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EDITORIAL

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Enhanced Heat Transfer Technology Based on Emission Reduction and Carbon Reduction in Cutting and Grinding

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Huge carbon emissions in machining process, which characterized by high energy consumption and usage of non-renewable resources, is becoming an obsession in the past decades. In the face of the international strategy of carbon peak, it is imperative to eliminate the usage of mineral cutting fluids and reduce energy consumption and carbon emissions by green cutting/grinding technologies, such as dry cutting, minimum quantity lubrication (MQL). However, higher heat output and temperature rise is caused in cutting zone, which leads to serious tool wear and deterioration of workpiece surface quality. To enhance the heat transfer performance and reduce carbon emission and energy consumption in the manufacturing process simultaneously, the exploration of enhanced heat transfer technology based on emission reduction and carbon reduction in cutting and grinding is a research hotspot at present. This Special Issue report on the above advanced technologies and research progress, including tool design and preparation, green lubricant preparation, multi-energy field assistance technologies, and processing mechanisms for difficult-to-cutting materials.

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From tool design and preparation aspect, the problems of insufficient cooling, lubrication capacity and high grinding temperature are trying to be solved. Ding's group [1] researched the grindability of titanium alloys using molybdenum disulfide (MoS_2) solid lubricant coated brazed cubic boron carbide (CBN) grinding wheel (MoS_2-coated CBN wheel). The lubrication mechanism of MoS_2 in the grinding process is analyzed, and the MoS_2-coated CBN wheel is prepared. This paper confirmed the advancement of MoS_2-coated CBN wheel from aspects of grinding force, grinding temperature, wheel wear and surface quality. This research provides high-quality and efficient technical support for titanium alloy grinding. In addition, the poor infiltration performance of lubricants leads to a sharp increase in force and heat in the grinding zone, due to the extremely complex distribution of the micro-channels between workpiece and grinding wheel. This problem could be solved by the slotted wheel with orderly arrangement of abrasives. Mao's group [2] established a theoretical model of grinding force with the orderly-micro-groove wheel for grinding hardening AISI 52100, taking into account the actual morphology of the wheel. The random thickness of undeformed chips which is expressed by a probabilistic expression clearly reflects the microstructure characteristics of the structural wheel. This research provides the theoretical support and new abrasives for reducing friction and improving heat transfer efficiency of lubricants in grinding process.

From the green lubricant preparation aspect, the vegetable oil-based nano-lubricants was proposed with higher heat transfer and tribological properties, which was verified to show improved performance and in MQL compared to traditional mineral oil-based cutting fluids. Li's group [3] comprehensively reviewed the mechanisms and application of vegetable oil-based nano-lubricants in machining. The effects of physical characteristics of vegetable oil on cooling and lubricating properties was discussed, by considering autoxidation and high-temperature oxidation from the molecular structure aspect, chemical modification and antioxidant additives of nano-lubricants, as well as extreme pressure performance of extreme pressure additives and nanoparticle additives. This paper also discusses the future prospects of vegetable oil for chemical modification and nanoparticle addition. In their another study [4], they researched the tribological performance of different concentrations of Al_2O_3 nano-lubricant on MQL milling. The intercoupling mechanisms of Al_2O_3 nanoparticles and cottonseed base oil was revealed and the optimal Al_2O_3 nanofluid concentration was obtained. They also explored the formation mechanism of physical adsorption film and tribological mechanism of graphene-ionic liquid nano-lubricant on grinding interface under MQL, by molecular dynamics simulation [5]. The combined action of physical adsorption film and chemical reaction film make graphene/IL nanofluids obtain excellent grinding performance.

From the multi-energy field assistance technologies aspect, high voltage electrostatic field and ultrasonic assistance are used to improve heat transfer performance and machining performance. To reduce the usage amount of lubricant, the lubricant is atomized to improve the specific surface area and jetted into cutting zone with help of high-pressure gas in MQL. However, the poor atomization performance of MQL limits the heat transfer performance of lubricants. Nanofluid composite electrostatic spraying (NCES) utilizes a high-voltage electrostatic field to control the droplet size and distribution after atomization. Liu's group [6] compared and evaluated the lubrication and processing properties of different lubricants NCES through friction and milling tests with different flow ratios of external and internal fluids. Compared with nanofluid MQL and electrostatic atomization (EA), NCES can more comprehensively improve the performance of MQL. This study provides theoretical and technical support for the selection of NCES external base fluid. In terms of the low polishing efficiency of the soft grinding material flow (SAF) method and its non-compliance with the concept of carbon reduction in industrial production, Tan's group [7] proposed a two-phase fluid multi-physicals modeling method for ultrasonic-assisted SAF. The cavitation effect in constrained flow channel can be reduced by the ultrasonic vibration, improving the turbulence intensity and uniformity of abrasive flow. The results indicate that ultrasonic assisted SAF method can improve processing efficiency and uniformity, achieving the goal of reducing carbon emissions. The relevant results can provide helpful references for the SAF method.

From the processing mechanisms of difficult-to-cutting materials aspect, the wear and surface damage of grinding wheels under strong thermal coupling are technical bottlenecks. Exploring the mechanical behavior of material removal and the mechanism of surface damage generation is the theoretical basis for achieving high-precision, high-efficiency, that is low energy consumption, and low-carbon grinding. Tang's group [8] conducted single- and double-varied-load nano scratch tests on single crystal 4H-SiC using the Berkovich nanoindentation system and analyzing the mechanisms of material removal and crack propagation. The lower loading rates increased the ductile region and critical depth of transition. This study provides an important reference for ensuring the high accuracy and long service life of single-crystal SiC.

From the papers published in this Special Issue, we hope they could provide new ideas and methods for researchers to enhance heat transfer technology based on emission reduction and carbon reduction. We also hope they will promote the continuous research on green manufacturing theory, tools, lubricant, clean cutting equipment and key functional components, and finally realize the application of green manufacturing technology in aerospace and other fields.

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Authors' Contributions
All authors read and approved the final manuscript.

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Declarations

Competing Interests
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