International Journal of Innovative Computing, Information and Control
Volume **8**, Number **5(B)**, May **2012**
ICIC International ©2012 ISSN 1349-4198
pp. 3495–3510

TRANSDUCTIVE NEUROFUZZY-BASED TORQUE CONTROL OF A MILLING PROCESS: RESULTS OF A CASE STUDY

Agustin Gajate[1], Andres Bustillo[2] and Rodolfo E. Haber[1]

[1]Centre for Automation and Robotics
Spanish Council for Scientific Research
Ctra. Campo Real Km. 0.200, 28500 Arganda del Rey (Madrid), Spain
{ agustin.gajate; rodolfo.haber }@car.upm-csic.es

[2]Department of Civil Engineering
University of Burgos
C/Francisco de Vitoria, s/n, 09001, Burgos, Spain
abustillo@ubu.es

Received January 2011; revised August 2011

Abstract. *This paper presents the design and implementation of an intelligent control system based on local neurofuzzy models of the milling process relayed through an Ethernet-based application. Its purpose is to control the spindle torque of a milling process by using an internal model control paradigm to modify the feed rate in real time. The stabilization of cutting torque is especially necessary in milling processes such as high-speed roughing of steel moulds and dies that present minor geometric uncertainties. Thus, maintenance of the cutting torque increases the material removal rate and reduces the risk of damage due to excessive spindle vibration, a very sensitive and expensive component in all high-speed milling machines. Torque control is therefore an interesting challenge from an industrial point of view. Direct and inverse local neurofuzzy models used in the internal model control paradigm are obtained through an identification process which uses representative input-output data from the system under study. These local neurofuzzy models are dynamically created online (for each new datum to be processed). Once obtained, the models that describe the dynamic process form the basis of the networked control system. This methodology is successfully applied in a production environment, in order to demonstrate improvements in both performance and effectiveness. Two different industrial tasks are tested: roughing of slots and roughing of surfaces with sudden, unexpected height steps. In both cases the control system demonstrated its capability to avoid torque peaks that could lead to spindle damage while maintaining high productivity.*

Keywords: Neurofuzzy systems, Transductive inference, Milling process, Torque control, Ethernet

1. **Introduction.** Nowadays, increasing manufacturing process productivity is a fundamental industrial requirement for the survival of many companies. In the case of metal removal processes, improvements in productivity can only be achieved by modifying the cutting conditions of the process, such as cutting speed and feed per tooth [1]. However, any modifications to cutting conditions will, in many cases, increase tool wear and cutting vibrations, thereby reducing the quality of the machined part. Moreover, in certain critical cases these modifications may even damage the machine itself. It is therefore necessary to develop intelligent control systems capable of controlling these modifications, so that the new cutting conditions do not produce these undesirable effects [2].

High-speed Milling (HSM) is one of the most complex processes in the manufacturing industry, because it involves so many variables that determine productivity, such as