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Research status of machining of silicon-aluminum carbide matrix composites

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Abstract

SiCp/Al matrix composites have excellent mechanical properties. In this paper, the processing research status of SiCp/Al matrix composites is reviewed, and the machining, grinding, and finite element simulation machining of SiCp/Al are analyzed. Research status. The problems existing in the processing and development of SiC-Al matrix composites are pointed out, and corresponding suggestions are put forward.

Keywords

Silicon-aluminum carbide matrix composites, machining, grinding, finite element.

1. Introduction

Composite material is a kind of material with special properties formed by artificial compounding of two or more materials with different physical and chemical properties, controlling appropriate processes, and realizing the complementarity of material properties [1]. The SiCp/Al composite material is made of aluminum as the matrix and ceramic as the reinforcing phase, and is made by pressure casting and powder metallurgy. Aluminum has the advantages of low melting point, mature processing technology, and low cost [2-3]. SiCp/Al composites have a series of excellent physical and mechanical properties such as low density, high strength, and high thermal conductivity [4-5]. They have important application value and have application prospects in the fields of aerospace, military manufacturing and transportation. Very broad [6-7]

Although the SiCp/Al composite material has the high strength and high hardness of SiC particles, it also weakens the toughness and plasticity of the aluminum matrix due to the existence of SiC. , making it a difficult-to-machine material. Therefore, the processing mechanism of SiCp/Al composite material is analyzed, and the tools and processing parameters suitable for processing SiCp/Al composite material are obtained, so that a good machined surface can be obtained. The wide application of materials in the industrial field is of great significance.

2. Research status of composite material processing

2.1. Research status of composite cutting machining

At present, cutting is a wide range of processing methods. Gatto [8] cut SiCp/Al (Vf=20%) composite materials and found that some SiC particles play a certain cutting role after work hardening, and remove the aluminum matrix together with the tool. Ge Yingfei et al. discussed the effect of the volume fraction and size of SiC particles on the surface morphology [9], and found that the cutting surface quality formed when the SiC particles were mostly removed by particle cutting was better. Duan Chunzheng et al. designed a new type of spring rapid knife drop device to analyze the influence of SiC particles on the chip formation process of composite materials. It was found that the greater the acceleration of the knife drop, the more effective the root of the chip obtained. The crack makes the chip force unbalanced, resulting in the chip It has an irregular zigzag shape [10]. Xu Lina designed two diamond oriented milling cutters to process SiCp/Al composite materials, and found that the surface quality of the two cutters was better than that of ordinary cutters[11]. Shoba[12] carried out cutting research on different low volume fraction SiCp/Al composites (with SiC content below 8%). They found that the greater the dislocation density between the matrix and the reinforcement phase, the greater the cutting force Tang Lingyan used cemented carbide-coated tools to process SiCp/Al composites, analyzed the influence of machining parameters on surface quality, and found that the main factors affecting edge defects were cutting speed and feed [13]. Zheng Wei used ultrasonic vibration to grind SiCp/Al composites to study the effect of process parameters on surface quality, and found that surface fractal dimension was negatively correlated with surface roughness [14]. Yadava et al. [15] found that cutting speed had the highest influence on tool wear rate when machining SiCp/Al composites. Deng et al. [16] used a milling force modeling method based on cutting thickness to process SiCp/Al composites with a ball-end milling cutter, and analyzed the milling force. - Milling force model of tool friction [17].

2.2. Research status of composite grinding processing

Due to the severe tool wear and the difficulty in obtaining good surface processing quality in cutting, as the status of grinding technology in traditional processing methods is getting higher and higher, more and more scholars have begun to pay attention to the research of grinding mechanism.

Du Jinguang used milling to process 45% SiCp/Al composite materials, and established the interaction model between particles and abrasive particles. It was found that in the process of material removal, the wear debris produced different forms under different processing parameters, including curved wear debris. , globular wear debris, flake wear debris, block wear debris, etc. [18]. Zhao Lei processed SiCp/Al composites through grinding wheel grinding, and studied the relationship between grinding force and volume fraction, grinding depth, and workpiece feed rate [19]. N.S.Hu et al. studied the effect of fiber angle on surface roughness, and found that the best surface roughness is 90° carbon fiber layup, and the surface roughness between 120°-180° is poor [20]. Thiagarajan et al. used cylindrical grinding to study the effects of cylindrical grinding parameters and SiC particle volume fraction on grinding force and surface roughness, and found that grinding force and surface roughness were positively correlated with grinding depth and feed rate. There is a negative correlation with the grinding wheel speed [21].

2.3. Current status of finite element simulation research on composite materials

With the rapid development of science and technology, finite element method is widely used in industrial processing because of its efficient, fast, and low-cost analysis of the processing mechanism of materials. In recent years, finite element simulation technology has been used to analyze the processing mechanism of composite materials many times at home and abroad. TengXiangyu et al. used finite element simulation to establish a two-dimensional cutting model. , found that materials containing nano-sized particles are more likely to generate continuous chips, while micro-sized particles are more prone to fracture and more likely to form discontinuous chips [22].ZhangJie et al. [23] created a three-dimensional microstructure model and an average model of SiCp/Al composites with a SiC content of 7%. The model simulates the elastoplastic deformation process of the material in the cutting state, as well as the crack generation and propagation process, and obtains the stress-strain curve and fracture shape. Liu Junwei [24] used ABAQUS software to establish a single-particle micro-milling model, and analyzed the influence of process parameters on the milling force. The study showed that the milling force increased with the increase of the milling depth and feed, among which the highest correlation with the milling force. The variable is the milling depth. Liuqing[25] used the cohesion zone model to study the stress-strain distribution between adjacent particles, and the analysis concluded that the stress-strain distribution in the composite material is mainly affected by the angle between the tensile direction and the centerline of the particle. The stress-strain distribution in the matrix has the greatest influence, and the model with an angle of 45° has the least influence on the stress-strain distribution in the matrix. Fathipour et al. [26] established a two-dimensional SiCp/Al composite simulation model and found that sawtooth chips were generated at different cutting speeds, and the size of the saw teeth was positively correlated with the cutting speed and feed.

Wu Yongxiang [27] established a two-dimensional cutting simulation model. As shown in Figure 1, the interface layer was considered to be the expansion of SiC particles, and the tie constraint method was used to establish and simulate the exfoliation state of SiC particles. main failure mode.

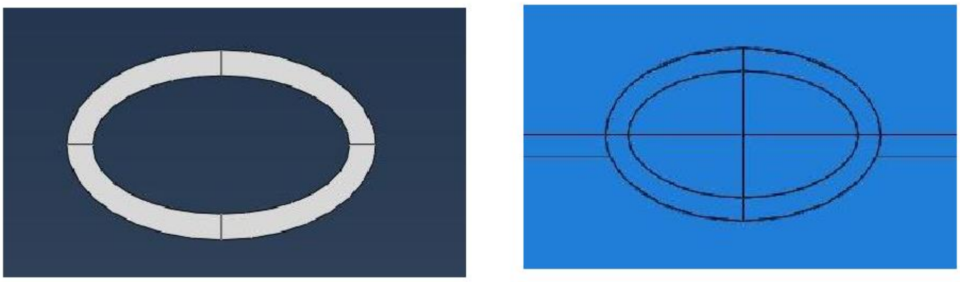

Fig. 1 geometric model of interface layer[27]

Wang Beibei et al. [28] studied SiCp/Al composites with different volume fractions by means of experiments and simulations, and analyzed that materials with more SiC content have more particle interactions when they are cut, resulting in greater cutting force and cutting value. The larger the fluctuation, the larger the strain value. YJ Nithiya Sandhiya [29] carried out two-dimensional finite element analysis and simulation of the orthogonal turning process of A356/SiCp composites. The effects of different relative positions, different sizes, and different shapes of SiC particles on chip formation and stress distribution were studied, and it was found that when the tool interacts with the particles at the bottom, regardless of particle size, it will debond and eventually break. Among them, the stress of circular particles is the largest, followed by hexagonal particles, and the stress of irregular particles is the smallest. Zhou Li from Shenyang University of Science and Technology [30-31] established a two-dimensional simulation model of random distribution of SiC particles (Fig. 2) to study the size of edge defects, and found that the depth of cut had a greater impact on the size of the edge than the cutting speed.

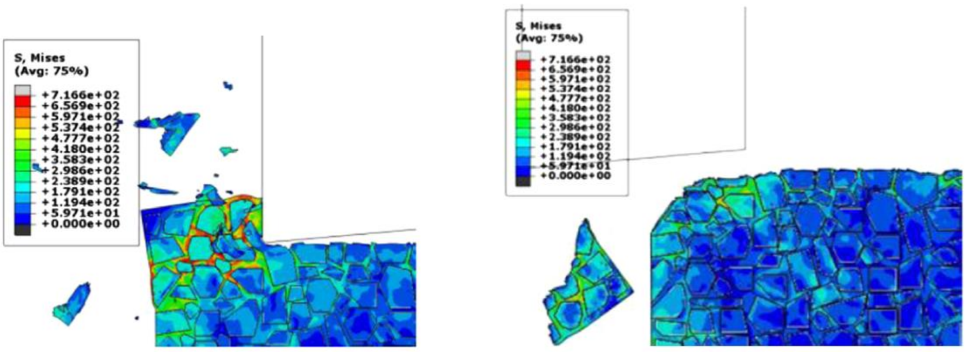

Fig. 2 Simulation results of edge defects [30]

3. Deficiencies and suggestions

Scholars at home and abroad have carried out in-depth research on the processing of SiCp/A1 composites, but most of them are composites with low volume fraction (Vf<45%), and for high volume fraction (Vf≥45%) composite materials are processed. There is less research; and the processing methods adopted by the researchers mainly focus on cutting processing, and there are few grinding experiments, and the research content of grinding experiments is mainly limited to grinding force, grinding temperature and surface roughness. The research on the removal mechanism of the material is relatively lacking. In the above research status, domestic and foreign scholars have used finite element simulation method to analyze the cutting (grinding) force, chip formation and surface roughness during the cutting/grinding process of composite materials. However, most scholars establish a two-dimensional simulation model to simulate the processing process, ignoring the modeling of the interface between the SiC particles and the Al matrix, and setting the SiC particles as elastic materials and evenly distributed, which deviates from the actual situation, so it can be established with the workpiece. A three-dimensional simulation model consistent with the actual situation is used to establish a two-phase interface layer, so as to explore the removal of SiC particles in the composite material, and the formation mechanism of the surface quality, etc.and to have a deeper understanding of the removal mechanism of the composite material.

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