UNIVERSITI PUTRA MALAYSIA

IN-PROCESS SURFACE ROUGHNESS MONITORING BASED ON WORKPIECE SURFACE TEMPERATURE FOR TURNING OPERATIONS

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

April 2011

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Professor Napsiah Ismail, PhD

Faculty: Engineering

As the machining process has been moving to the stage of full automation over the years, one of the fundamental requirements is the ability to accurately predict the output performance and controlling the required surface quality. The focus of present study is to predict and monitor the surface roughness (Ra) in-process using workpiece surface temperature (T) of a turning workpiece, supported by the cutting tool vibration represented by (RMS). Thus, an in-process surface roughness monitoring and control system during the machining process were developed via temperature sensing in order to achieve a good trade-off between cost and performance, with a high reliability and a reduced computing time, and using sensors that do not disturb the machining process.

Response surface method (RSM) and analysis of variance (ANOVA) are used to get the relationship between different response variables (surface roughness, workpiece surface temperature, and cutting tool vibration) and the input parameters (cutting

speed, feed rate, and depth of cut). The experimental results showed that workpiece surface temperature can be sensed and used effectively as an indicator of the cutting performance. Thus, it is possible to increase machine utilization and decrease production cost in an automated manufacturing environment.

An effective monitoring method presented in this research using Grey relational analysis (GRA) to identify the surface roughness utilizes the grey relational coefficient (GRC) and grey relational grades (GRG), using in-process measured multi performance responses.

An artificial intelligence approach developed then for cutting parameters identification using multi adaptive network based fuzzy inference system (MANFIS). Two models architectures were presented, multi-input-multi-output (MIMO) ANFIS and single-input-multi-output (SIMO) ANFIS. The results show that the developed MANFIS models can be used successfully for machinability data selection once the desired surface roughness entered to the system.

The present study also, takes into account the degree of the influence of the workpiece diameter and overhung length and their interaction with the cutting parameters on the surface roughness. The diameter was identified to be the most influence on the surface roughness followed by the length and there is a significant interaction between them and the feed rate and depth of cut. The experimental results show that the workpiece surface roughness improved with bigger diameter and shorter length of the workpiece.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia untuk memenuhi keperluan untuk ijazah Doktor Falsafah

PEMANTAUAN DALAM-PROSES KEKASARAN PERMUKAAN BAHAN KERJA MELALUI SUHU PERMUKAAN UNTUK OPERASI "TURNING"

Oleh

ADEEL H. SUHAIL

April 2011

Pengerusi: Profesor Napsiah Ismail, PhD

Fakulti: Kejuruteraan

Sejajar dengan teknologi pemesinan yang menuju ke arah automasi, salah satu syarat-syarat asas adalah keupayaan untuk menjangkakan dengan tepat prestasi pengeluaran dan pengawalan ciri-ciri kualiti permukaan yang ditetapkan. Fokus penyelidikan ini adalah untuk meramal dan memantau dalam-proses kekasaran permukaan atau "in-process surface roughness" (Ra) melalui suhu permukaan bahan kerja (T) dalam operasi "turning" dengan bantuan pengesan suhu infra merah , disokong oleh getaran dari alat pemotong oleh (RMS) serta dibantu oleh pemecut. Dengan itu, sistem pengesanan dan kawalan "in-process surface roughness" semasa proses pembikinan telah direka melalui kaedah pengesanan suhu untuk mendapatkan keseimbangan antara kos dan prestasi yang meyakinkan, dalam jangka masa yang lebih pendek dan tanpa mempengaruhi proses yang dikehendaki .

"Response surface method (RSM)" dan "analysis of variance (ANOVA)" telah digunakan untuk mengenalpasti hubungan antara beberapa pembolehubah

tindakbalas (kekasaran permukaan, suhu permukaan bahan kerja dan getaran dari alat pemotong) dan pembolehubah dimanipulasikan (kelajuan pemotongan, kadar pembekalan dan kedalaman potongan). Keputusan eksperimen menunjukkan bahawa suhu permukaaan bahan kerja boleh dikesan secara efektif dan digunakan sebagai penentuukur untuk mengenalpasti prestasi pemotongan. Oleh itu,peningkatan penggunaan mesin dan pengurangan kos pengeluaran di dalam sektor pengeluaran boleh dicapai.

Kaedah pemantauan secara efektif di dalam penyelidikan ini mengaplikasikan "Grey relational analysis (GRA)" untuk mengenalpasti kekasaran permukaan, melalui "Grey relational coefficient (GRC)" dan "Grey relational grades (GRG)" dengan penggunaan tindakbalas prestasi dalam-proses yang telah diukur.

Pendekatan kecerdasan buatan telah dimajukan untuk pengenalpastian parameter pemotongan menggunakan "multi adaptive network based fuzzy inference system (MANFIS)". Dua model seni bina telah dibentangkan iaitu "multi-input-multi-output (MIMO)" dan "single-input-multi-output (SIMO)". Hasil kajian menunjukkan bahawa model MANFIS yang telah ditambahbaikkan boleh digunakan dengan jayanya untuk pemilihan data secara automatik setelah kekasaran permukaan yang diingini dimasukkan ke dalam sistem.

Penyelidikan ini juga mengambil kira kepentingan garis pusat bahan kerja dan lebihan jarak serta interaksi dengan parameter pemotongan terhadap kekasaran permukaan. Garis pusat bahan kerja telah dikenalpasti sebagai faktor yang mempengaruhi kekasaran permukaan, diikuti oleh jarak. Seterusnya, terdapat

interaksi antara faktor-faktor tersebut dan kadar pembekalan dan kedalaman potongan. Keputusan eksperimen menunjukkan bahawa kekasaran permukaan bahan kerja menjadi bertambah baik dengan garis pusat yang lebih besar dan bahan kerja yang lebih pendek.

ACKNOWLEDGEMENTS

In the name of Allah, the most Beneficent, the most Merciful Praise be to Allah who gave me the power, the strength and the patience to complete this study; and blessings and peace be upon our prophet Muhammad (S.A.A.W).

I would like to sincerely thank my supervisor, Associate Professor Datin Dr. Napsiah Ismail, for his patience, advice, guidance, and encouragement toward the completion of this thesis. I am grateful to Associate Professor Dr. S. V. Wong and Dr. Nawal Aswan Abdul Jalil for being my supervisory committee members.

My special appreciation goes to my wife Rwnak and my daughter Ayah. I also wish to express my appreciation to my parents and all my brothers and sisters.

I certify that an Examination Committee met on **15 April 2011** to conduct the final examination of **Adeel H. Suhail** on his thesis entitled " **In-process surface roughness monitoring based on workpiece surface temperature for turning operations** " in accordance with Universities and the University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Purta Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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ADEEL H. SUHAIL

Date: 15 April 2011

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