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Editorial

Heat Treatment of Metals

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1. Introduction and Scope

Microstructure design is a key issue in obtaining the target metal's properties. Hence, it is very important to put in evidence the relations existing between properties and microstructure features in alloys [1–10]. At the same time a key issue is to understand which are the different processes and or heat treatment able to modify them [11–20]. It is well known that the use of heat treatments is one of the most adopted solutions used to metals microstructure and thus obtain or tune the target properties. In particular, it is true for innovative high-performance alloys designed for frontiers applications as nuclear fusion reactors or ferromagnetic components as manufactured by additive manufacturing [21–25]. In fact, almost all metallic alloys respond to heat treatments.: their response is anyway strongly affected by microstructure hence resulting in different behaviors. The identification and development of processes and different analysis methods led to several possibilities for new research fields and practical applications. As an example, the development of additive manufacturing has promoted research efforts on the use of heat treatment methods for as-built alloys or for ultra-fast heat treatments having a strong industrial impact in terms of affordability and reliability. This Special Issue contains contributions on the effect of microstructure of innovative and/or traditional heat treatments on alloys. In addition, the application of quite different methodologies and investigation techniques is strongly desired as the possibility of combining information coming from different investigation methods will lead to different and complementary looks into the relation between properties and microstructure in the different considered alloys (e.g., the influence of the microstructure on mechanical and/or magnetic properties).

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2. An Overview of Published Articles

This special issue consists of the following five research papers:

Fortini, A.; Bertarelli, E.; Cassola, M.; Merlin, M. An Industrial-Scale Study of the Hardness and Microstructural Effects of Isothermal Heat Treatment Parameters on EN 100CrMo7 Bearing Steel. *Appl. Sci.*, 2024, 14, https://doi.org/10.3390/app14020737.

Merlin, M.; Morales, C.; Ferroni, M.; Fortinet, A.; Soffritti, C. Influence of Heat Treatment Parameters on the Microstructure of 17-4 PH Single Tracks Fabricated by Direct Energy Deposition. *Appl. Sci.*, 2024, 14, 700, https://doi.org/10.3390/app14020700.

Gaggiotti, M.; Albini, L.; Stornelli, G.; Tiracorrendo, G.; Landi, L.; Di Schino, A. Ultra-Fast Heating Treatment Effect on Microstructure, Mechanical Properties and Magnetic Characteristics of Non-Oriented Grain Electrical Steels. *Appl. Sci.*, 2023, 13, 9833, https://doi.org/10.3390/app13179833.

Dudko, V.; Yuzbekova, D.; Kaynishev, R. Strengthening Mechanisms in a Medium-Carbon Steel Subjected to Thermo-Mechanical Processing. *Appl. Sci.*, 2023, 13, 9614, https://doi.org/10.3390/app13179614.

Rogowski, M.; Fabrykiewicz, M.; Szymański, P.; Andrzejczyk, R.; The In-House Method of Manufacturing a Low-Cost Heat Pipe with Specified Thermophysical Properties and Geometry. *Appl. Sci.*, 2023, 13, 8415, https://doi.org/10.3390/app13148415.

Fortini et al. (Contribution n.1) report about the 100CrMo7. This material is usually adopted for bearings in rotating machinery and therefore its production route calls for specific and will identify heat treatment parameters in order to guarantee the best achievable mechanical properties as obtained by microstructure optimization. The standard heat treatment adopted for this class of materials consist in an austenitization step, followed by quenching in a salt bath. The paper reported in this special issue shows a comparison between two different routes (based on martempering and austempering) finalized to reach hardness and microstructure desired targets on EN 100CrMo7 large-size rings. The paper focused on the effects of temperature and holding time on microstructure. In addition, the effect of the tempering stage in retained austenite content modification is investigated in detail. Based on the achieved results the most promising hardness values are achieved by martempering. On the other hand, austempered materials showed an hardness loss especially in the middle of the rings. The conducted experiments put in evidence that the cooling rate is a key parameter and that its role is prevalent with respect to holding time. Such industrial-scale analysis, which was carried out on real scale components allowed to reach a specific knowledge about how to manage heat treatment parameters so to respond to the nominal guidelines provided by steel suppliers. These outcomes offer clear insights able to optimize industrial heat treatment parameters, with strong implications regarding steel bearings' products.

Merlin et al. (Contribution n.2) focuses on post-fabrication heat treatment (PFHT) as a tool aimed to target microstructure and mechanical properties of components produced by additive manufacturing. They report that in 17-4 PH martensitic stainless steel PFHT promotes the formation of precipitates rich in cupper and of niobium particles. Authors describe how PFHTs act on the properties of 17-4 PH components manufactured by direct energy deposition method. The effect of aging temperatures and times is reported together with that of direct aging strategy. Optical microscopy, X-ray diffractometry, and transmission electron microscopy were adopted to put in evidence the effect of PFHTs on microstructural evolution. In addition, mechanical behavior was analyzed by means of Vickers microhardness indentations.

Gaggiotti et al. (Contribution n.3) describe the effect of rapid annealing on microstructure, mechanical properties, and magnetic properties of Non-Grain Oriented Electrical Steel (NGO). The Ultra-Fast Heating (UFH) tests were conducted by a transversal induction heater on 0.5 mm NGO cold rolled silicon steels specimens. The effect of both heating power and the strip speed is considered. The comparison between a typical microstructure as achieved by traditional processing route and the one achieved by ultra-fast heating process shows that UFH process leads to a a well detectable grain size refinement. The results appear to be quite promising for NGO scientific and technical community: in particular, they out in evidence the opportunity given by UFH application to NGO steels in order to face tensile properties comparable to those as achieved by the heating rates typical of conventional process.

Dudko et al. (Contribution n.4) in their paper analyze the effect of heat treatment on the strengthening mechanisms vanadium and niobium micro-alloyed high resistance steel. The show that in the case of tempered material the main contribution is given by dislocation effect; on the contrary, in the case of tempformed material the effect of precipitates dispersion is the main factor affecting yield strength.

Rogowski et al. (Contribution n.5) focuses on the in-house method of manufacturing a low-cost heat pipe with specified thermophysical properties and geometry. Their paper presents a clear description of manufacturing and testing method of pipes with specific properties and geometry. The heat pipes presented in their paper were fully manufactured with the use of basic workshop tools, without the use of specialized and automated CNC machines. Utensils used during the process were either made by hand or using desktop FDM 3D printers. During the evaluation of heat pipes' performance within PCM (coconut oil), simple statistical functions were used. One-dimensional and two-dimensional histograms were used to visualize data obtained during this research. The presented method allows the manufacturing of heat pipes that are, on average, able to melt about 35% more PCM than an empty copper pipe with the exact same geometry. The HPs' performance in coconut oil was evaluated on the basis of their future applications.

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