative approach results in product differentiation, strengthening of cooperative ties, and access to the diffusion of technological and organizational innovations, inputs, specific solutions, and specialized labor. Thus, it aims to maintain a healthy balance between competition and cooperation. 28 Research, Development, and Innovation projects were engaged in the first 5 years of the program, proposing improvements in the various phases of the tooling production life cycle in search of increased durability, repairability, productivity, and applications in innovative materials and processes. The projects were and are being executed through partnerships between 39 Science and Technology Institutions and 164 companies (toolmakers, assemblers, systems manufacturers), with support from representative entities. Some projects focused on basic and disruptive research, while others were looking to solve problems with higher TRL. The total financial contribution committed was approximately 33 million dollars.

Speaker Country:

Brazil

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Fatigue / 42

Microstructure, defects and fatigue response of high strength tool steels

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The martensitic tool steel family is tailored for different specific working environments, ranging from cold work to hot work applications demonstrating high hardness, toughness and wear resistance. Nowadays, their microstructure is continuously upgraded by either composition developments or processing techniques. Both ways introduce new types of defects making the investigation of their fatigue response of significance importance for the industry. This study presents a comprehensive comparison of four advanced tool steels in terms of their microstructure, common defects, and fatigue performance in the High Cycle Fatigue (HCF) and the Very High Cycle Fatigue (VHCF) regimes. The materials investigated belong to two categories: i) Cold work tool steels; one of medium and one of high alloying composition, and ii) Hot work tool steels, one manufactured through an ingot casting and forging route and one via additive manufacturing.

Microstructural analysis, conducted via SEM and EBSD, revealed varying levels of carbides and martensitic lath blocks sizes, which may influence both the fatigue performance and the type/size of defects present in each steel. Fatigue tests were carried out at stress ratios of R=-1 and R=0.1, using a servohydraulic machine in load control at 30 Hz frequency and an ultrasound machine in displacement control at 20 kHz frequency. The fractured surfaces were analyzed in depth via SEM.

The steel grades are compared based on their strengths, martensitic structures and defect size distributions. and the fatigue strength using probabilistic approaches and the Murakami model. Finally, failure probability curves were produced for each material. This analysis provides crucial insights into the relationship between microstructural features, defect distributions, and fatigue performance, which are essential for optimizing the design and manufacturing of martensitic tool steels, especially in the context of HCF and VHCF regimes.

Speaker Country:

Sweden

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Sustainability / **43**

Sustainable PM high-speed steels: Options and challenges

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A sustainable steel production involves using renewable energy sources, reducing carbon dioxide emissions, and minimizing and recycling waste during the production process. However, the most significant effect in case of tool steels is increasing the scrap rate during melting, and more specifically using correctly sorted scrap. To achieve this, a circular economy involving steel producer, customer and scrap dealer must be set up. One challenge is that high performance tools are mostly coated to improve their performance. However, coatings contain elements which are usually not used as alloying elements in tool steel production. Hence, the properties of the tooling material could be influenced by introducing unwanted alloying elements via scrap. A solution would be to remove the coating prior to using the scrap for new steel production. The aim of this work was to elucidate the usage of correctly sorted scrap in terms of CO2 emission and how it possibly affects material properties and performance in application.

Speaker Country:

Austria

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Materials, Properties & Microstructure / **44**

Low temperature reversed austenite in the AISI D2 matrix

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As a possibility to understand the mechanisms of austenite stabilization due to stress relief heat treatment in a cold work tool steel, this work has used the concept of matrix steel and evaluated the composition of the matrix of AISI D2 tool steel (MSD2). This work presents the characterization of two conditions: quenched and quenched followed by stress relief heat treatment. The specimens were submitted to optical microscopy, optical microscopy with differential interference contrast, field emission gun electron scanning microscopy, thermodynamic analyses, and X-Ray diffraction. An unexpected low temperature austenite was found when the stress relief heat treatment was applied. The mechanism of low temperature austenite seems to be analogous to the reverted austenite; being the low temperature austenite precipitation in detriment of M23C6 carbides. The low temperature austenite coexists with the retained austenite.

Speaker Country:

Brasil

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Surface Treatment & Coating / 45

Tribological and microstructural characterization of Coatings used on C75 tool steel

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C75 tool steel is a very widely used material in several technological fields due to its low cost and high availability combined with good mechanical properties. However, the material is prone to environmental degradation, sometimes combined with tribological degradation, in which case a coating is necessary to avoid these problems, with the main aim of increasing the environmental and mechanical degradation. In particular for this purpose, Ni-based coatings, Cr-based coatings.
The samples were subjected to microstructural characterization using SEM in cross-section to evaluate both the thickness and the microstructure of the coatings. Vickers microhardness tests were then carried out at different loads, from HV2 to HV0.01 in plan view. To evaluate both the adhesion and abrasion resistance of the coatings, scratch tests were carried out with a constant initial load of 1N, increasing by 1N per test until scratches were visible to the naked eye. The tribological characterization was carried out using a tribometer in a pin-on-disc configuration. The tests lasted 1 hour, at a speed of 300 rpm, with an applied load of 50 N. The counter material was a C40 pin with a diameter of 6 mm. The wear traces were then analysed using SEM to assess the wear mechanism and a stylus profilometer to assess the depth of the wear trace, which was necessary to calculate the wear rate.
The analyses showed that not all electroplated coatings are effective against the main degradations analysed in this work. Specifically, samples with thicker coatings performed worse than those with thinner coatings. In fact, some coatings improved wear relative to bare steel, while others proved to improve the wear resistance of the coated system. It should be noted that in some cases the surface hardness was improved abruptly (above 1000HV).

Speaker Country:

Italia

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Surface Treatment & Coating / **46**

Wear performance of EDM-machined cermet substrates with different surface finishes

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The tribological behaviour of materials machined by electro discharge machining (EDM) is strongly influenced by microstructural changes in the surface layers. This technique is commonly used to machine cemented carbides, which are known for their high hardness and excellent wear resistance.

In this research, the impact of different surface finishes on the tribological properties of cemented carbides was examined. In order to obtain different surface finishes, samples were extracted using the EDM process and then subjected to sandblasting, grinding and lapping operations.

The microstructure of each sample was analysed using optical and scanning electron microscopy (SEM) with an EDXS probe for chemical composition analysis and GDOES for further investigation. Mechanical properties were measured through microhardness tests. For the tribological characterization, wear tests were performed under different loading conditions. The wear traces were examined with a stylus profilometer and SEM, both in top view and in cross section.

Experimental results revealed that EDM and ground specimens showed superior wear resistance. Surface treatments that generated more defects resulted in lower tribological performance. In contrast, super-finishing treatments provided slight improvements in wear resistance, but too small compared to the increase in costs.

Speaker Country:

Italy

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Die Casting / **47**

Effect of H13 coating thickness on the mechanical and thermal properties of copper alloy substrates deposited via laser cladding

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Copper alloy components, such as molds and tooling, allow efficient thermal dissipation but are prone to surface damage due to their relatively low strength. Applying hard coatings such as tool steels deposited by laser cladding, can significantly enhance surface strength, thereby extending the lifespan of these components.
In this study, H13 coatings with varying thicknesses were deposited onto copper-beryllium alloy substrates using laser cladding, with an intermediate stainless steel layer applied to suppress cracking. The morphology, microstructure, and elemental distribution of the H13 coatings were characterized. Additionally, the effect of coating thickness on the heat-affected zone depth, microhardness, load-bearing capacity, and thermal conductivity of the copper-beryllium substrates was carefully examined.

Speaker Country:

Italy

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / **48**

Effect of titanium carbide additivation on the microstructure and processability of H13 tool steel in PBF-LB/M

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In-situ alloying via laser-based powder bed fusion of metals (PBF-LB/M) has gained attention as an alternative to pre-alloyed powders. In steel making, this method is particularly advantageous for the additivation of carbides like titanium carbide (TiC) which should not fully melt during the PBF-LB/M process. On the one hand side, this ensures that the carbon content in the steel matrix is not excessively elevated, thus reducing the risk of cracking, compared to pre-alloyed steels with high carbon content. On the other hand, this method offers the potential to realize a mixture of coarse carbides being advantageous for resistance against abrasive wear and fine carbides which form by re-precipitation and contribute to grain refinement, secondary hardening and an isotropic microstructure. This study focuses on determining the limits of TiC, added to H13 tool steel powder, that can still be processed effectively using PBF-LB/M, while evaluating the influence of TiC content on the resulting microstructure. To achieve this, H13 tool steel powder was mixed with varying amounts of TiC. During PBF-LB/M, the laser scanning speed was varied to examine the influence of energy input on the dissolution of the carbides and on the material properties. The microstructural characteristics were analyzed and hardness tests were performed. The results are compared and discussed to assess the relationship between TiC-particles added to the steel powder, laser processing parameters and the resulting microstructure.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Additive Manufacturing / 49

New dual-hardening AM alloy for tooling in HPDC

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Hot work tool steels are generally used among others for applications in aluminum pressure die-casting. Laser based additive manufacturing (AM) technologies allow producing dies and inserts with complex geometries and conformal cooling, resulting in higher product quality and increased process profitability. Nowadays only few steel powder alloys for AM of dies and tools are adopted widescale. Due to their easy printability, mainly 18%Ni-maraging steels such as W722 (DIN 1.2709, ≈ Maragin 300) are used. Nevertheless, they are originally not designed for applications in pressure die-casting, according to their mechanical and thermophysical properties. The major disadvantages compared to typical hot work tool steels type of H11 (DIN. 1.2343) or H13 (DIN. 1.2344) is their lower resistance against thermal shock and chemical dissolution of the steel by the liquid aluminum. However, H11/H13 are critical to process by the Selective Laser Melting (SLM) process and should be preheated to at least 200℃ because of their high carbon content of approximately 0,4% wt. Therefore, the research and development of new steel alloys with high process stability and hence reproducible quality by SLM is necessary
In this work, a new dual hardening model alloy W808 AMPO particularly developed for SLM processing of dies and tools in aluminum pressure die-casting will be presented. Samples are printed on SLM 280 HT at different preheating temperatures. Subsequently the mechanical and thermophysical properties in the fully heat-treated conditions are analyzed. The corresponding microstructures are investigated using optical microscopy and scanning electron microscopy. Furthermore, the test alloys are examined regarding their thermochemical and thermal shock resistance. The results are compared and discussed with those of W722 (1.2709) as well as W300 (H11, 1.2343).

Speaker Country:

Österreich

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Surface Treatment & Coating / 50

Laser surface modification of CrVN coatings for self-lubricating performance

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Hot forming, especially hot forging is a very demanding forming application requiring tool material with high strength and toughness and above all good wear resistance at elevated temperatures. Prevailing wear mechanisms in hot forming are abrasive wear and galling, with abrasive wear leading to dimensions mismatch and galling to unstable friction and poor surface quality of the forgings. In order to reduce tool wear and improve forming process different wear resistant coatings like CrN are used. However, relatively high coefficient of friction of CrN coatings against soft metals hinders their applicability, still requiring the use of different lubricants in the most demanding applications. Vanadium nitride (VN), on the other hand has attracted increasing interest as VN is easily oxidized to form Magneli phase vanadium oxides with easy slipping shear planes, leading to self-lubricating properties.
Therefore, the aim of our work was to study the effect of V content and laser surface modification of CrVN coatings on triblogical properties and formation of self-lubricating tribofilms. CrN coatings doped with V in concentrations from 15 to 30 % were deposited by industrial DC-magnetron sputtering system and further surface modified with IPG Fiber laser using different laser power and scanning speed. The aim of laser surface modification was to induce formation of lubricious oxides on the coating's surface. Surface modified CrVN coatings were then tested on load-scanner and under reciprocating sliding conditions. Tribological testing of CrVN coatings with different V content was performed at room and elevated temperatures (up to 600℃) against typical structural steel and Al alloy for hot forging and results evaluated in terms of coefficient of friction, wear volume, critical load for galling initiation and wear track surface analysis. Surface analysis was focused on the formation of self-lubricating oxides and tribofilms.

Speaker Country:

Slovenia

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Plenary Session / **51**

What's ahead for remelted Tool steels and update on PM & AM Tool steels

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The speech will also focus on the production of Metal Powders and Powder Metallurgical Steels and especially its associated production technologies like HIP, MIM and AM. As they are and will become key future core technologies for several demanding products and thus for the usage in different associated industries. The presentation will also highlight the actual supply and demand situation of metal powders and the manufactured metal powder steels, will introduce leading manufacturers of both powders and steels, and summarizes installed capacity and new capacity that are on the way as well as new players that enter this high value industry. The presentation will also highlight the recent developments in the world of Forged Special Steels and remelted steels (nickel alloys, stainless steel, alloy tool steel and alloy steel) as well as will give an overview about end-user demand and structures of these special steels and also summarize the actual status of installations on a global scale.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Fatigue / 52

The propagation of short cracks near individual microstructural features studied in situ

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For most metalworking tools, cutting-edge loads fluctuate at high levels during the industrial application, leading to material fatigue and tool failure. Usually, fatigue crack propagation is observed on cracks emanating from large, through-specimen-width notches that average a large number of microstructural features along the crack front, which does not represent reality. To address the lack of appropriate methods to monitor the propagation of application-relevant microstructurally short cracks a novel method is proposed: The technique enables in situ measurement of microstructurally short cracks emanating from an artificial defect of application-relevant size near a small number of microstructural features by use of the alternating-current potential drop method. The current work demonstrates the technique on the example of µm-sized semi-elliptical notches introduced via focused ion beam milling into industrial-grade high-speed steel. The propagation of microstructurally short cracks near systematically varied microstructural features was monitored. The fatigue crack extensions calculated based on the in situ measured current signals showed good agreement with fractographs made after the test specimens' final fracture.

Speaker Country:

Austria

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Materials, Properties & Microstructure / 53

Martensitic stainless steel as coatings for continuous caster rolls

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In a continuous slab casting machine (CCM), rolls support the solid skin of the slab during casting. They are subjected to high corrosive and abrasive conditions and cyclic thermomechanical loading,

caused by repeated contact with the hot metal (1100–1200 ℃) and cooling in a water steam atmosphere. The combination of these effects leads to surface degradation. To limit the surface cracking phenomena, carbon steel rolls are coated with a hard facing material. Martensitic stainless steel is a widely used solution for this application. Anyway, the target is to further improve the coating performances and extend roll's life, since each time the rolls reach the end of their life the segment must be removed from the machine for maintenance, leading to a decrease in the production and higher operational cost.
In this paper an example of coating degradation phenomenon will be analyzed to study the mechanism of damage. Then, a changing in the coating deposition process will be proposed to improve the microstructure of the coating, increasing in this way the working life of the component.

Speaker Country:

Italy

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Die Casting / 54

Sustainable development of established steels for high-pressure die casting tools

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Aluminum die casting plays a major role in automotive construction and is becoming even more important due to new production technologies such as giga-casting. In the interests of climate-friendly production, however, the CO2 footprint across the entire process chain must also be increasingly considered and approaches must be sought to minimize CO2 emissions. Toolmaking must not be left out of this either. The production of tools based on a conventional process chain is usually carried out on a remelted, soft-annealed established 5% chromium steel with a vacuum hardening after mechanical pre-machining. Since this chain is both time-consuming and cost-intensive, several process owners are involved and CO2 is emitted through the consumption of energy and overuse, considerations were made as to the extent to which production can be significantly shortened without reducing tool life. To this end, it is advisable to optimize established 5% chromium steels in terms of alloying and metallurgy in such a way that a pre-quenched and tempered bar represents the starting point for toolmaking. The report describes first tests with the comparative presentation of the mechanical-technological properties including the feasibility of high-speed machining. Based on the first experience, a second test was set up, which was again slightly changed in its chemical composition to achieve a hardness level of 44-46 HRc. This was used to evaluate an alternative production method for die-casting tools.

Speaker Country:

Deutschland

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Die Casting / 55

Design and application of novel hot work die steel with high strength, high toughness and high heat conduction coefficient

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The integrated die-casting technology significantly enhances the production efficiency of new energy vehicles while reducing costs, leading a revolution in the new energy vehicle industry. This technology places higher demands on the die steel materials used, and the availability of large-sized die steel is one of the bottlenecks encountered in the industrialization and application of this technology. Currently, the die steel used for integrated die-casting structural components of new energy vehicle bodies is not specifically developed for integrated die-casting technology. The large size of the dies causes difficulties in heat dissipation, and localized overheating can rapidly soften the die, leading to failure. Moreover, the challenges in heat dissipation severely affect the mechanical properties of the structural components. To address this issue, we used warm forging technology to improve the toughness of the high thermal conductivity die steel Fastcool50, which has already been successfully applied in the mold inserts at Tesla's Shanghai Gigafactory. At the same time, we systematically analyzed the mechanisms affecting the strength, toughness and thermal conductivity of hot work die steel. Meanwhile we are developing a new type hot work die steel, aiming to utilize traditional forging processes to produce large-sized hot work die steel materials that balance strength, toughness and thermal conductivity. This new die steel is expected to be applicable in fields such as aluminum alloy die-casting and hot forming.

Speaker Country:

China

Are you interested in publishing the paper in a Steel Research International special issue?:

Yes

Plenary Session / 56

Sustainability of tool steels: PCF calculation of tool steels, the impact of tool steel PCF for the PCF of the products made with them and how to reduce tool steel PCF

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Tool steels are indispensable for the mass production of forgings and many other goods. The Product Carbon Footprint (PCF) of mass produced goods is becoming increasingly important for buyers in the automotive industry and in other sectors. So the PCF of tool steels, which need to be incorporated into a cradle-to-gate calculation of a product made with them, becomes increasingly important, too.
This contribution covers three topics:
•How to quickly calculate the PCF of tool steels using the Footprint Reduction Tool FRED. FRED is a web-basedprogram steming from an industry association project. With FRED, users can generate PCFs which comply to ISO14067. FRED is easy to use and very economic
•It will be shown what influence the tool steel PCF has on the PCF of a product made using tool steel.These calculations can be made using FRED, too
•Approaches to reduce the PCF of tool steels are important for the tool steel maker as his Corporate-Carbon Footprint (CCF) determines the evaluation of his sustainability efforts. Accordingly, ways to reduce the CO_2 emissions during tool steel production will be discussed

Speaker Country:

Germany

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Fineblanking / **57**

Digital transformation in fine blanking

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Fine blanking is a manufacturing process combining forming and blanking operations to produce metal parts from coils with high dimensional accuracy, smooth edges, and minimal post-processing requirements. However, challenges such as unexpected tool wear and fluctuations in material properties can lead to unplanned machine downtimes, increased scrap production, costly finishing treatments, and expensive repairs or replacements of tool components. To address these issues effectively, it is essential to implement tool condition monitoring and non-destructive material testing as part of the digital transformation of the fine blanking process. This presentation will explore various data analysis techniques leading to the empowerment of manufacturers to proactively manage tool wear and material property variations through informed decision-making and adaptive process control, enhancing overall efficiency and product quality.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

Plenary Session / **58**

Sustainable and secure molybdenum supply for the European tool steel industry

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Increasing physical demands on tool steels are directly reflected in a higher molybdenum alloy content. Depending on their application, tool steels are classified into:
• Cold-work tool steels (Mo ≤1.8%)
• Hot-work tool steels (Mo ≤3.0%)
• High-speed tool steels (Mo ≥5%)
Molybdenum additions to tool steels increase both hardness and wear resistance while providing acceptable toughness. By reducing the critical cooling rate for martensite transformation, molybdenum allows promoting the formation of an optimal martensitic matrix, even in massive and intricate molds that cannot be cooled rapidly without distorting or cracking. Considering this prominent role of molybdenum as an alloying element to high-performance tool steels, aspects of sustainability and

strategic supply security necessarily come into focus. This contribution details the mining and supply scenario for molybdenum starting from geological survey data and scrutinizes it against the evolution on the demand side. The main contributions to carbon footprint along the molybdenum processing chain and practicable efforts to lower these will be discussed. Since the closure of Norway's Knaben molybdenum mine in 1973, Europe entirely relies on overseas supplies of molybdenum concentrate. The ongoing development of the Malmbjerg mining project in Greenland can reinstate a fully EU-based supply chain. The cornerstones and status of this strategically important project will be presented.

Speaker Country:

Belgium

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59

Test

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Test

Speaker Country:

Austria

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Additive Manufacturing / 60

Influence of heat treatment and scan rotation on the microstructure of hot work steel manufactured using L-PBF

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Additive manufacturing (AM) provides a unique opportunity to have freedom in design. Often it is necessary to perform post treatment processes on the printed component to adjust the mechanical properties. This is particularly true for martensitic H13 tool steels manufactured with laser-powder bed fusion (L-PBF) where repeated thermal cycles as the result of the addition of the new top layer, can give rise to columnar growth and microstructural inhomogeneities. Considering the unit size and texture of martensitic microstructure as directly under influence of the size of the prior austenite grains (PAGs), the focus of the investigation lies in the PAG size of the as-built (AB) and heat-treated (HT) conditions. Furthermore, four types of samples with different scan rotations (0°, 45°, 67°, and 90°) were investigated. The AB material displayed a characteristic cell structure with cell boundaries enriched in alloying elements as well as nano-sized carbides at triple joints and intercellular

regions. A key finding of this research is tha the heat treatment gives rise to PAG size refinement as the result of recrystallization and pinning effect from carbide hindering the grain growth during austenitization.

Speaker Country:

Sweden

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Yes

Die Casting / 61

Sustainable production and service behaviour of extra-large die casting dies

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coming soon

Speaker Country:

Italy

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Die Casting / 62

Trends and developments in HPDC-tooling

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High-Pressure Die-Casting is the most important process in light-metal casting for mass production especially in the automotive sector. The process is well established for a wide range of components all over the vehicle from engine and drive train components over gear boxes and electronic housing to body in white components and subframes. Due to recent trends and legal restrictions the industry is currently undergoing a comprehensive transformation process. As the “classical” components and traditional mass products which have been used in ICE-vehicles will decrease within the next decade, new components will increase their market shares. There is clear trend towards large scale components with a high degree of functional integration such as battery housings or car underbodies.
These developments bring along huge challenges in HPDC-tooling. On the one hand the size of tool inserts become larger and larger leading to new concepts for hot working steel producers as well as for the tool makers and – last but not least – the producers of HPDC-machines. On the other hand, functional integration in HPDC-cast parts involves challenging components in which both

thin-walled and thick-walled areas are combined, which have to be handled both in terms of filling and solidification technology. Modern toolmaking has to handle die inserts of large sizes produced from bulk material in combination with sub-inserts produced in additive manufacturing in order to realize effective cooling systems to avoid solidification defects or die soldering in the thick walled sections of the cast parts. PVD-coatings or structured surfaces are commonly in use to improve the flow length of the metal and reduce abrasive wear at the tool's surface.
As thermo-mechanical fatigue is the most important factor when it comes to the question for the longevity of the HPDC-tool, steep temperature gradients at the surface have to be avoided. As in the past the thermal management of the tool during production was adjusted via (excessive) surface spraying with water sprays today this method is more and more replaced by micro spraying where only a thin release agent layer is applied onto the tool surface, which reduces tensile stresses and heat checking but presents tool designers with the challenge of ensuring adequate temperature control of die inserts during the design process. Innovative simulation techniques and sophisticated sensor technologies are therefore becoming increasingly important in process planning, tool design and during the process. In addition, digital approaches such as neural networks or machine learning are becoming increasingly important. The European die casting industry can only succeed in the increasingly difficult global market environment if all these challenges are successfully mastered and a high level of innovation is maintained.

Speaker Country:

Austria

Are you interested in publishing the paper in a Steel Research International special issue?:

No

Fatigue / 63

Mean stress sensitivity for carbide-rich PM tool steels under axial and torsional loading

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Designing cold-work tools against fatigue fracture under uniaxial and multiaxial cyclic loading is of great economic relevance for industry to increase the productivity in metal cold forming processes. To implement more resource-efficient and low-emission production chains, minimizing retooling times, increasing tool service lifes and produced quantities per tool is of particular interest to society. Apart from wear resistance, the fatigue strength of carbide-rich, high-alloyed tool steels is the important lifetime-limiting factor.
As reported in the literature, tools in massive cold forming of complex shaped parts often fail due to fatigue fracture. In the design of cyclically stressed tools made of carbide-rich tool steels, besides factors influencing the fatigue properties such as the degree of multi-axiality, possible non-proportionality, notch effect or microstructural features, it is necessary to consider characteristic material properties such as the mean stress sensitivity (M) and the ratio of torsional to axial fatigue strength (D). So far, these material properties have not been studied sufficiently, which makes it difficult to evaluate tool service lifes under real operating conditions.
In this work, HCF fatigue properties under axial and torsional loading with systematic variation of the stress ratio are presented for the powder metallurgical (PM) steels M3, D2 and V10. In addition, the crack-initiating defects are identified and correlated with the fatigue strength according to Murakami's model. It is shown that the fatigue strength is directly related to the steel cleanliness and the manufacturing-dependent defect sizes. Based on the results, new material-specific correlations for HCF strength, M, D and Haigh diagram plots are introduced.

Speaker Country:

Germany

Are you interested in publishing the paper in a Steel Research International special issue?:

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Plenary Session / **64**

Sustainable tool steel production - global challenges and solutions

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The challenges facing the steel industry — energy-intensive processes, availability of CO2-neutral energy and raw materials and complex supply chains — cannot be solved without sustainable and innovative solutions.

Depending on the region, there are different opportunities and risks for a tool steel producer to achieve decarbonization targets, among other things.

Speaker Country:

Austria

Are you interested in publishing the paper in a Steel Research International special issue?:

Plenary Session / **65**

Die technology, sustainable materials, and smart industry at Volvo Cars

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Manufacturing Engineering Casting & Stamping within Volvo Cars is continuously evaluating, developing, and implementing new technology.
This presentation gives an overview of recent research and implementations in the area of die technology and sustainable materials used in casting and stamping at Volvo Cars.
Volvo Cars has also started the journey towards Smart Manufacturing & Digital Twins, an area with great potential and challenging research topics.

Speaker Country:

Sweden

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No