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Extended Abstract

Experimental investigation of porous metal materials in high-speed micro-milling process

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Abstract

Porous stainless steels, which have recently extended to the microscale domain, have been widely used for biomedical materials because they have good strength-to-weight ratio and superior corrosion resistance. Most components fabricated from porous materials still require secondary machining despite being produced in near-net shapes. However, they have poor machinability. High cutting force, high cutting temperature, poor surface integrity, and severe tool wear are encountered in the machining process of the difficult-to-cut porous materials. This article focuses on the micro-cutting performances and effects of cutting parameters in the micro-milling of porous stainless steel materials, including tool wear patterns and mechanism, effects of tool wear and cutting parameters on surface topography, cutting force, and cutting temperature. Comparative experiments were performed to investigate surface burr and cutting performances of porous materials in the micro-milling process. The effects of machining parameters on porous stainless steels in micromilling are studied. Furthermore, a preliminary relationship of cutting parameters with micro-milling force and milling temperature is also established. The tool wear patterns and mechanisms were observed. Based on the findings, this article concluded that tool wear influences the surface morphology of the machined part and the effects of structural porosity on the cutting process during the micromachining of porous materials. Porous metal materials have been widely used in aerospace, mechanical engineering, chemical engineering, environmental protection engineering, and biomedical engineering with the development of new materials. The mechanical properties of porous metal materials are influenced by microstructure characteristics. Porous materials can properly control pore diameter, direction, and distribution with their improvement and breakthrough in the manufacturing technology. However, the internal structure of porous materials is far more complex than this to meet the requirements in terms of pore size, porosity level, and material components. The whole connection with the external environment can be divided into three types: open hole, semiopen hole, and closed hole. However, the whole connection needs to be simplified or to take equivalent treatments in many cases of research because of the diversity and complexity of porous metal materials. The complex and irregular microstructure can be simplified to the regular and uniform model for analysis using the principle of homogenization. The cross-sectional shapes of the holes include triangle, square, hexagon, circle, and ellipse shapes. The surface microstructure of porous stainless steel materials. The internal microstructure of porous materials, including pore shape, pore diameter, and distribution rule, directly affects mechanical characteristics and machinability. Several studies have been conducted on the machining mechanisms of the microstructure of porous materials. The complex microstructure of materials has great influence on machining quality and surface integrity. When macro machining porous materials, cutter wear was studied by Artamonov and Kononenko found that the effect of structural porosity on cutting forces experienced during micromachining is significant. Popov focused on finding the relationship between micro-milling performances and material microstructure effects. Furthermore, the non-conventional machining of porous materials was investigated to overcome difficulties in the conventional machining process. Titanium, ferrous alloys, and ceramic are used as the predominant porous materials in bone engineering and have received significant research attention. Jasperson et al.13 compared micro-pin-fin and micromachining considering thermal–hydraulic performance and manufacturability. Shen and Brinson14 studied the finite element modeling of porous titanium. Microstructure-level machining modeling of ferrous alloys was investigated by Chuzhoy.15 Abolghasemi Fakhri et al. used an image based methodology to establish correlations between porosity and cutting force in micro-milling of porous titanium foams. Sharma et al. presented an experimental work on wire electrical discharge machining process which identifies the influence of process parameters that affect the cutting rate, dimensional shift, and surface roughness while machining of porous nickel–titanium (Ni40Ti60) alloy. Porous stainless steel is also widely used in biomedical applications because of its excellent performance of strength and creep resistance.18–20 the super mechanical properties are considered as a double-edged sword because porous stainless steels have poor machinability. Dewidar and Khalil20 studied the processing and mechanical properties of porous 316L stainless steels for biomedical applications. However, the machinability and machining process of the porous stainless steel material have not been fully investigated, especially in the micro-cutting process.

Keywords: Porous material, micro-milling, cutting parameters.

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