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Editorial

Alloy and Process Design of Metallic Materials

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1. Introduction and Scope

Metallic materials have witnessed substantial developments over the past two decades. For instance, it is noteworthy that over 75% of the steel varieties currently in production were not available at the beginning of the millennium [1]. Indeed, designing new modern metallic materials is essentially a microstructural task; indeed, controlling the microstructure is precisely what enables the achievement of the desired combination of engineering properties for an application. A quantitative understanding of the multivariate nature of microstructure–property relations presents the basis for designing alloy composition and associated processing parameters. In the context of developing new or improved metallic materials for commercial use, reducing manufacturing costs by saving alloying elements, decreasing energy consumption, and increasing production rates by shortening production times are fundamental prerequisites for successful material design. This is especially so in an era of continuously increasing global resource consumption and pollutant emissions. Sustainable technological advancements in the development of metallic materials require a better understanding of the underlying physical mechanisms that govern their behavior.

Within the field of the newly developed metallic materials, high-entropy alloys (HEAs) stand out as an exceptionally promising group, offering a wealth of potential for future advancements in metal alloys. These innovative alloys hold the key to numerous exciting opportunities due to their remarkable and potentially advantageous properties. Recent research findings suggest that certain high-entropy alloys exhibit notably improved strength-to-weight ratios, enhanced fracture resistance, superior tensile strength, and greater resistance to corrosion and oxidation compared to traditional alloy alloys [2].

The central theme of this Special Issue concerns the application of metallurgical techniques for the design of alloy compositions and/or adopting relevant processing parameters to satisfy the specific performance requirements of metallic materials.

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2. Contributions

This Special Issue features ten original research articles covering three types of metal alloy, namely, steel, ductile iron and aluminum alloys. Emphasis is placed on comprehending phase transformation and utilizing methods to control microstructures and properties, all while keeping a close eye on alloying and processing costs.

This Issue presents 6 articles on the topic of steel. Microalloyed pipeline steel is investigated in terms of its microstructure development and mechanical properties by Soliman [3]. This study revealed that the traditional strength–ductility trade-off can be overcome by selecting a proper cooling rate and coiling temperature without altering the deformation parameters. An important observation of this study was that differences in yield strength result from different thermomechanical processes (TMPs) fade following the strain aging. Ahmed et al. [4] presented a study examining two grades of rebars, B400B-R and V-alloyed B500B, produced via the Tempcore process in two different diameters. For B400B-R D32, optimized parameters resulted in reduced core and surface hardness, as well as lower yield and tensile strength compared to D20. In contrast, B500B D32 showed increased hardness, higher yield strength, and similar tensile strength to D20, indicating the advantages of V-alloying and longer quenching times. The potential of V-alloying to enhance tempered martensite is also highlighted. Low-cost aluminum alloyed nano-bainitic steels were developed by Akram et al. [5]. The authors concluded that the addition of aluminum beyond 3 wt. % is not recommended because of its adverse effects on ductility. For applications at elevated temperatures, Emmrich and Krupp [6] presented a study on the development of a novel low-density, high-strength forging steel based on the addition of aluminum and niobium. The alloys showed a fast and massive increase in hardness due to precipitation of Laves phase during aging. Blankart et al. [7] successfully used dilatometric measurements to determine a robust process window for Q & P. This ensured that the desired balance between strength and ductility was achieved consistently, while also minimizing the likelihood of high scrap rates. In essence, a robust process window is the key to unlocking the full potential of medium-manganese steels in industrial praxis. Huang et al. [8] highlighted the dependence of microstructure development on the alloying composition and thermal cycling parameters during wire arc additive manufacturing (WAAM). They suggested that the HSLA steels are more suitable for producing softer and consequently tougher components than that produced from the conventional welding wires.

This Issue presents two original articles about developing ductile iron. Ahmed et al. [9] developed different grades of novel ductile irons and ADI with excellent strength/ductility balance using several alloying contents of nickel, copper and microalloying with niobium. Additionally, special nanocarbon powder was added to the molten iron to enhance the nucleation tendency of spheroidal graphite and compensate for the possible negative effect of Nb addition on nodule morphology. The work of Abdelmonem et al. [10] highlighted, for the first time, the aging behavior of the dual matrix ductile iron. An increase of yield strength up to ~11% was observed due to aging. The peak aging response is followed by a decrease in yield strength due to martensite tempering.

Regarding the aluminum alloys, two research articles are included in this issue. Žbontar et al. [11] showed how cooling rates in high-pressure die casting (HPDC) of AlSi9Cu3 aluminum alloy affected microstructural constituents, mechanical properties. By analyzing castings of varying thicknesses and employing numerical simulations to determine cooling rates, it was found that increasing the cooling rate from 60 K/s to 125 K/s led to an average strength increase from 261 MPa to 335 MPa at 5% deformation. Soliman et al. [12] developed routes for processing Al–SiCp (SiC particulate metal matrix composite) sheets with improved microstructures; namely, the uniform distribution of SiCp and minimized porosity throughout the whole material, thereby improving mechanical properties of the composite.

The processing–microstructure–property relationships introduced in this Issue are valuable in assisting the development, improvement and validation of the physical models and mechanisms explaining material behavior. We hope that this Issue provides new directions for alloy and process design.

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