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Editorial

Structure–Properties–Processing Relationships in Metallic Materials

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1. Introduction and Scope

The steady innovation of materials has been assisted by the introduction of simulation and analytical technique tools in the development chain. The necessity for increased efficiency and power and low emissions and, in parallel, safety, has brought forth new, advanced, high and ultra-high strength multiphase steel grades into use in the automotive industry, one of the most competitive sectors in the world. The steadily stricter rules for vehicle emissions forces the broader usage of light-weight metals and alloys.

Microstructure–properties relationships in combination with processing or alloying strategies for the development of tailored microstructures and, thus, mechanical properties, in new alloys have been intensively investigated by academia and industry throughout the years. Simulation approaches for addressing not only diffusional but also shear and displacive transformations are now of great interest for process simulation and the control of microstructure evolution, taking into consideration processing conditions and/or limitations. Alloys with a need for texture-oriented rolling and/or with tailored rolling and heat treatment schedules underline the necessity for proper structure–properties–processing control.

2. Contributions

In the current Special Issue of *Metals*, we host six contributions from academia and industry on their latest research developments and achievements in their applied research field. These elucidate on the effect of temperature during forming operations, e.g., in aluminum alloys closely analyzed via texture evaluation. Additionally, the opportunities that derive from microstructure and process simulation ensure that from the deeper understanding of the microstructure evolution, a further optimization of the alloys can be achieved, taking the capabilities of the forming equipment and the reduction schedules into consideration. Furthermore, trace elements and their effect in critical properties such as steel hot ductility performance or the role of non-metallic inclusions in the mechanical behavior of cold drawn pearlitic steel are also reviewed in this Special Issue.

Papadopoulou et al. [1] show how during forming, thickness reduction and thermal treatment affect the recrystallization and evolution of the crystallographic texture of Al5182, which in turn influences the mechanical properties. Thus, by controlling the texture via proper reduction sequences, targeted r-values, yield and tensile strength can be obtained to suit further forming of the material. Gavalas and Papaefthymiou [2] clearly show how flatness, an important quality characteristic of rolled products, is tricky to be controlled by a rolling mill operator and how a proper thermo-mechanical finite element model can be of significant assistance by identifying critical process parameters (e.g., strip temperature, cooling characteristics, roll core temperature and the evolution of the thermal camber). Baganis et al. [3] apply phase field simulation for the optimization of Al6XXX heat treatment in order to help understand how microstructure evolution during heat treatment, more specifically recrystallisation kinetics, grain growth and interface mobility, affects the mechanical properties of this Al-Mg-Si alloy family.

In their work, Guo et al. [4] show the important role of trace impurities such as phosphorus and rare earth cerium on the hot ductility in the performance of advanced SA508-4N RPV steel. The addition of P and Ce is able to facilitate the occurrence of the dynamic recrystallization (DR) of the steel, lowering the initial temperature of DR from ~900 to ~850 °C and thereby enhancing the hot ductility performance. Consequently, the combined addition of P and Ce can significantly improve the hot ductility of SA508-4N RPV steel, thereby improving its continuous casting performance and hot workability [4].

Toribio et al. [5] showed the importance of detailed metallographic and scanning electron microscope (SEM) microstructure analysis of microstructural defects exhibited by pearlitic steels in order to unveil how their evolution by cold drawing has consequences on the isotropic/anisotropic fracture behavior of different steels. Such defects caused by non-metallic inclusions have a very relevant role in the fracture behavior of cold drawn pearlitic steels [5]. Papadopoulou et al. [6] also present the importance of advanced microstructure analysis in understanding microstructure evolution and optimizing mechanical behavior. The effect of thermal processing on the initial microstructure, texture evolution and anisotropy, as shown by the example of Al3104 sheets, has a paramount effect on mechanical properties [6]. The texture characteristics, i.e., the preservation of an increased amount of S components, and the presence of strain-free elongated grains along with the coexistence of a complex and resistant-to-crack-propagation substructure consisting of both high-angle grain boundaries (HAGBs) and subgrain boundaries (SGBs) can lead to an optimal combination of Δr and r_m parameters [6].

These contributions underline the importance of synergetic experimental and simulation analyses for the optimization of modern materials using thermal processing steps, rolling mills, casting machines, etc., as tools for the development of proper microstructures suitable for advanced applications.

3. Conclusions

Today, for material optimization purposes amongst traditional physical metallurgical approaches and new characterization techniques, simulation studies on microstructure–properties relationships provide great benefits for the scientific and technical evaluation of existing alloys. The optimization and the development of new alloys can be performed based on the processing capabilities (thermal and forming operational needs).

Our constant aim is to bridge academia and industry, providing the required theoretical aspects for advanced applications in the industry under the prism of microstructure–properties–processing relationships incorporating simulation (both numerical and physical) that can serve the purpose of the optimization of new materials to be applied and/or concepts and novel aspects of current or new, to-be-adopted steel grades.

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