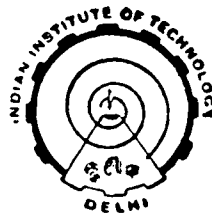


**MEASUREMENT AND ANALYSIS OF THE ROUGHNESS  
OF GROUND SURFACES AND ITS APPLICATION  
IN MONITORING WHEEL WEAR**

By  
**THOMAS JAYASINGH**

A thesis submitted to the  
Indian Institute of Technology, Delhi  
for the award of the degree of  
**DOCTOR OF PHILOSOPHY**



**INSTRUMENT DESIGN DEVELOPMENT CENTRE  
INDIAN INSTITUTE OF TECHNOLOGY, DELHI  
JUNE 1987**

*Dedicated*

*to*

*my mother*

## ACKNOWLEDGEMENTS

I am sincerely grateful and highly indebted to my supervisors, Dr. Anand Prakash, Chief Design Engineer, Instrument Design Development Centre and Prof. U.R.K. Rao, Department of Mechanical Engineering, Indian Institute of Technology, Delhi, for their systematic guidance and constant encouragement at every stage of this research work.

I am specially thankful to Dr. V. Radhakrishnan, Dean, Industrial Research and Development Centre, Indian Institute of Technology, Madras, for his interest and valuable suggestions at various stages of this research work. Thanks are also due to Prof. R. Arokiasamy, Member, UPSC, New Delhi.

I take this opportunity to show my gratitude towards Dr.V.C. Kulandaisamy, vice chancellor, Anna University and Dr. S. Sathik, Director, Madras Institute of Technology, Madras for sponsoring me under the Quality Improvement Programme of the Ministry of Education, Government of India.

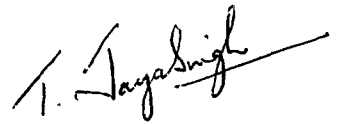
I express my thanks to Mr. Gajanan Hegde (Type-0-Graphic Centre, Munirka, New Delhi) for extending the services of his

Wordprocessor, to Mr. P.N. Prasad for his help in preparing the drawings and to Mr. R. Baskaran for his help in correcting the manuscript.

Finally, I am thankful to my wife, Nimmi and my son Niraj whose understanding and unconditional love allowed me the freedom to be a researcher.

New Delhi

June, 1987

A handwritten signature in black ink, appearing to read 'T. Jayasingh', with a long horizontal stroke extending to the right.

(THOMAS JAYASINGH)

## CERTIFICATE

This is to Certify that the thesis entitled "MEASUREMENT AND ANALYSIS OF THE ROUGHNESS OF GROUND SURFACES AND ITS APPLICATION IN MONITORING WHEEL WEAR" being submitted by Mr. Thomas Jayasingh, for the award of the degree of Doctor of Philosophy, to the Indian Institute of Technology, Delhi, is a record of bonafide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis which to our knowledge has reached the requisite standard. 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. ANAND PRAKASH)  
Chief Design Engineer  
Instrument Design Development  
Centre  
IIT, New Delhi - 110 016



(PROF. U.R.K.RAO)  
Professor  
Department of Mechanical  
Engineering  
IIT, New Delhi - 110 016

## ABSTRACT

The growing interest in developing efficient adaptive control systems for the optimization of the grinding process has resulted in research directed towards finding suitable techniques for the on-line identification of the grinding process. This thesis deals with the study carried out towards the monitoring of grinding wheel wear through measurement and analysis of the ground surface microgeometry. Since commercially available roughness measuring instruments were not suited for the extensive analysis of the surface profiles required in this study, two different systems have been designed and developed for this purpose. Spectrum analysis which has found wide application in the study of machine tool systems, has been used for the analysis of surface profiles in this investigation.

Experiments are carried out on a horizontal spindle surface grinder using alumina wheels on high speed steel workpieces. The power spectrum of the ground surface profiles obtained at different intervals are examined alongwith the corresponding radial wheelwear, force and vibration signals. Further, Scanning Electron Microscope (SEM) photographs obtained from samples removed from the wheel at different intervals are used to study the changes occurring on the wheel during the progress of wheel wear.

An attempt has been made to investigate whether radial wheel wear correlates well with one or more of the different roughness parameters. An approach has been proposed for simulation of wheel wear on the digital computer. Power spectra obtained by the simulation of the development of wear flats are compared with those obtained experimentally on ground workpieces. The results of the investigations are of relevance to the on-line identification of wheel wear for possible application to adaptive control.

## CONTENTS

	PAGE NO.
NOMENCLATURE	(ix)
LIST OF FIGURES AND TABLES	(xii)
CHAPTER 1 INTRODUCTION	1
CHAPTER 2 LITERATURE SURVEY	4
2.1 Introduction	
2.2 Analysis of surface profiles	
2.3 Measurement of grinding wheel topography	
2.4 Monitoring of wheel wear in grinding	
CHAPTER 3 SURFACE ROUGHNESS MEASUREMENT AND ANALYSIS SCHEMES	15
3.1 Introduction	
3.2 Surface roughness measurement and analysis using a microprocessor based data acquisition system (Scheme I)	
3.2.1 Pick-up and traverse mechanism	
3.2.2 Signal conditioning	
3.2.3 Design and construction of the data acquisition system	
3.2.4 Storage of digital data	
3.2.5 Computation of roughness parameters and functions	
3.3 Surface roughness measurement and analysis using a signal analyser (Scheme II)	
3.3.1 Roughness measuring equipment	
3.3.2 Signal conditioning and recording	
3.3.3 Signal analyser	
3.3.4 Recording and printing of results	
CHAPTER 4 EXPERIMENTAL DETAILS	42
4.1 Introduction	
4.2 Radial wheel wear measurements	
4.3 Measurement of grinding force	
4.4 Measurement of workpiece vibration	
4.5 Measurement of Workpiece surface profiles	
4.6 Experimental procedure	

CHAPTER 5	TECHNIQUES FOR THE ASSESSMENT OF GRINDING WHEEL WEAR	50
5.1	Introduction	
5.2	Assessment of grinding wheel condition by measurement of radial wheel wear	
5.2.1	Observations	
5.3	Assessment of grinding wheel wear by analysis of cutting force and vibration signals	
5.3.1	Observations	
5.4	Assessment of grinding wheel wear by roughness parameters of the ground surface	
5.4.1	Surface roughness parameters	
5.4.2	Statistical analysis	
5.4.3	Observations	
5.5	Assessment of grinding wheel surface condition using SEM photographs	
5.5.1	Use of SEM to grinding research	
5.5.2	Preparation of samples	
5.5.3	Observations	
CHAPTER 6	MONITORING OF GRINDING WHEEL WEAR BY SPECTRUM ANALYSIS OF GROUND SURFACE PROFILES	73
6.1	Introduction	
6.2	Spectrum analysis of surface profiles	
6.3	Surface generation in a grinding process	
6.4	Experimental procedure	
6.5	Observations.	
CHAPTER 7	COMPUTER SIMULATION OF WEAR	82
7.1	Introduction	
7.2	Wear mechanism	
7.3	Sample profile	
7.4	Computer simulation	
7.5	Results and discussions	
CHAPTER 8	DISCUSSION OF RESULTS	93
8.1	Radial wheel wear	
8.2	Tangential force	
8.3	Vibration	
8.4	Roughness parameters	
8.5	SEM photographs	

8.6	Power spectrum	
8.7	Simulation of wear	
8.7	General discussion	
CHAPTER 9	CONCLUSION AND SUGGESTIONS FOR FUTURE WORK	103
9.1	Conclusions	
9.2	Suggestions for future work	
REFERENCES		106
APPENDIX A	Typical output of measuring system (Scheme I)	111
APPENDIX B	Circuit diagram of sample and hold (S/H) and analog to digital (A/D) converter section of the data acquisition system	113
APPENDIX C	DETAILS OF EQUIPMENT	114
C.1	RACAL FM tape recorder	
C.2	Iwatsu signal analyser	
C.3	Talysurf 6 surface roughness measuring equipment	
C.4	Rectilinear recorder	
C.5	Video printer	
C.6	X-Y plotter	
C.7	Oscillographic recorder	
C.8	Surface grinding machine	
C.9	Accelerometer	
C.10	Vibration meter	
APPENDIX D	A LIST OF SELECTED ROUGHNESS PARAMETERS	118
CURRICULUM VITAE		