Chapter 3
Machining Mechanism of Minimum Quantity Lubrication Grinding

ABSTRACT

To facilitate the analysis of experimental theory, this chapter studied the machining mechanism related to the grinding of NMQL and the three mechanisms of sliding, ploughing, and cutting of the abrasive grinding process. A mathematical model of the micro-grinding force was established, and the micro-grinding force can be used to express the force of the grinding zone. The grinding force component was divided into the force of cutting and sliding, removing the constant cutting force during the grinding process, retaining the varying sliding friction force, and determining the sliding friction coefficient to characterize the lubrication performance. It reflected the influence of different lubrication conditions on the friction part. The methods for measuring the temperature during grinding were introduced, including direct contact temperature measurement and non-contact temperature measurement. At present, thermocouple temperature measurement is a commonly used and more accurate temperature measurement method, and the characteristics of each temperature measurement method were analyzed.

3.1 INTRODUCTION

Grinding machining method, which is of extremely strong technological adaptability, can realize machining of all kinds of material like metal, ceramics, glass, stone material, fireproofing material, concrete, skeleton and composite material, and many difficult-to-machine materials can only be machined through grinding; it can realize all kinds of precision machining like hogging machining, rough machining, precision machining and ultraprecision machining for plane, cylindrical surface, spherical surface, involute tooth, spiral surface and free-form surface. Grinding machining tool, which is a tool with most categories, has been extensively applied to multiple industries like mechanical manufacturing, light industry, building and fireproofing materials, and the number of already known categories has exceeded 3,000. Grinding machining is an important machining method supporting various industries in national economy.

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As abrasive grain and chip are very fine with small grinding force and numerous abrasive grains participate in grinding, grinding machining can easily obtain a surface with high precision and low roughness and it is the main precision machining means. Especially very fine abrasive grains can be used to obtain nanoscale cutting edge radius so as to realize extremely fine cutting and acquire zero-defect surface with machining precision of 0.1μm and surface roughness of $R_a \approx 0.025 \sim 0.008μm$. Therefore, it is the main ultraprecision machining means and has been importantly applied to high-tech fields like modern aerospace, precision machinery and instruments, electronic information, sophisticated weapons and small-scale and micro-machines, etc.

For ordinary materials, grinding machining may be intensely competed by milling, reaming and turning methods (Li et al., 2015; Nieslony et al., 2018). However, for a new generation of materials like ceramics, metallic ceramic composite materials, whisker-reinforcing materials and high-temperature superalloy, hard cutting is never the opponent of grinding machining. For instance, grinding is the only method of machining superalloy workpiece used in jet aircraft engines and also the only method of machining automobile and optical elements made of semiconductor silicon, ceramics and glass.

Grinding machine is habitually regarded as a kind of precision machining method which can acquire bright and clean part surface and accurate tolerance. Indeed, no other methods can compete with grinding machining, but grinding machining is never restricted to this application. Actually, many abrasive materials are exhausted in heavy-load grinding. Grinding machining pursues effectively and rapidly removing materials without consideration of surface quality. Grinding machining can use grinding wheel saw web with 20μm thickness like paper for precision cutting of microelectronic circuit silicon wafers and can clear away billet steel under heavy-load condition at 220kW machine power and 1600cm³/min removal rate in the casting factory or steel plant.

Another competitive actual application field of grinding machining is machining of ultrahard or crisp materials which can't be effectively machined. In the production of quenched steel parts like cutting tool and bearing ring, grinding machining can easily complete machining of annealed steel or quenched steel, but other methods are restricted. Machining of nonmetallic brittle materials like ceramics, hard alloy and glass can only be completed through grinding machining.

Even though grinding machining is very important in the industry, it has not received deserved attention. Removal of material of the same volume through precision machining is of higher cost than other machining methods, so it is applied as this is unavoidable. Of course, as material removal margin is continuously reduced due to near-net shape precision casting and forging technologies, grinding machining will become more economical as the direct forming method not needing turning and milling.

Among commonly used machining methods, grinding machining is least known and most neglected without any doubt, because grinding machining process is too complicated to figure out. As quantity of cutting edges is large, geometric shape is irregular, grinding velocity is high and grinding depth of each abrasive grain is small and nonidentical, any intention to analyze grinding mechanism is hopeless, and grinding spark flow sprayed from grinding wheel nozzle has added to air of mystery among people.

Grinding machining can acquire high part machining quality and surface precision, so it has been widely applied to machining process. Compared with other cutting methods, grinding force is large and grinding velocity is high. Therefore, its specific grinding energy is greater than other cutting modes by multiple times, a large quantity of heat is generated in the grinding area, and moreover, grinding process can be completed within a very short time, it’s difficult for heat to be diffused out, so heat is aggregated in the grinding area in quantity. These heat quantities seriously restrict workpiece surface machining performance, machining precision and efficiency (Li et al., 2016). In addition, both micromorphology