Chapter 1

INTRODUCTION

Grinding is one of the oldest manufacturing processes. Already since the Stone Age grinding was used to sharpen the tools of the prehistoric man. Wooden arrows were sharpened by rubbing it on gravel. Later harder stone was ground with relatively soft sandstone to obtain axes. In the Middle Ages watermill driven grinding stones were used to produce tools, ploughs and weapons. Despite of the drawings of Leonardo Da Vinci around the year 1500, the first actual grinding wheel was manufactured just as late as the 19th century. Looking at the history of grinding it is clear that the whole evolution of the grinding process is in line with the discovery of new and harder abrasives: from gravel and sandstone via natural oxides such as corundum to diamonds and synthetic carbides [1].

By the discovery of synthetic abrasives such as silicon carbide, in the late 19th century, the development of the grinding process made a major breakthrough. The first commercial activities started during that time. From that period the research on grinding developed in two different directions because of the complexity of the whole process. Industry focussed on practical solutions and therefore large databases of all kinds of machining problems were designed [2]. The solutions were mainly based on empirical and semi-empirical relations between processing parameters and the final result. Even now, the quality and productivity depends still on the experience of the operator.

Nevertheless in the sixties of the 20th century, the first models on grinding were proposed. Most of these first models were based on the two dimensional topography of the grinding wheel. One of the main difficulties was to get the actual profiles and to find the active cutting edges from the profiles. By the
development of more powerful computers the models started to extend to better statistics and later to full three-dimensional models. Still one of the major goals is to predict the evolution of or the change in materials properties during the grinding process based on materials constants and the processing parameters [3, 4].

In the current century grinding is still often involved in the manufacturing of many products and components because the shaping technology such as sintering is not as accurate as required by the size specifications. The grinding type of machining process is almost chosen exclusively for finishing purposes since grinding has a high material removal rate combined with a relatively high precision. However, it is well known that the process may induce damage at the machined surface. This damage may affect the functional properties of the material being ground. For example, the cracks may reduce the mechanical strength of a component, the residual stress may change the magnetic permeability by magnetostriction [5] and phase changes can influence the paintability of the material. This thesis is therefore focused on fundamental aspects of grinding to predict the changes in materials properties.

We will present a new model that is verified with experimental results. The model is based on the statistics of the three-dimensional topography of the grinding wheel and the interaction of a single abrasive grain with the workpiece [6]. New profilometer techniques like scanning confocal microscopy make it possible to record surface profiles with very steep angles in a short time. Therefore it is now possible to obtain all the cutting edges of the abrasive grains on the grinding wheel, which are used to describe the statistical properties of the grinding wheel. As a result of faster computers with larger memory it is possible to do real-time simulations of the grinding process including the calculation of the surface roughness, grinding forces and even residual stresses. Furthermore, the residual stresses can be used to estimate the change in magnetic permeability or the change in piezoelectric properties of the material.

In order to verify the grinding model two different materials were used for the grinding experiments: cemented carbides (cobalt–tungsten carbide) and MnZn ferrite. Both materials have a different industrial background and have different applications. Also from the materials point of view it is interesting to study the grinding process of both materials since the mechanical properties are quite different. It is therefore expected that they exhibit different material removal
behaviour and thus the damage induced at the machined surface also may be of another type. The material removal behaviour can be studied by scratch tests since the grinding process can be assumed as the superposition of many scratches of individual abrasive grains on the surface of the workpiece.

Cemented carbides or so-called hardmetals are widely employed in dies, cutting and drilling tools because of their superb performance. Because of the high wear resistance, grinding of these materials with diamond abrasive wheels consumes a main part of the industrial produced diamonds [1]. The induced residual stresses, defects and plastic deformation will affect the fracture strength and therefore the lifetime of the tools. Studying the grinding process and material removal behaviour may result in a more efficient way of machining [7].

MnZn ferrites are often used for magnetic applications such as transformers, inductors, filters and video heads because of the high magnetic permeability and high electrical resistivity. Grinding of these products is often required to smooth the surface or to get accurate dimensional tolerances. It is known that during the machining of this ceramic material residual stresses are induced, which affects the magnetic properties at the ground surface by magnetostriction [5]. Also pullout of grains and fracture plays an important role in the formation of a smooth surface [8]. The scanning confocal microscope allows us to study the profile of the ground surface of these ceramics where pullout and fracture lead to steep surface slopes. Because of the high depth of focus of a scanning electron microscope, it can be used to image the ground ceramic surfaces with a high roughness.

Finally the results of the grinding model are compared with the real grinding experiments. As is demonstrated in this thesis it is possible to predict changes in the functional properties of materials after grinding reasonably well. However, certain assumptions were made during the simulations regarding the rigidity of the grinding wheel and materials properties like elasticity. But it is still necessary to know many details of the materials to be ground. Properties like average grain size, microstructure, hardness, fracture toughness and elastic modulus are essential for the estimation of the residual stress, number of cracks and so on.

In chapter 2 the basic concepts of grinding will be discussed and also the experimental tools will be described in this chapter. In the next chapter the model will be presented including some general results of the simulations. The
outcome of the grinding experiments on the tungsten carbide hardmetals will be illustrated in chapter 4. In chapter 5 some results of ground MnZn ferrites will be shown. Finally in the outlook we will seek for further developments and new applications in grinding and the modelling of grinding.

REFERENCES

1. S. Malkin, Grinding technology, theory and applications of machining with abrasives, Society of Manufacturing Engineers (SME), Michigan, 1989