ENHANCEMENT OF THE MACHINING SURFACE ROUGHNESS MODEL WITH CUCKOO ALGORITHM

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"This thesis is special dedicated to my lovely parents, Encik Mohamad bin Abu Bakar and Puan Karimah bt Awang, my lovely siblings Zanariah bt Mohamad and Liza bt Mohamad, my lovely nieces and nephews Fatin Munirah Najwa, Afiq Iskandar, Arif Shaifuddin, Adam Haikal and Fatin Nur Khalisha, and my dearly loved Mohamad Faizal bin Abdullah for their endless love, support and courage"

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ABSTRACT

Quality of machining products is generally associated with the surface roughness (R_a) which is one of the important aspects that could affect machining performances. This study seeks to find the minimum value of R_a for a modern machining process, Abrasive Water Jet (AWJ). This study proposed Cuckoo algorithm to improve the surface roughness of the AWJ process because, since 2013, there has only been one study on the algorithm. R_a model in AWJ has five machining parameters comprising traverse speed (V), water jet pressure (P), standoff distance (h), abrasive grit size (D) and abrasive flow rate (m). These parameters in the R_a model have contributed to the best solution for machining performance by achieving the minimum values. In this study, to obtain better results, the parameters in the standard R_a model were enhanced in the modeling process where the number of parameters has been reduced. The enhanced parameters in the model are represented by "Q". Computational techniques were used to evaluate the model whereas SPSS were used to validate the results. The result shows that minimum R_a value of the proposed model is 2.1709 μm. It was much lower than the results of three computational techniques which are Artificial Neural Network (ANN), Regression analysis and Support Vector Machine (SVM) by about 29.2 %, 23.8 % and 19.3% respectively.

ABSTRAK

Kualiti pemesinan biasanya dikaitkan dengan kekasaran permukaan (R_a), dan ia adalah salah satu daripada aspek penting yang mempengaruhi prestasi pemesinan. Kajian ini bertujuan untuk mencari nilai minimum R_a bagi proses pemesinan moden, pelelas jet air (AWJ). Kajian ini mencadangkan algoritma Cuckoo untuk meningkatkan kekasaran permukaan proses AWJ kerana, sejak 2013, hanya terdapat satu kajian ke atas algoritma Cuckoo. Model R_a dalam AWJ mempunyai lima parameter pemesinan yang terdiri daripada *traverse speed (V), water jet pressure (P), standoff distance (h), abrasive grit size (D)* dan *abrasive flow rate (m).* Parameter dalam model R_a ini menyumbang kepada penyelesaian yang terbaik untuk prestasi pemesinan dengan mencapai nilai minimum. Dalam kajian ini, untuk memberikan hasil ketetapan model yang lebih baik, parameter dalam model R_a yang piawai diubahsuai dalam proses pemodelan yang mana bilangan parameter tersebut telah dikurangkan. Parameter yang diubahsuai dalam model diwakili oleh *'Q'*. Teknik-teknik pengiraan digunakan untuk menilai model manakala SPSS digunakan untuk mengesahkan keputusan. Keputusan menunjukkan bahawa nilai minumum R_a model yang dicadangkan ialah 2.1709 µm. Ianya lebih rendah berbanding keputusan tiga teknik pengiraan iaitu ANN, Analisis Regrasi dan SVM sebanyak 29.2 %, 23.8 % dan 19.3% .

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter gives an overview of the research conducted in this study. The topics include background of the study, problem statement, aim, objectives, scopes and significance of the research.

1.1 Background of the study

Nowadays, the manufacturing industries are highly competitive. Manufacture's ultimate goal is to produce high quality products with reduced cost and production time. Machining is a part of the operation for almost all manufactures of metal products. Generally, the machining operations can be classified into two types which are traditional and non-traditional (modern). Traditional machining is the process of removing unwanted segment of metal work piece in the form of chips such as turning, drilling and milling. Modern machining or non-traditional machining uses technology such as abrasive water jet (AWJ), ultrasonic machining (USM), chemical machining (CHM), electrochemical machining (ECM) and photochemical machining (PCM).

The selection of machining process parameters is very crucial in order for the machine operations to be successful (Rao and Pawar, 2010a). The success of a machining process also depends on the proper selection of cutting condition based on cost and quality factors. The major issue arise in machining process is how to obtain accurate results of machining performance measurement such as surface roughness. Commonly, the selection of cutting conditions in machining process is left to the machine operator. Moreover, in machining cutting process, the process was done continuously in order to get the target value despite the cutting material can be used only once. Thus, this process will increase cost with a lot of wasted used material used. Machinist experience is important for the machining process and plays a major rule although sometimes it is difficult to maintain the optimum values for each experiment (Aggarwal, 2005).

Recently, machining technology has been improved significantly to meet the requirements of manufacturing in different fields. There are two fields that have been of interest to researches in machining, which are modeling and optimization. According to Zain *et al.* (2011a), modeling in machining refers to the process of estimating the potential minimum or maximum values of machining performance while optimization refers to the process of estimating optimal solution of cutting condition that leads to the minimum or maximum machining values of machining performances. Various techniques were considered and carried out to model and optimize the machining performances. This study only focuses on modeling of machining performance. The primary purpose of the machining modeling is to estimate the minimum values (such as surface roughness, operation time, operation cost etc.) or maximum values (such as material removal rate, tool wear etc.) of machining performance measurements.

Based on previous literature, surface roughness is one of the machining performance measurements mostly studied by researchers (Çaydaş and Ekici, 2012; Salgado *et al.,* 2009; Zain *et al.,* 2010a, 2010b, 2010c). Surface roughness is a measure of the technological quality of a product which greatly influences manufacturing cost. It describes the geometry of the machined surfaces and combined with the surface texture. Surface roughness is also a technological quality measurement of a product and a factor that considerably affects the manufacturing cost (Caydas and Hascalik, 2008). Surface roughness plays an important role in wear resistance, tensile, ductility and fatigue strength for machine parts (Wang and Chang, 2004). Surface roughness is widely use as an index of product quality and in most cases a technical requirement for mechanical products (Yusup *et al.,* 2012; Benardos *et al.,* 2003). On the other hand, having a desired surface quality is a great importance for the functional behavior of the part. In order to find the desired value of surface roughness, several parameters need to be considered such as cutting tools properties, machining parameters, work piece properties and cutting phenomenon (Zain *et al.,* 2012a, 2012b). Various techniques have been considered by a number of researchers to model and optimize machining problems. This technique includes Artificial Neural Network, ANN (McCulloch and Pitts, 1943), Fuzzy set-theory (Zadeh *et al.,* 1988), Genetic Algorithm, GA (Holland *et al.,* 1970), Particle Swarm Optimization, PSO (Kennedy and Eberhart, 1995) and Ant Colony Optimization, ACO (Dorigo *et al.,* 1997).

Despite various techniques being applied in machining problem, only one machining research dealt with Cuckoo algorithm which was conducted by Yildiz *et al.* (2013) for optimization of machining parameters in end milling process labeled as one of the conventional machining processes. The author concluded that Cuckoo was a very effective and robust approach for the optimization of machining optimization problems. This study deals with modeling of surface roughness for abrasive water jet (AWJ) operation, classified as one of the modern machining processes. The results from this study contribute new knowledge to the machining field.

1.2 Problem Statement

The success of machining process depends on the proper selection of cutting condition based on cost and quality factors. The major issue in machining process is how to estimate and obtain accurate result of process parameters, such as surface roughness values using various machining factors of cutting operations. Conventionally, experimental trial was done repeatedly using different combination of cutting values to estimate the possible minimum value of machining performance. This is fully depended on mechanist experience who conducts the experiment. In such cases, machinist experience plays a major role but sometimes it is difficult to maintain the optimum values for each experiment (Aggawal and Singh, 2005).

With the help of computational approaches in estimating machining performances, minimum machinist expertise is required and the machining cost can be reduced. Hence, this study introduces the Cuckoo algorithm in producing and estimating minimum surface roughness value of machining process. In recent years, Cuckoo Search which is a combination with Levy Flight has become a new trend in current research especially in optimization of machining parameters. Cuckoo Search is capable to solve the problems of various fields such as engineering design (Yang and Deb *et al.,* 2010; Walton *et al.,* 2011; Noghrehabadi *et al.,* 2011; Kaveh *et al.,* 2011), software testing and data generation (Bacanin *et al.,* 2012; Kavita *et al.,* 2011; Perumal *et al.,* 2011) and pattern recognition problems (Vazquez *et al.,* 2011; Rani *et al.,* 2011; Ehsan *et al.,* 2011).

However, in some cases, the data in machining model may contain irrelevance and redundant features that is used as input features in development of surface roughness model using Cuckoo algorithm. This irrelevance and redundant data need to be eliminated from the input features in order to get a better prediction model. Standard surface roughness model approach does not have the ability to recognize this irrelevant element. So, there is a need for the model that is able to remove the unwanted data in order to improve the model performance. As a result, this study promotes the enhanced surface roughness mainly an extension of the idea by Wang *et al.* (2007) where the current problem on the standard equation was reduced to produce a better result in modeling process.

In relation to the machining problem discussed above, three research question of this study are:

i. How to estimate potential values of the machining process parameters to get possible values of minimum surface roughness?
ii. How to modify the existing standard model in order to give better results of surface roughness?
iii. How to identify the effectiveness of proposed enhancement model?

1.3 Aim

The aim of the study is to enhance the surface roughness model with Cuckoo algorithm to find the best minimum value of surface roughness, R_a for AWJ machining process.

1.4 Objectives

The objectives of the study are:

i. To implement standard surface roughness model with Cuckoo algorithm in estimating the minimum value surface roughness of AWJ.
ii. To enhance surface roughness model with Cuckoo algorithm for estimating the minimum surface roughness value of AWJ process.
iii. To validate and evaluate the performance of the proposed enhancement model in estimating minimum surface roughness value.

1.5 Scopes

The scopes of the study are:

i. Focus on abrasive water jet, AWJ classified as one of the modern machining processes.
ii. Surface roughness, R_a is machining performance considered for AWJ process.
iii. Five AWJ's process parameters such as traverse speed *V,* water jet pressure *P*, standoff distance *h*, abrasive grit size *d* and abrasive flow rate *m* will be considered.
iv. Experimental data of AWJ are based on the experiment conducted by Caydas and Hascalik (2008).

1.6 Significance of the research

This study is to analyze the performance of proposed enhancement of surface roughness model for AWJ process with Cuckoo algorithm in prediction of machining surface roughness value. To indicate the effectiveness of the proposed enhancement model, the final results are compared with the experimental data (Caydas and Hascalik, 2008), SVM (Deris *et al.,* 2013), ANN (Caydas and Hascalik, 2008) and Regression (Caydas and Hascalik, 2008) in order to view the effectiveness of the proposed enhancement model in estimating the value of surface roughness, $R_{a.}$ The proposed enhancement model is considered as a new research project in machining for estimating the machining surface roughness model.

1.7 Summary

This chapter discussed several topics related to the idea of research implementation. Background of the study, problem statement, aim, objectives, scopes and significance of the research were described in this chapter.

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