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Editorial

Special Issue on "Modeling, Optimization and Design Method of Metal Manufacturing Processes"

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Metal manufacturing processes are essential techniques to convert raw materials into desired metal products, which contributes significantly to the growth of industry and our society. In recent years, there has been a rapid increase in the demand for accurate modeling, proper optimization, and design methods prior to manufacturing processes, in order to achieve the sustainable, high-efficient, and low-cost production of metal products. The purposes of this Special Issue on "Modeling, Optimization and Design Method of Metal Manufacturing Processes" are to investigate and discuss the fundamental aspect of some metal manufacturing processes, as well as to highlight advancements in their development and applications. This Special Issue is available online at: https://www.mdpi.com/journal/processes/special_issues/metal_manufacturing_processes.

Machine learning algorithm in manufacturing metal products

In the production of large amounts of metal products, the industry is continuously seeking to improve the manufacturing efficiency and reduce energy consumption. As many manufacturing actions are selected based on operator experience, providing operators with sufficient technical support is recognized as one of the effective strategies for enhancing production efficiency. Recently, an application of machine learning algorithms in the manufacturing process obviously facilitated the working efficiency of the operators.

The paper by Andreiana et al. [1] introduces a reinforcement learning (RL) algorithm (concretely Q-Learning) as the core of a decision support system (DSS) in the steel manufacturing process of the Composition Adjustment by Sealed Argon Bubbling with Oxygen Blowing (CAS–OB), which provides significant benefits to operators in taking proper and correct decisions during manufacturing processes, especially for those who are less experienced. The proposed algorithm successfully learns the process using raw data from the historical database and recommends the same operation as those taken by the operator 69.23% of the time. Furthermore, incorporating the operator's experience into the DSS knowledge could facilitate the integration of operators with limited experience.

The paper by Chen et al. [2] presents a soft sensor modeling method called a just-in-time learning-based triple-weighted regularized extreme-learning machine (JITL-TWRELM) to measure the real-time liquid aluminum temperature in the manufacturing of aluminum on the regenerative aluminum smelting furnace. To address the process time-varying problem, a weighted JITL method (WJITL) is used to update the online local models, and a regularized extreme-learning machine model—with respect to sample similarities and variable correlations—is established as the local modeling method. The proposed models show satisfactory prediction accuracy in the manufacturing of aluminum.

Fabrication and mechanical property optimization of metals

The additive manufacturing of metal or alloys has attracted great attention in recent years. Selective laser melting (SLM) is a common additive manufacturing technology that has been widely used to fabricate some complex metal structures. The paper by Ran et al. [3] compares the mechanical properties of a metallic 3D auxetic structure produced by the SLM and micro-assembled (MA) methods, and investigates the influences of size effect on the deformation mechanism of C5131 bronze 3D auxetic structures with a negative Poisson's ratio, using both FEM simulations and experiment verification. This paper provides helpful instructions for establishing an accurate constitutive model for predicting the evolution of the mechanical behaviors of a 3D auxetic structure.

To expand the applications of metals, it is necessary to conduct optimization on their mechanical properties, which could be achieved by modifying their microstructures—particularly, grain size and phase composition. Reducing the grain size or modifying the phase composition are important approaches to achieve the superior mechanical strength of the metals. The paper by Wang et al. [4] introduces a method of element alloying to modify the microstructures of materials for obtaining high mechanical properties. The authors investigate the effects of Ca addition on the morphological modification of Al–Fe–Si alloys. Their results show that optimization of the amount of Ca addition (0.01–0.1 wt.%) is capable of refining α-AlFeSi and β-AlFeSi morphologies and transforming the β-AlFeSi phase into α-AlFeSi phase, thereby enhancing the mechanical performances of the alloys.

The review paper summarized by Cui et al. [5] provides state-of-the-art information regarding the effects of equal-channel angular-pressing (ECAP) processing parameters, such as passes, temperature and routes, on the microstructural evolution of metallic materials. Based on existing studies, the various parameters required to achieve submicron and nanoscale grain sizes as well as different phases are analyzed, providing practical guidance for optimizing the processing parameters during the ECAP of different metallic materials. A large strain rate and dynamic recrystallization are supposed to be the main mechanisms of grain refinement. The plastic deformation mechanism of the ECAP process is also discussed from the perspectives of dislocation slipping and twinning behavior. Additionally, some challenges and perspectives of the ECAP are presented at the end of this paper in an effort to enhance the ECAP manufacturing process.

Numerical simulation and experiments in the machining of metals

Mechanical machining is one of the primary techniques to manufacture metal components, especially to obtain the desired final parts with high precision and form accuracy, and it mainly includes milling, turning, drilling and grinding. The finite element method (FEM) has been widely used in the numerical simulation of the machining processes for parameter optimization and cost savings. The paper by Tagiuri et al. [6] uses the FEM-based DEFORM-2D software to simulate the machining performance in the orthogonal milling of AISI 1045 steel, and the authors study interactions between chamfer width, chamfer angle, sharp angle, cutting speed and feed rate. More specifically, the simulation results are statistically analyzed to determine significant parameters using the analysis of variance (ANOVA) test, indicating that both chamfer and sharp tools, feed rate, cutting speed, and their interactions are the most important parameters that influence machining temperature and stress.

To achieve highly efficient and low-cost machining, it is essential to reduce tool wear by optimizing the structure of cutting tools. The paper by Yin et al. [7] experimentally investigates the edge structure of polycrystalline cubic boron nitride (PCBN) tools and cutting parameters on machining performance in the dry turning of grey cast irons, and the results indicate that a minimum surface roughness could be obtained with a feed rate of 0.15 mm/r that exceeds the tool chamfer width in the turning process. The paper also analyzes the PCBN tool wear mechanism, revealing that the micro notches on the rake face and micro-chipping on the tool chamfer are the main tool wear modes. Another paper by Kwok et al. [8] introduces diamond protection films by hot-filament chemical vapor deposition (HFCVD) on the drilling tool for drilling high-frequency printed circuit boards (PCBs). The paper demonstrates that the tool wear with nanocrystalline protection films is almost 90% less than microcrystalline diamond-coated tools, resulting in a significant increase in tool life. In addition, their findings emphasize the significance of HFCVD parameters for coated drills that process high-frequency PCBs, thereby contributing to the highly efficient production of PCBs for industrial applications.

Aside from cutting parameters, the machining performance of metals can also be improved by modifying the microstructures of the materials, especially for microscale machining. The paper by Jing et al. [9] experimentally investigates the effects of grain size on the surface integrity, cutting forces and chip formation in the micro-turning of oxygen-free high-conductivity (OFHC) copper. By comparing the feed rates and material microstructures, it is found that a smooth surface and small width of the flake structure can be achieved when the feed rates are equivalent to the grain sizes.

The review paper by Huo et al. [10] summarizes the mechanical machining performance and applications of Fe-based amorphous alloys, which are known as difficult-to-machine materials due to their extreme hardness and severe chemical tool wear. The review also compares various assisted machining approaches, including tool-assisted machining, low-temperature lubrication-assisted machining and magnetic field-assisted machining, for improving the machining performance of Fe-based amorphous alloys. In the future, it is anticipated that difficult-to-machine amorphous alloys will be machined using a combination of the above assisted machining methods. This paper provides useful and practical instructions for the optimization and design of metal machining processes.

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