EXPERIMENTAL STUDY AND ANN MODELLING OF R_k PARAMETERS IN HONING PROCESS

RAN VIJAY SINGH

DEPARTMENT OF APPLIED MECHANICS

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

August 2009

Experimental Study and ANN Modelling of R_k Parameters in Honing Process

RAN VIJAY SINGH

Applied Mechanics Department

Submitted
in fulfillment of the requirements of the degree of

Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

August 2009

Dedicated

to

P A R E N T S

CERTIFICATE

This is to certify that the thesis entitled **"Experimental Study and ANN Modelling of R_k Parameters in Honing Process"** being submitted by Mr. Ran Vijay Singh to the Indian Institute of Technology, Delhi for the award of degree of Doctor of Philosophy is a record of bonafide research work carried out by him. Mr. Ran Vijay Singh has worked under our supervision and guidance and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard for the Doctor of Philosophy degree.

The results contained in this thesis have not been submitted in part or full, to any other university or institute for the award of any degree or diploma.

Dr A K Raghav

Department of Applied Mechanics
Indian Institute of Technology Delhi
New Delhi 110016 India

Prof K S Shishodia

Department of Applied Mechanics
Indian Institute of Technology Delhi
New Delhi 110016 India

Prof G S Sekhon

Department of Applied Mechanics
Indian Institute of Technology Delhi
New Delhi 110016 India

ACKNOWLEDGEMENTS

I express my deepest sense of gratitude and indebtedness to Dr. A.K. Raghav, Prof. K. S. Shishodia and Prof. G. S. Sekhon for their untiring motivation, valuable guidance, encouragement and suggestions throughout this research work. I am extremely thankful to Prof. Y. Nath (Head Applied Mechanics Dept.) and Prof. S.N. Singh (Dean, IRD) for their valuable discussions, guidance and support at various stages of this work. I wish to express my gratitude to Dr. P.M. Pandey, Mechanical Engineering Department for allowing me to measure the R_k surface roughnesses on *Taylor-Hobson Intra* measuring instrument.

I am grateful to Mr. Dinesh Mallik, Dy Manager at AMTEK SICCARDI INDIA LIMITED, Manesar (Haryana) and Mr. A. B. Mathur, General Manager (Operations) for allowing me to perform experiments at AMTEK AUTO LIMITED (UNIT-I), Sohna. I express sincere thanks to Prof. A. S. Sachdeva, Ex-Dean, Faculty of technology, Delhi University, Delhi for co-operation and encouragement.

I am also thankful to Mr. Nidur Singh (Research Scholar) for great support and help in MATLAB programing. I owe special thanks to Ms. Dolly (student) for her help and cooperation.

Last but not the least, I wish to express deepest gratitude to my parents for encouraging me to achieve higher aims in my academic career.

Ran Vijay Singh
IIT, Delhi

ABSTRACT

Fine finishing processes, such as honing, are extremely complex. They are not amenable to exact mathematical analysis. Several factors related to inputs, machine tool, cutting tool, and process variables affect the quality of output including surface finish, rate of production and economy of manufacture. In the case of the honing process, quality of the machined surface is perhaps of the greatest importance. Traditionally centre line average or R_a value has been the most commonly used measure of surface quality of manufactured components. In recent years, however the specification of a single R_a value has been found to be inadequate when questions such as contact area, contact mechanics and wear have to be addressed while designing industrial components such as the connecting rod. There is an increasing tendency for a fuller specification of the surface characteristics. For example ISO 13565-2 specifies as many as five parameters (collectively called as the R_k parameters) for describing the surface quality. These include the reduced peak height R_{pk}, the reduced valley depth R_{vk}, the core roughness height R_k, material ratio M_{r1} separating the core roughness from the material side, and the material ratio M_{r2} separating the core roughness free from material side. Newer surface measuring instruments such as Talysurf Intra are capable for measuring the various R_k parameters. Analysis of processes, such as honing, requires a multi-input and multi-output approach. Conventional regression analysis is often inadequate to cope with such situations, especially when extensive experimental data is scarce or expensive to obtain. A more modern approach, exemplified by artificial neural networks, may however be used to tackle such problems. ANNs possess a number of plus factors in their favour, namely universal function approximation capability, resistance to noise and missing data, and accommodation of multiple non-linear variables having unknown or complex interaction.

The present work is devoted to the development of ANN models for the analysis of the honing process applied to an actual industrial component, namely a connecting rod of a motorbike. The components were honed using manual stroking in an actual industrial setting. The surface quality of the honed components was measured in terms of the R_k parameters. Six process parameters, namely grit size, honing temperature, honing speed, honing feed, honing time and operator experience in years were considered as the input variables. Fractional factorial design was used to reduce the number of expensive experiments to the minimum. Three layered structure, back propagation of error and three fold cross-over data approach were used to develop the proposed ANN models. Two types of models were investigated. The first type, called single output type has six input variables and a single output variable. The second type of the model, called as the multiple output type, has six input variables and five output variables (corresponding to the five R_k parameters). Prediction error statistics and hypothesis testing were used to compare alternative models. Extensive computational results indicate the viability of the proposed models. The best among the proposed ANN models was used to study the effect of process parameters on each of the five R_k parameters.

CONTENTS