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硕 士 学 位 论 文

硬质合金材料磨削机理的仿真与实验研究

Simulation and Experimental Research on Grinding Mechanism of Cemented Carbide

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摘 要

磨削加工技术是先进制造技术中的重要领域，是现代机械制造业中实现精密加工、超精密加工最有效、应用最广的加工工艺技术。磨削过程是一个典型的复杂力学过程，其中包括高度非线性热力耦合等技术难题，理论研究困难。随着计算机和数值计算技术的发展，借助有限元法来模拟、研究金属切削过程得以实现和发展。有限元仿真技术在磨削中的应用主要是分析研究磨削加工过程中的物理现象，并将这一系列磨削过程通过计算机模拟出来。根据有限元解析的结果，还可将磨削加工过程的应力、应变、温度、应变速率等物理量的变化实现可视化。本文基于有限元分析方法，建立单颗磨粒和虚拟砂轮的有限元模型，并对磨削力、磨削温度、磨损及应力进行了有限元仿真。

论文主要包括以下几个方面的内容：

1. 建立了单颗磨粒磨削仿真的有限元模型，包括磨粒的几何模型，材料的本构模型，磨粒与工件的网格划分等。通过单颗磨粒磨削的有限元仿真，研究了磨粒粒度及磨削参数对磨削力、磨削温度和磨粒磨损的影响。

2. 提出了一种虚拟砂轮的建摸方法，为了防止磨粒的重叠，采用了虚拟格子的方法。利用 VHX-600E 型超景深显微镜测量了砂轮表面的磨粒密度，为了便于虚拟砂轮的建模，将磨粒简化为六面体。采用该虚拟砂轮，建立了有限元仿真模型，分析了工件表面的残余应力分布和工件的变形情况。

3. 基于多颗磨粒磨削研究和砂轮表面磨粒分布情况，进行了磨削力预测。根据接触弧长、磨削宽度、接触面积和磨粒密度，计算总的磨粒数和有效磨粒数；将多颗粒磨削的磨削力结果集成，预测磨削力。

4. 设计了正交磨削和单因素磨削实验方案，在可转位刀片周边磨床（2MZK7150）上进行了初步的工程实验研究。得出了冷却液和磨削参数对磨削力的影响规律。将实验磨削力与预测磨削力进行对比分析，误差结果表明，仿真与实验结果是一致的。

关键词：有限元仿真；硬质合金；端面磨削；磨削力；磨削温度

Abstract

The grinding technology is one of the most important technologies in the advanced manufacturing fields, and it is as well the most effective and widely used basic technology in the precision machining and the ultra-precision machining fields in the modern mechanical manufacturing. The grinding process is a typical complex mechanical problem, which includes high nonlinearity and thermo-mechanical problems, because of this, there are many problems which are difficult to be explained in theory. With the development of computer and numerical calculation technology, using FEM to simulate the cutting process has been achieved and developed in recent years. The main purposes of FEM are to simulate and analyze the physical phenomena during the grinding process. And then according to the results of simulation and analysis, the physical quantities such as stress, strain, temperature and strain rate etc in the grinding process can be visualized. On the basis of FEM, the paper established the models of single-particle and virtual grinding wheel to research the grinding force, grinding temperature, wear and stress of the grinding wheel.

The main contents of the paper are shown as follows:

1. The finite element model of single-particle was established which included geometric mode of particle and workpiece, constitutive material model of workpiece, etc. Through the FEM, the paper studied the effects of particle granularity and grinding parameters on grinding force, grinding temperature and abrasive wear.

2. The paper proposed a method of virtual grid to build the virtual grinding wheel to avoid overlapping among grains. The grain density of grinding wheel was measured by the VHX-600E to measure grain density, and the grains were simplified into a cube. Based on virtual grinding wheel, the finite element model of virtual grinding process was established to study the residual stress distribution and deformation of workpiece.

3. The grinding force was predicted based on simulation of grain distribution

and virtual grinding process. The number of the total Grain and effective grain were calculated based on wheel-workpiece contact length, grinding width, contact area and grain density. The predict force is a resultant force of single-particle.

4. An orthogonal and single factor grinding experiment was designed to check the rightness of the research in the grinding machine tool (2MZK7150). Furthermore, the effects of coolant and grinding parameters to grinding force were found. From the test, the predicted force met the test result, which proved that the result was consistent.

Keywords：Finite element simulation; Cemented carbide；Face grinding；Grinding force; Grinding temperature

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