OPTIMIZATION OF MILLING PARAMETERS USING ANT COLONY OPTIMIZATION

MOHD SAUPI BIN MOHD SAUKI

A report submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2008

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

Signature:
Name of Supervisor: MR MOHD FADZIL FAISAE BIN AB RASHID
Position: LECTURER
Date: 14 NOVEMBER 2008

Signature:
Name of Panel: MADAM SITI HARYANI BINTI TOMADI
Position: LECTURER
Date: 14 NOVEMBER 2008

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurently submitted for award of other degree.

Signature:
Name: MOHD SAUPI BIN MOHD SAUKI
ID Number: ME05057
Date: 14 NOVEMBER 2008

Dedicated to my beloved

Mother and Father

For their endless support in term of motivation,

supportive and caring as well throughout the whole project

ACKNOWLEDGEMENTS

First of all I am grateful to ALLAH S.W.T for blessing me in finishing my final year project (PSM) with success in achieving my objectives to complete this project.

Secondly I want to thank my family for giving morale support and encouragement in completing my project and also throughout my study in UMP as they are my inspiration to success. I also would like to thank my supervisor Mr. Mohd Fadzil Faisae Ab. Rashid for guiding and supervising my final year project throughout these two semesters. He has been very helpful to me in finishing my project and I appreciate every advice that he gave me in correcting my mistake. I beg for the forgiveness to my supervisor for any mistakes and things that I done wrong while doing my project.

Lastly I want to thank all my friends that have given me advice and encouragement in completing my project. Thank you very much to all and May ALLAH S.W.T bless you.

ABSTRACT

In process planning of conventional milling, selecting reasonable milling parameters is necessary to satisfy requirements involving machining economics, quality and safety. This study is to develop optimization procedures based on the Ant Colony Optimization (ACO). This method was demonstrated for the optimization of machining parameters for milling operation. The machining parameters in milling operations consist of cutting speed, feed rate and depth of cut. These machining parameters significantly impact on the cost, productivity and quality of machining parts. The developed strategy based on the maximize production rate criterion. This study describes development and utilization of an optimization system, which determines optimum machining parameters for milling operations. The ACO simulation is develop to achieve the objective to optimize milling parameters to maximize the production rate in milling operation. The Matlab software will be use to develop the ACO simulation. All the references are taken from related articles, journals and books. An example to apply the Ant Colony Algorithm to the problem has been presented at the end of the paper to give clear picture from the application of the system and its efficiency. The result obtained from this simulation will compare with another method like Genetic Algorithm (GA) and Linear Programming Technique (LPT) to validation. The simulation based on ACO algorithm are successful develop and the optimization of parameters values is to maximize the production rate is obtain from the simulation.

ABSTRAK

Dalam proses perancangan untuk mengunakan mesin kisar konvensional, pemilihan parameter mesin kisar yang sesuai akan memenuhi segala keperluan dalam penjimatan ekonomi, kualiti dan keselamatan. Kajian ini adalah berdasarkan proses untuk mengoptimumkan parameter yang digunakan oleh mesin kisar mengunakan kaedah *Ant Colony Optimization (ACO).* Proses ini akan dijalankan untuk mengoptimumkan parameter untuk operasi mesin kisar. Parameter yang terlibat dalam proses mesin kisar ialah seperti kelajuan mata pemotong, kadar pemotongan dan kedalaman pemotongan. Semua parameter ini akan memberi kesan terhadap kos pemesinan, kadar penghasilan produk dan kualiti produk. Strategi ini digunakan untuk memaksimumkan kadar pengeluaran produk yang dihasilkan mengunakan mesin kisar. Kajian ini akan menerangkan secara terperinci tentang penghasilan dan pengunaan kaedah *ACO* untuk mengoptimumkan parameter ketika proses mengunakan mesin kisar. Simulasi untuk kaedah *ACO* akan dihasilkan untuk mencapai objektif kajian ini iaitu untuk mengoptimumkan parameter bagi memaksimumkan kadar pengeluaran produk. Perisian Matlab akan digunakan untuk menghasilkan simulasi untuk kaedah *ACO*. Semua rujukan adalah diambil dari artikel, jurnal dan buku yang berkaitan. Satu contoh masalah akan digunakan untuk menerangkan cara pengunaan kaedah *ACO* untuk memberi gambaran yang lebih jelas tentang kaedah ini. Keputusan yang diperolehi daripada simulasi ini akan dibandingkan dengan keputusan daripada kaedah lain seperti *Genetic Algorithm (GA)* dan *Linear Programming Technique (LPT)* yang diambil daripada sumber rujukan untuk pengesahan. Simulasi menggunakan kaedah *ACO* berjaya dibangunkan dan menghasilkan nilai parameter yang paling optimum untuk memaksimumkan kadar pengeluaran.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The advance of modern technology and a new generation of manufacturing equipment, particularly computer numerical control (CNC) machine, have brought enormous changes to the manufacturing sector. Generally, the handbook or human experience is used to select convenient machine parameters in manufacturing industry. In process planning of conventional milling, selecting reasonable milling parameters is necessary to satisfy requirements involving machining economics, quality and safety. M. Tolouei-Rad (1996).

The machining parameters in milling operations consists of cutting speed, depth of cut, feed rate and number of passes. These machining parameters significantly impact on the cost, productivity and quality of machining parts. The effective optimizations of these parameters affect dramatically the cost and production time of machined components as well as the quality of final products. M. Tolouei-Rad (1996).

1.2 PROBLEM STATEMENT

Establishment of efficient machining parameters has been a problem that has confronted manufacturing industries for nearly a century, and is still the subject of many studies.

Optimum machining parameters are of great concern in manufacturing environments, where economy of machining operation plays a key role in competitiveness in the market.

Although NC machines can reduce lead times considerably, the machining time is almost the same as in conventional machining when machining parameters are selected from machining databases or handbooks.

1.3 OBJECTIVES

(i) Develop Ant Colony Optimization (ACO) algorithm to optimize milling parameters.
(ii) Determine optimum milling parameters to maximize production rate.

1.4 SCOPE OF THE PROJECT

(i) The research will use ACO algorithm to optimize milling parameters to maximize production rate.
(ii) All the references are taken from related articles and journals.
(iii) All of this constant are taken from the references.
(iv) This study not involved any experiment.

1.5 IMPORTANT OF STUDY

This project will increase the knowledge about the way to optimize the machining parameter in order that to obtain minimum production time, maximum profit rate and minimum production cost. Optimization the machining parameter will avoid from doing any waste in production especially for material and time.

As a future engineer, must able to know about the way to optimize the parameter of milling or other machining processes in order that to increase the profit of the company. This study also giving a new knowledge about the method that using for optimize the machining operation like Ant Colony Optimization (ACO), Genetic Algorithm, Taguchi method, Tribes method etc.

1.6 SUMMARY

This chapter has been discussed generally about project background, problem statement, question which has been formulate from the problems, objective of the project and scope of the project in order to achieve the objective as mentioned.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Determination of the optimal cutting parameters (cutting conditions) such as the number of passes, depth of cut, speed, and feed is considered as a crucial stage of milling machining processes and especially in process planning. This is mainly due to the complex nature of optimization of machining operations that require the following:

(i) Knowledge of machining like drilling, turning or milling.
(ii) Empirical equations relating the tool life, forces, power, surface finish, material removal rate, and arbor deflection to develop realistic constraints.
(iii) Specification of machine tool capabilities like maximum power or maximum feed available from a machine tool.
(iv) Development of an effective optimization criterion like maximum production rate, minimum production cost, maximum profit or a combination of these.
(v) Knowledge of mathematical and numerical optimization techniques, such as the Simplex method, Search method, Geometric programming and dynamic programming.
(vi) Knowledge of stochastic optimization techniques, such as the Genetic Algorithms, Simulated Annealing, Scatter Search, Particle Swarm Optimization and Tribes.

2.1.1 Milling Machine

Milling is the process of machining flat, curved, or irregular surfaces by feeding the work piece against a rotating cutter containing a number of cutting edges. The usual mill consists basically of a motor driven spindle, which mounts and revolves the milling cutter, and a reciprocating adjustable worktable, which mounts and feeds the work piece. (Wikipedia, milling machine)

Milling machines are basically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer - type. Most milling machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power-operated table feeds. (Wikipedia, milling machine)

A milling machine is a machine tool that cuts metal with a multiple-tooth cutting tool called a milling cutter. The work piece is fastened to the milling machine table and is fed against the revolving milling cutter. The milling cutters can have cutting teeth on the periphery or sides or both. (Wikipedia, milling machine)

Milling machines can be classified under three main headings:

(i) General Purpose machines - these are mainly the column and knee type (horizontal & vertical machines).
(ii) High Production types with fixed beds- (horizontal types).
(iii) Special Purpose machines such as duplicating, profiling, rise and fall, rotary table, planetary and double end types.

Milling attachments can also be fitted to other machine tools including lathes planning machines and drill bench presses can be used with milling cutters. Milling machine is one of the most versatile conventional machine tools with a wide range of metal cutting capability. Many complicated operations such as indexing, gang milling, and straddle milling can be carried out on a milling machine. (Wikipedia, milling machine)

2.2 PREVIOUS METHOD

Many methods are used by related journal to optimizing milling parameters. M. Tolouei-Rad (1996), use Method of Feasible Direction for this purpose. This work does the optimization on unit cost, unit time and total profit rate resulting from all the machining operations required to produce the product. The parameter considered is depth of cut, feed rate and cutting speed. These values have been determined based on optimum machining parameters in comparison with those resulting from handbook recommendations. The result achieved when optimum machining parameters have been employed.

V. Tandon, H. El-Mounayri and H. Kishawy (2001) used Particle Swarm Optimization (PSO) for this optimization. This work has presented a new approach to optimizing the cutting conditions in end milling (feed and speed) subject to a near to comprehensive set of constraints. The original set of seventeen constraints was reduced to an equivalent set (of only three equations). Next, a production cost objective function was used to define the parameter to optimize (in this case, minimize). An algorithm for PSO was then developed and used to robustly and efficiently find the optimum cutting conditions. Both feed and speed were considered during optimization. The new technique has several advantages and benefits and is suitable for use with ANN based models.

G. Prabhaharan, N. Baskar, P. Asokan and R. Saravanan (2005), outlines the development of an optimization strategy to determine the optimum cutting parameters for multi-tool milling operations like face milling, corner milling, pocket milling and slot milling. The developed strategy based on the maximum profit rate criterion and incorporates five technological constraints. In this paper, optimization procedures based on the genetic algorithm, hill climbing algorithm and memetic algorithm were demonstrated for the optimization of machining parameters for milling operation. An objective function based on maximum profit in milling operation has been developed. Results obtained are used in NC machine. The results are compared and analyzed with method of feasible directions and handbook recommendations.

H.H Hasssan, J.A Ghani and I.A Choudhury (2003) used Taguchi optimization methodology, which is applied to optimize cutting parameters in end milling when machining hardened steel AISI H13 with TiN coated P10 carbide insert tool under semi-finishing and finishing conditions of high speed cutting. The milling parameters evaluated is cutting speed, feed rate and depth of cut. Using Taguchi method for design of experiment (DOE), other significant effects such as the interaction among milling parameters are also investigated. The paper shows that the Taguchi method is suitable to solve the stated problem with minimum number of trials as compared with a full factorial design.

J. Balic, M. Milfelner and F. Cus (2005), outline an approach for the systematic design of condition monitoring system for machine tool and machining operations. The research is based on utilising the genetic optimization method for the on-line optimization of the cutting parameters and to design a program for the signal processing and for the detection of fault conditions for milling processes. Cutting parameters and the measured cutting forces are selected in this work as an application of the proposed approach.

Godfrey C. Onwubolu (2005), proposes a new optimization technique based on Tribes for determination of the cutting parameters in multi-pass milling operations such as plain milling and face milling by simultaneously considering multi-pass rough machining and finish machining. The optimum milling parameters are determined by minimizing the maximum production rate criterion subject to several practical technological constraints. The cutting model formulated is a nonlinear, constrained programming problem. Experimental results show that the proposed Tribes-based approach is both effective and efficient.

Ali Riza Yildiz (2007), presents a new hybrid optimization approach based on immune algorithm and hill climbing local search algorithm. The purpose of the present research is to develop a new optimization approach for solving manufacturing optimization problems and to optimize machining parameters for milling operations. This research is the first application of immune algorithm to the optimization of machining parameters. In order to evaluate the proposed optimization approach, single objective test problem, multi objective I-beam and machine-tool optimization problems taken from the literature are solved. The results of the hybrid approach for the case study are compared with those of genetic algorithm, the feasible direction method and handbook recommendation. Finally, the hybrid approach is applied to a case study for milling operations to show its effectiveness in machining operations.

J. Sun, Z.G. Wang, M. Rahman and Y.S. Wong (2005), presents an approach to select the optimal machining parameters for multi-pass milling. It is based on two recent approaches, genetic algorithm (GA) and simulated annealing (SA), which has been applied to many difficult combinatorial optimization problems with certain strengths and weaknesses. In order to improve the performance of GSA further, the parallel genetic simulated annealing (PGSA) has been developed and used to optimize the cutting parameters for multi-pass milling process. For comparison, conventional parallel GA (PGA) is also chosen as another optimization method. An application example that has been solved previously using the geometric programming (GP) and dynamic programming (DP) method is presented. From the results, PGSA is shown to be more suitable and efficient for optimizing the cutting parameters for milling operation than GPCDP and PGA.

G.H. Qin, M. Wan, W.H. Zhang and G. Tan (2007), present the procedure integrates the cutting force module consisting of calculating the instantaneous uncut chip thickness (IUCT), calibrating the instantaneous cutting force coefficients (ICFC) and the cutting process module consisting of calculating the cutting configuration and static form errors. It used to check the process reasonability and to optimize the process parameters for high precision milling. Comparisons of the cutting forces and form errors obtained numerically and experimentally confirm the validity of the proposed simulation procedure.

M. Cengiz Kayacan, Oguz Çolak and Cahit Kurbanoglu (2005), used genetic expression programming method is used for predicting surface roughness of milling surface with related to cutting parameters. CNC milling has become one of the most competent, productive and flexible manufacturing methods, for complicated or sculptured surfaces. In order to design, optimize, built up to sophisticated, multi-axis milling centers, their expected manufacturing output is at least beneficial. Therefore data, such as the surface roughness, cutting parameters and dynamic cutting behavior are very helpful, especially when they are computationally produced, by artificial intelligent techniques. Cutting speed, feed and depth of cut of end milling operations are collected for predicting surface roughness.

2.2.1 Summarize from Literature Review

Use of many methods has been reported in the literature to solve optimization problem for machining parameters include Feasible Directions (M. Tolouei-Rad, 1996), Particle Swarm Optimization (V. Tandon, 2001), Memetic Algorithm (N. Baskar, 2005), Taguchi Method (J.A Ghani, 2003), Genetic Algorithm (M. Milfelner, 2005), Tribes Algorithm (Godfrey C. Onwubolu, 2005), Immune Algorithm (Ali Riza Yildiz, 2007), Simulated Annealing (Z.G Wang, 2005), Simulation Procedure (M.Wan, 2007), Genetic Expression Programming (Oguz Colak, 2005).

There are many parameters that can considered in optimize milling machining processes. The few parameters were reported include depth of cut, feed rate, chip depth of cut, work piece speed, cutting force, cutting speed, number of passes, tool diameter and tool length. The most three parameter that uses by literature is depth of cut, feed rate and cutting speed.

Table 2.1: Previous Method

Journal	Author	Year	Method	Parameter
1	• M. Tolouei-Rad • I.M. Bidhendi	1996	Feasible Directions	• Depth of Cut • Feed Rate • Cutting Speed
2	• V. Tandon • H. El-Mounayri • H. Kishawy	2001	Particle Swarm Optimization	• Depth of Cut • Feed Rate • Cutting Speed • Number of Passes
3	• N. Baskar • P. Asokan • R. Saravanan • G. Prabhaharan	2005	Memetic Algorithm	• Depth of Cut • Feed Rate • Cutting Speed • Cutting Force
4	• J.A Ghani • I.A Choudhury • H.H Hasssan	2003	Taguchi Method	• Depth of Cut • Feed Rate • Cutting Speed • Cutting Force
5	• M. Milfelner • F. Cus • J. Balic	2005	Genetic Algorithm	• Cutting Force
6	• Godfrey C. Onwubolu	2005	Tribes Algorithm	• Depth of Cut • Feed Rate • Cutting Speed • Chip depth of cut
7	• Ali Riza Yildiz	2007	Immune Algorithm	• Depth of Cut • Feed Rate • Cutting Speed
8	• Z.G. Wang • M. Rahman • Y.S. Wong • J. Sun	2005	Simulated Annealing	• Depth of Cut • Feed Rate • Cutting Speed • Number of Passes
9	• M. Wan • W.H. Zhang • G. Tan • G.H. Qin	2007	Simulation Procedure	• Depth of Cut • Feed Rate • Cutting Speed
10	• Oguz Çolak • Cahit Kurbanoglu • M. Cengiz Kayacan	2005	Genetic Expression Programming	• Depth of Cut • Feed Rate • Cutting Speed

2.3 METHOD

Use of many methods has been reported in the literature to solve optimization problems for machining parameters. All the method use the different procedure in optimize the machining parameter with the same objective including minimum production cost, minimum production time, maximum metal removal rate and maximum profit rate. These methods include:

(i) Feasible directions
(ii) Particle Swarm Optimization
(iii) Memetic Algorithm
(iv) Taguchi Method
(v) Genetic Algorithm
(vi) Tribes Algorithm
(vii) Immune Algorithm
(viii) Ant Colony Optimization
(ix) Simulated Annealing
(x) Simulation Procedure
(xi) Genetic Expression Programming

For this study, the milling parameters will optimize by Ant Colony Optimization (ACO) method. The research and analysis will be done to this method will be applied to this problem.