

## **Chapter 9**

# **Conclusions and Recommendation**

### **9.1 Conclusions**

Diamond polishing is a complex process due to the extreme hardness of diamond. Polishing of thermally stable polycrystalline diamond composite is even trickier, because another hard to polish ceramic material with different properties is added to the composite as bonding material. This thesis has established a sound scientific methodology for the effective and efficient polishing of the thermally stable PCD composite. The research work includes development of an effective polishing technology for cutting tools made of these PCD composites, design and manufacture of a special polishing machine, comprehensive experimental and theoretical investigation of the polishing mechanism, and optimization of the polishing process to obtain a required surface finish efficiently.

After reviewing and comparing various polishing techniques and their material removal mechanisms from the literature, and based on the present application, the dynamic friction

polishing technique for PCD composite was selected for the thesis work. Dynamic friction polishing (DFP) utilizes the thermo-chemical reactions between the PCD surfaces and a catalytic metal disk rotating at high peripheral speed and predetermined pressure, to enable highly efficient abrasive-free polishing.

According to the requirements of DFP for PCD composite, such as temperature range generated by a proper range of sliding speed and pressure, catalytic metals, precise and uniform polishing of PCD surface, etc, a special polishing machine was designed and manufactured in-house to carry out the DFP of PCD composites efficiently and in a controllable manner.

A number of characterization techniques were used in our experiments for examinations of the surface integrity and investigation of the PCD polishing process by micro-structural, chemical structure analysis and temperature measurement. A combination of the various characterization methods has been used in the comprehensive study of the PCD polishing process, and exploration of the material removal mechanism by experimentally investigating the PCD specimen surface before and after polishing, and the polishing-produced debris. It was found that diamond had transformed to non-diamond carbon and SiC to amorphous silicon oxide/carbide. It is clear that the chemical reactions of carbon and SiC with metals or oxygen play an important role in the material removal of PCD, and these reactions occur only at elevated temperatures.

A theoretical model was developed to predict temperature rise at the interface of the polishing disk and PCD asperities. The effects of PCD surface roughness, material

properties, polishing speed and polishing pressure on the surface temperature rise were studied using the developed model. On-line temperature measurements were carried out to determine subsurface temperatures for a range of polishing conditions. A method was also developed to extrapolate these measured temperatures to the PCD surface. The predicted interface temperature gives an upper limit and the extrapolated temperature from measurement gives a lower limit of the polishing temperature.

The material removal mechanism is further explored by theoretic study of the interface reactions at these polishing conditions, such as temperature range, contacting with catalytic metals and polishing environment. Based on the experimental results and theoretical analyses, the material removal mechanism of dynamic friction polishing can be described as follows: conversion of diamond into non-diamond carbon takes place due to the frictional heating and the interaction of diamond with the catalyst metal disk; then a part of the transformed material is detached from the PCD surface as it is weakly bonded; another part of the non-diamond carbon oxidizes and escapes as CO or CO<sub>2</sub> gas and the rest diffuses into the metal disk. Meanwhile, another component of PCD, SiC also chemically reacts and transforms to amorphous silicon oxide/carbide, which is then mechanically or chemically removed.

Finally an attempt was made to optimise the polishing process by investigating the effect of polishing parameters on material removal rate, surface characteristics and cracking /fracture of PCD to achieve the surface roughness of industrial PCD cutting tools, 0.06  $\mu\text{m}$  Ra. It was found that combining dynamic friction polishing and mechanical abrasive polishing, a

very high polishing rate and good quality surface could be obtained. The final surface roughness could be reduced to 50 nm Ra for both types of PCD specimens considered from a pre-polishing value of 0.7 or 1.6  $\mu\text{m Ra}$ . The polishing time required was 18 minutes, a ten fold reduction compared with the mechanical abrasive polishing currently used in industry.

In general, this research work developed an effective polishing technology for cutting tools made of thermally stable PCD composites. The material removal mechanism has been comprehensively investigated both experimentally and theoretically. Process optimization was used to achieve the required surface finish efficiently and effectively.

## **9.2 Suggestions for Future Work**

Dynamic friction polishing of thermally stable PCD composites just started from the present project. Further research needs to be carried out to improve this polishing technique and extend the application of these PCD materials. The priority of the future research is to optimize the polishing process.

First, the polishing disk can be improved by using combined catalytic metals. Because during DFP, the material removal rate of diamond is faster than that of SiC, further mechanical abrasive polishing needs to be applied to remove the protruding SiC and further polish the PCD to generate the required surface finish. Further research should be

conducted on the catalytic metals to optimize the composition and percentage of combined catalytic metals in the polishing disk for a uniform material removal of diamond and SiC from the PCD composite surface.

Moreover, it was noticed that if two or more consecutive tests under identical conditions were conducted one after the other within a very short time interval, e.g., a few minutes, the material removal rate would vary in the second and subsequent tests. The mechanism responsible for such a rate change is unclear yet. Further research needs to be carried out to understand whether it is due to the rise in polishing temperature and/or some changes of conditions at the specimen-disk interface, and then find out the mechanism and provide guidelines for industrial application.

The material removal mechanism should be further investigated at different polishing parameters and environment, and a material removal mechanism map for the polishing process would be helpful for industrial application. A model of the material removal rate associated with the polishing parameters and surface quality should be developed.

The present polishing research is mainly applicable to planar surfaces; further work should consider more complex non-planar surfaces, which will broaden the applications of PCD due to its excellent properties.