Chapter 9

A Soft Computing System for Modelling the Manufacture of Steel Components

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ABSTRACT

This chapter presents a soft computing system developed to optimize the laser milling manufacture of high value steel components, a relatively new and interesting industrial technique. This applied research presents a multidisciplinary study based on the application of unsupervised neural projection models in conjunction with identification systems, in order to find the optimal operating conditions in this industrial issue. Sensors on a laser milling centre capture the data used in this industrial case of study defined under the frame of a machine-tool that manufactures steel components for high value molds and dies. Then a detailed study of the laser milling manufacture of high value steel components is presented based mainly on the analysis of four features: angle error, depth error, surface roughness and material removal rate. The presented model is based on a two-phases application. The first phase uses an unsupervised neural projection model capable of determine if the data collected is informative enough. The second phase is focus on identifying a model for the laser-milling process based on low-order models such as Black Box ones. The whole system is capable of approximating the optimal form of the model. Finally, it is shown that the Box-Jenkins and Output Error algorithms, which calculate the function of a linear system based on its input and output variables, are the most appropriate models to control such indus-

DOI: 10.4018/978-1-61520-893-7.ch009

trial task for the case of the analysed steel tools. The model can be applied to laser milling optimization of other materials of industrial interest and also to other industrial multivariable processes like High Speed Milling or Laser Cladding.

INTRODUCTION

Soft computing represents a collection or set of computational techniques and intelligent systems principles in machine learning, computer science and some engineering disciplines, which investigate, simulate, and analyze very complex issues and phenomena in order to solve real-world problems. Laser Milling is nowadays a very interesting industrial task, which, in general, consists on the controlled evaporation of waste material due to its interaction with high-energy pulsed laser beams.

The operator of a conventional milling machine is aware at all times of the amount of waste material removed, but the same can not be said of a laser milling machine. In this case, the amount of vaporized material depends not only on laser pulse characteristics, but also on the composition of the material to be removed. Indeed, in industrial conditions, the input process variables that could be measured show a too complex relation between then to obtain a proper modelisation using analytical or empirical models.Then a soft computing model that could predict the exact amount of material that each laser pulse is able to remove would contribute to the industrial use and development of this new technology. In this case we are focus on laser milling of steel components. It is an especially interesting industrial process, due to the broad use of steel as base material for different kind of manufacture tools, like molds and dies. One of the applications of this technology to these industrial tools is the deep indelible engraving of serial numbers or barcodes for quality control and security reasons for automotive industry (Wendland et al., 2005). The soft computing model proposed in this paper is able to optimize the manufacturing process and to control laser milling to the level of accuracy that is required for the manufacture of these deep indelible engravings. It has been developed using a combination of Soft computing models and it is applied here to a data set taken from micro-manufacturing laser milling of steel components.

Unsupervised connectionist models can be used as an initial phase or step before a model is established. They are used to analyze the internal structure of the data sets in order to establish that they are sufficiently informative. In the worst case, experiments have to be carried out again.

System identification is a field that refers to the set of techniques used to provide a mathematical model M for estimating the behaviour of a signal of a process for a certain period of time prediction interval (Ljung, 1999). In this study is applied after the use of connectionist models in order to identify the exact amount of material that each laser pulse is able to remove.

The rest of the chapter is organized as follows. Following the introduction, a two-phase process is described to identify the optimal conditions for the industrial laser milling of steel components. The case study that outlines the practical application of the model is then presented. Finally, some different modelling systems are applied and compared, in order to select the optimal model, before ending with some conclusions and future work.

AN INDUSTRIAL PROCESS FOR STEEL COMPONENTS MODELLING

Analyse of the Internal Structure of the Data Set

Cooperative Maximum-Likelihood Hebbian Learning (CMLHL) (Corchado & Fyfe, 2003; Corchado et al., 2003) is used in this research in

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