

Chapter 8

Simulation of Grinding by Means of the Finite Element Method and Artificial Neural Networks

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ABSTRACT

Simulation of grinding is a topic of great interest due to the wide application of the process in modern industry. Several modeling methods have been utilized in order to accurately describe the complex phenomena taking place during the process, the most common being the Finite Element Method (FEM) and the Artificial Neural Networks (ANN). In the present work, a FEM model and an ANN model for precision surface grinding, are presented. Furthermore, a new approach, a combination of the aforementioned methods, is proposed, and a hybrid model is presented. This model comprises the advantages of both FEM and ANN models. The three kinds of models described in this work are able to accurately predict several grinding features that define the outcome of the process and the quality of the final product.

INTRODUCTION

Computational methods play a key role in the contemporary manufacturing sector that strives for quality. The industrial and academic interest in the role of computers in manufacturing technology

is increasing since modeling and simulation are able to lead to optimization of processes and at the same time reduce expensive and time consuming experimental work. This is especially applicable for material removal processes that are involved in numerous final products that demand high quality.

Grinding, a traditional finishing operation, could be no exception to this trend. As a manufac-

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turing process it is able to produce high workpiece surface quality. Improvements in its performance have allowed for the use of grinding in bulk removal of metal, maintaining at the same time its characteristic to be able to perform precision processing, thus opening new areas of application in today's industrial practice. The ability of the process to be applied on metals and other difficult to machine materials such as ceramics and composites is certainly an advantage of this manufacturing method.

However, the energy per unit volume of material being removed from the workpiece during grinding is very large. This energy is almost entirely converted into heat, causing a significant rise of the workpiece temperature and, therefore, thermal damage. The areas of the workpiece that are affected are described as *heat affected zones*. Thermal load is connected to the maximum workpiece temperature reached during the process and therefore the maximum temperature of the ground workpiece surface is of great importance. Nevertheless, certain difficulties arise when measuring surface temperatures during grinding, mainly due to the set-up of the process; a lot of research pertaining to grinding is performed through modeling and simulation instead of experimental investigation.

In this book chapter a review of the previous work performed so far is provided. Then, thermal Finite Element Method (FEM) grinding models which are able to predict the temperatures on the surface and within the workpiece and finally determine the heat affected zones that may appear, are presented. In order to accomplish this, grinding forces are experimentally measured and grinding simulations are performed.

Additionally, Artificial Neural Networks simulations are performed; soft computing methods, as this one, are becoming popular in manufacturing technology modeling. By using the same experimental data, as those used in FEM models, new models are created that can predict grinding forces for various grinding conditions.

As a novel contribution, FEM results on surface temperatures are used as input data to ANN models which in turn are able to predict with accuracy surface temperatures for various combinations of grinding conditions. These "hybrid" models are evaluated and compared to plain FEM or ANN models. The proposed analysis exhibits the simulation of grinding both with FEM and ANN, as well as a combination of the two methods, and draws useful conclusions.

BACKGROUND

Grinding is a manufacturing process characterized by complex relationships between process parameters, workpiece and cutting tools characteristics as well as quality features of the finished products. Researchers have utilized modeling and simulation for several decades, now, in order to investigate grinding more thoroughly, explain phenomena taking place during the process and achieve its optimization.

Grinding models are used for the prediction of surface roughness, wear characteristics, grinding forces, grinding energy and surface integrity among others. Grinding forces are essential for calculating grinding energy, which in turn determines surface integrity; grinding energy is transformed into heat dissipated into wheel, chip, workpiece and cutting fluid, if present. Excessive heat loading of the workpiece leads to the formation of heat affected zones. This heat input is responsible for a number of defects in the workpiece like metallurgical alterations, microcracks and residual stresses. High surface temperatures are connected to these phenomena and may lead to grinding burn (Malkin, 1978; Malkin and Guo, 2007). Because of the importance of the heat transfer problems in grinding, thermal modelling has proved to be of utmost importance. Thermal models relate all the process parameters in order to determine grinding temperatures.

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