FUZZY PID CONTROLLER APPLIED ON MILLING MACHINE

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ABSTRACT

This project report deals with development of the control system for the milling machine. Vibration during turning process caused chatter in surface product and affects the outcome of products. The control system used to suppress vibration a chatter using machining process. Dynamic model diagram and mathematically model had derived from the two degree of freedom (2-DOF) for the cutting tool. The research project has only focused to Y-axis direction for milling machine. Control system used in this project is passive system. For active system that had been introduces two type of controller such as typically technique proportional-integral-derivative (PID) and Fuzzy Logic Control (FLC). To complete the active system, linear actuator had been used. The simulation had been run using MATLAB/SIMULINK software. Comparative study had been done between passive and active control system. From comparative study, Fuzzy PID showed an effectiveness result that suppresses vibration during machining process. Fuzzy PID produced small error nether than typically PID and passive system. For the conclusion Fuzzy PID controller is superior robust, stable and accurate controller compare the PID controller.

ABSTRAK

Laporan projek ini berkaitan dengan pembangunan sistem kawalan bagi mesin pengisar. Getaran ketika proses pengisaran menyebabkan getaran yang terhasil sendiri pada permukaan buatan dan menjejaskan hasil buatan. Sistem kawalan yang digunakan untuk meghilang getaran. getaran yang terhasil sendiri yang menggunakan proses pemesinan. Gambar rajah model dinamik dan matematik model telah diperolehi dua darjah kebebasan (2-DOF) daripada alat pemotong. Projek penyelidikan hanya tertumpu ke arah paksi-Y untuk mesin pengisaran. Sistem kawalan yang digunakan dalam projek ini adalah sistem pasif. Bagi sistem aktif yang telah memperkenalkan dua jenis pengawal seperti teknik biasanya berkadar-penting-terbitan (PID) dan Kawalan Logik Fuzi (FLC). Untuk melengkapkan sistem aktif, penggerak lelurus yang telah digunakan. Simulasi telah dijalankan menggunakan perisian MATLAB / Simulink. Kajian perbandingan telah dilakukan di antara sistem kawalan pasif dan aktif. Dari kajian perbandingan, PID Fuzzy menunjukkan hasil keberkesanan yang menghilangkan getaran semasa proses pemesinan. PID Fuzzy menghasilkan kesilapan kecil berbanding sistem PID dan pasif. Kesimpulannya, Pengawal PID Fuzzy adalah pengawal yang unggul teguh, stabil dan tepat membandingkan pengawal PID.

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LIST OF ABBRIEVATIONS

PID	Proportional-Integral-Derivative
FLC	Fuzzy Logic Control
FL	Fuzzy Logic
HHS	High Speed Steel
CV	Cilia Vibration

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

An industrial sector especially in manufacturing second most used is milling machines. The milling machine in production line requires high precision for every single part of product. It important to make sure the part has standardized for every components. A product had standardized and specific tolerance can assemble easily. The machining process is started time to maintain quality of product. The milling machine is used to investigate about the disturbed vibration. From that point, the advance precision milling machine is high prices compare the conventional milling machine. So, this project comes out with idea to implement the control system in the milling machine.

The basic concept of milling machine operated which spins the workpiece and the cutting tool standing at the static point. Milling machine can operated the machining process such as cutting, milling or deformation shape with several of cutting tool type.
When the workpiece not clamp vary well, it produced vibration for the whole machine. So, the solution for this problem by design control system to sense the vibration and suppresses it. For the better machines, the body structure is solidly constructed with broad bearing surface for stability and manufactured with great precision. It helps ensure the components manufactured on the machines can meet the required tolerances and repeatability.

Milling machines operated to remove the material from a rotating workpiece via the movements of various cutting tools. Sometimes in the milling process, frequently occurs the problem related to relative dynamic motion between cutting tool and workpiece. It cause chatter that give the results bad surface finishing in the workpiece.

From this study, the performance of milling machine and the accuracy machine can increase by overcome the problem relative to dynamic motion between cutting tool and workpiece. Two type of active control system investigated to achieve target of study. The active systems used are proportional-integral-derivative (PID) and PID hybrid by Fuzzy Logic Control (FLC) The control system is function to reduce of the dynamic motion between cutting tool and workpiece by control the vibration of the cutting tool. The controller also can reduce noise level that related with the tool life.

This Final Year Project (FYP) title is "Fuzzy PID controller applied on milling machine". It's been done in order to suppress the vibration that generate in the milling machine. This study will investigate by simulation scheme control diagram.
Simulation will run in the MATLAB/SIMULINK® software. This topic will elaborate more detail in the chapter 2 and chapter 3.

1.2 PROBLEM STATEMENT

Most of mechanical component such as machines or structures will failure cause by vibration. This situation also happens in the milling machine, the second most machines used in industry. Many problems have been found such as chatter. Chatter is a dynamic instability of the cutting process. Chatter cause from the interaction of the dynamics metal cutting process and the structural dynamics of the machine tool. If chatter uncontrolled, it easily spoil the surface accuracy, damage the cutting tool blade and also produce irritating unacceptable noise.

Therefore, the typical techniques such PID used to investigate for reduce chatter in milling operations. A few methods used to suppress vibration. The first technique used is a passive control system. Passive control is method used the tuned vibration absorber for the suppression of chatter. The other technique is active control system technique. For active control, the actuator or sensor has added in the system to detect and suppress it.

Active control methods have become increasingly popular compare to passive control. Active vibration control has be chose to suppress the vibration in milling machine. The detail of the active control system explains in the chapter 2. For all this problem and ideas to solve the vibration will discuss in the next chapter.

1.3 OBJECTIVE

The Objective of this project was aimed to suppress vibration on milling machine using Fuzzy PID controller.

1.4 SCOPE OF WORK

(i) Find dynamic model of cutting tool for milling machine and parameter of marching

(ii) Derive mathematical modeling of cutting tools model and controller with external disturbance presences

(iii) Use MATLab / simulink to do simulation regarding cutting tool model and controller with external disturbances presences.

(iv) Applied intelligent element into controller in simulation

1.5 SIGNIFICANT OF STUDY

There are few significances of this study when objectives have been achieved. The significance of study is investigated suitable scheme control system for milling machine. The scheme control system function to suppress vibration in the milling machine. Control system designed implement in the cutting tool. The parameter used base on milling process. This study focus on simulation method with simulate control system have been design by using MATLAB/SIMULINK® software and investigate every type of controller suitable for this system.

The experiment study can be continuous for more real live situation the vibration in milling machine. This study tried improve the milling machine performance base on many type of expectation for the accuracy of the product and the other. The idea to create the active vibration control system to overcome the chatter milling operation by implement controller. This control system technology can be commercialized for industrial sector.

CHAPTER 2

LITERATURE REVIEWS

2.1 INTRODUCTION

The main purpose of this literature review is to get the information from reference books, journals, technical papers and website to complete the project. For this chapter, some information from different sources will be discussed.

This chapter is more to recognize the basic understanding of knowledge about the study. The topics like milling machine, vibration, active vibration control and also controller should be familiar for facilitate of investigation. Know the knowledge of milling machine operation and the parameter that related and suitable to apply in this study. Recognize the mathematical model of cutting tool by the dynamic model. The method to use for study is simulation. So, the controller that will use listed, learn and can be adept to apply for the next chapter. Proportional integral-derivative (PID) control and Fuzzy Logic control (FLC) are the controller use for this study. The method to design, tune, set parameter and software use will explain detail in this chapter.

Besides that, the important thing should know vibration control. From that point, the previous study will be reference to know the technique used. The technique PID and Fuzzy Logic control (FLC) will briefly elaborated and analyzed. The comparative study will make between this two controllers, the conventional PID technique and PID controller with Fuzzy Logic (FL). This study consists with two active controllers that implementing in milling machine cutting tool. For PID controller, the method review is Ziegler–Nichols method or the other suitable method. Besides that, Fuzzy Logic Control (FLC) review about the type of fuzzy control concept such as fuzzification, rules evaluation, aggregation and defuzzification. For further study, this PID technique and PID with Fuzzy logic control added will used in simulation.

2.2 MILLING MACHINE

Milling is the process of machining flat, curved, or irregular surfaces by feeding the workpiece against a rotating cutter containing a number of cutting edges. Milling machines are basically classified as vertical or horizontal.(Mehdi K. and Rigal J.F., 2004). Milling process is the second most common method (after turning) for metal cutting and especially for the finishing of machined parts.

In modern industry the goal is to manufacture low cost, high quality products in short time. Predictive models of machining processes and tool life can be applied to help businesses gain a competitive edge. In this time of expanding global markets, it has become essential for manufacturers to improve process efficiencies, maintain stricter part tolerances, and enhance part quality. (Liu K. J. and Rouch K. E., 1991)

Figure 2.1: Milling machine

Source: Laboratory of Faculty Mechanical Engineering of Universiti Malaysia(UMP)

2.2.1 Cutting Tools

Cutting tools are related to the cutting force and it is important to understand it. There are many types of cutting tools that can see and use in machining operation, and different tools have different range of selection parameters and it also depends to the workpiece that to machine. .(Mehdi K. and Rigal J.F., 2004). In order to achieve effective cutting, the features of the milling cutter must be critically considered. The milling cutter features include shape, flutes, center cutting, helix angle, shank, roughing, and coatings. (Krar,et al, 2011).

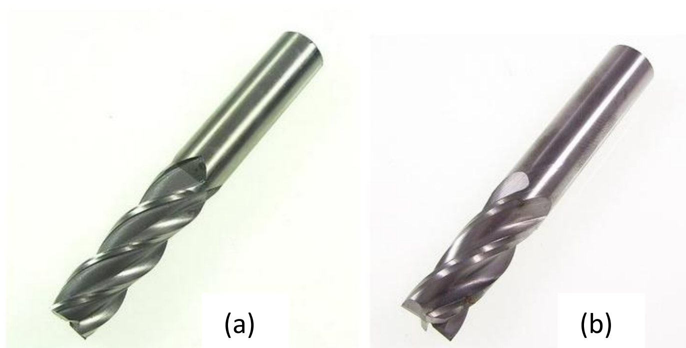


Figure 2.2: Milling cutters that will be use in this project. (a) 4 flute high speed steel cutter (b) 4 flute solid carbide cutter

Source: Laboratory of Faculty Mechanical Engineering of Universiti Malaysia Pahang

High speed steel (HSS) are most versatile than other materials. HSS are excellent for general purpose work, or where there are related to vibration and chatter problems. Cemented tungsten carbide classifies in hard metals family and produced by powder metallurgy techniques.(Liu K. J. and Rouch K. E., 1991). So that, they have quality that make them suitable for metal cutting tools. Cemented carbide can operated at speeds 3 to 10 times faster than conventional HSS cutting tools.

2.2.2 Machine Tool Vibration

The machine, cutting tool and workpiece form a structural system having complicate dynamic characteristics. Under certain conditions, vibrations of the structural system may occur and as with all the types of machinery these vibration may be divided into three basic types:

2.2.2.1 Free or Transient Vibration

Free vibration is a system is left to vibrate its own after an initial disturbance and no external force act on the system. It is produced by resulting from impulse transferred to structure through its foundation from rapid reversals of reciprocating masses such as machine tables or from the initial engagement of cutting tools. The structure is deflected and oscillates in its natural modes of vibration until the damping present in the structure causes the motion to die away. (Geoffrey et.al, 2006)

2.2.2.2 Force Vibration

Force vibration is a system that is subjected to a repeating external force. It is produced by resulting periodic system within the system such as unbalanced rotating masses or intermittent engagement of multi-tooth cutters (milling), or transmitted through the foundations from nearby machinery. The machine tool will oscillate at the forcing frequency, and if it this frequency corresponds to one of natural frequencies of the structure, the machine will resonate in the corresponding natural mode of vibration. (Geoffrey et.al, 2006)

2.2.2.3 Self –Exited Vibration (Chatter)

Self-exited vibration is a violent relative vibration between the workpiece and the tool. It is produced by resulting from dynamic instability of the cutting process. (Geoffrey and Winston, 2006)This phenomenon is commonly referred to as machine tool chatter and typically, large tool-work engagements are attempted, oscillations suddenly build up in the structure, effectively limiting metal removal rates. The structure again oscillates in one of its natural modes of vibration. (Geoffrey et.al. 2006)

2.2.3 Vibration in Milling Machine

Due to its intermittent nature the milling process involves both self-excited and forced vibration. In a stable milling process, the dominant vibration is usually due to intermittent cutting loads on the workpieces and occurs at a tooth-passing frequency given by N_z RPM/60, where N_z is the number of tool teeth and RPM is the rotational speed of the spindle. Spindle speeds in conventional milling operations are typically in the range of 500–5000 RPM, depending on the materials to be processed and on the cutting tool geometry and material. Since the number of the teeth can vary between 2 and 12, the tooth-passing frequencies range between 17 and 1000 Hz. (Rashid et.al, 2005)

In many modern milling operations, the work-holding fixtures, with rigid couplings connecting to the table (bolts), do not provide sufficient damping to control the resonant response, and significant improvements are needed. Passive vibration cancellation is normally achieved by appending a supplementary structure (dynamic absorber) with a natural frequency similar to the disturbing frequency. When the disturbance is at a given frequency, i.e., a forced vibration problem, this damping treatment may or may not be effective, depending on how close the disturbance frequencies are to the resonant frequency being damped. In this case, active vibration cancellation should be used to control the dynamic behavior of the structure. (Rashid et.al., 2005)

2.3 DYANAMIC MODEL DIAGRAM

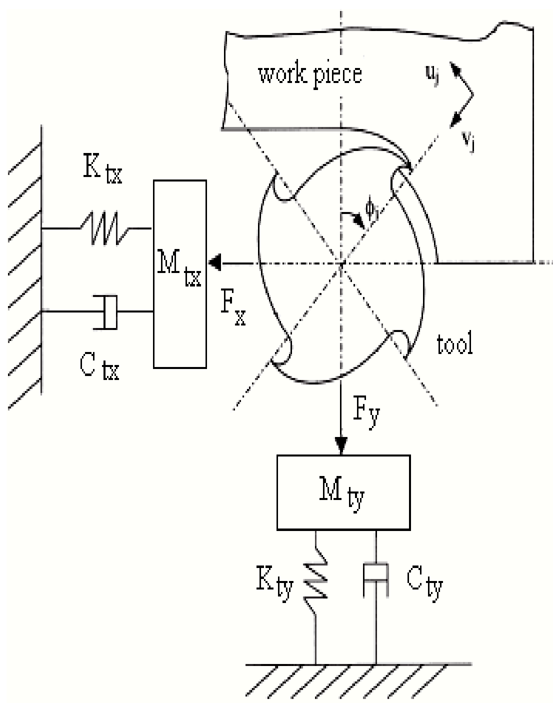
Dynamic model is can relate to dynamic modeling. Dynamic modeling is a dynamic model refers to runtime model of the system. (Marin d. et al ,2009). Dynamic models keep changing with reference to time. Dynamic modeling is flexible as it can change with time as it shows what an object does with many possibilities that might arise in time. Dynamic model on the other hand consists of sequence of operations, state changes, activities, interactions and memory. (Balachandran B. and Zhaoa M.X, 2001)

Two structures contribute to the cutting dynamics: the spindle system and feeding system. (Marin d. et al ,2009). The spindle system is modeled by a second order in system X and Y direction.(Mansor M.H., et.al,2010) .Equations for tool/spindle system are.

$$M_{tx}\ddot{x}(t) + C_{tx}\dot{x}(t) + K_{tx}(t) = F_x \quad (2.1)$$

$$M_{ty}\ddot{y}(t) + C_{ty}\dot{y}(t) + K_{ty}\,y(t) = F_y \quad (2.2)$$

Where M_t, C_t and Kt represent tool mass, damping and stiffness, respectively; X_t and Y_t are the displacements of the tool in X - and Y - directions, respectively, and $F(t)$ is the cutting force.



The figure 2.3: Dynamic model for cutting tool

Source: Marin.D et al ,2009

The formation of cutting force and the excitation of the machine structure by the cutting force contribute to the cutting dynamics (Boiko I et. al, 2006). The dynamic model of the milling cutter used in this paper is assumed to be a system with two modes of vibration in two perpendicular directions, X and Y while the feed direction is while the feed direction is along the X-axis. (Balachandran B. and Zhaoa M.X, 2001).

The milling system under consideration is shown in figure. 2.3, where the X-Y axis coordinate system is fixed with respect to the machine tool structure and its axes are aligned with the principal modes of oscillation. This is a common characteristic of the spindle tool assembly, which is the most flexible part of a typical milling machine. The milling cutter has *n* teeth, which are assumed to be equally spaced

2.3.1 Dynamic Model Parameter

For the calculations, it based on the experimental results of Halley. The following experimentally identify parameters were used: m =2:586 kg; k= 2:2 x 10^6 N/m; c =18:13 N s/m. The taken values are almost same as the any model on milling machine. It is right to choose these values. (Insperger et.al, 2001).

2.4 MATHEMATICAL MODELLING

Mathematical modeling is the highlighted model to understand before assess the proposed design. (Ab. Rashid M.F.F.et. al.,2009). A mathematical model of a dynamic system is defined by set of equation that represent the dynamics of the system accurately or least fairly accurate. (Norman S.N., 2008). The system can be represented in many ways of depending on one's perspective. There are many types of mathematical modeling as listed as below

i) Linear system
ii) Linear time invariant system and linear time varying system
iii) Non linear system
iv) Linearized dynamic model

v) Transfer function

vi) Translational mechanical system

Mathematical model related are transfer function and translational mechanical system. (Norman S.N., 2008). Transfer function is a mathematical model representation. For a linear, time invariant differential equation. It is defined as the ratio of Laplace transform of the output to Laplace transform of the input under the assumption that the initial conditions are zero.

Translating mechanical system is three basic elements used to a model. There are elements are spring, damper, and mass. (Norman S.N., 2008). The stated variables are the displacement x (t), velocity v (t), acceleration (t) and forces f (t). The dynamic model for the translational mechanical system can be derived applying the Newton's second law of motion.

2.5 MAT LAB SIMULINK

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation.(Lieping Z. et. al.,2007).Control System Engineering, John Wiley and Sons (Asia) Pte Ltd, Fifth Edition. Using the MATLAB product, technical computing problems can be solved faster than with traditional programming languages, such as C, C++, and FORTRAN. MATLAB is used in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology. MATLAB provides a number of features for documenting and sharing work.(Lieping Z. et. al.,2007).. MATLAB code can integrated with other languages and applications, and distribute MATLAB algorithms and applications. The MATLAB system consists of these main parts:

2.5.1 Mathematical Function Library

This library is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

2.5.2 The Language

The MATLAB language is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. (Norman S.N., 2008). It allows both "programming in the small" to rapidly create quick programs do not intend to reuse. "Programming in the large" also can be done to create complex application programs intended for reuse.

2.5.3 Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. (Norman S.N., 2008) It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow to fully customize the appearance of graphics as well as to build complete graphical user interfaces on MATLAB applications.

2.6 ACTUATOR

2.6.1 Linear Actuator

2.6.1.1 Linear Actuator based on Cilia Vibration

Actuators based on vibration are typically found in parts feeders and ultrasonic motors. (Khidir E.A et. al,2007), The former can move many small objects simultaneously. However, it is impossible to generate a drive force because the force is dominated by the mass of the objects and the friction coefficient. The latter can generate a fairly large torque and a high energy density; however, a specific mechanism such as belt drives or motion guides are necessary for the movement of objects that have various shapes. (Khidir E.A et. al,2007), As for the application of cilia vibrations (CV) drive micro mobile robots and mountain-climbing micro robots.

A cilia vibration actuator is proposed for conveyance versatility and improvement of cilia fragility. (Takeshi et al, 2003)The CV actuator described here has special features as follows:

i. Linear drive motion for various shapes of objects as long as the actuator can clamp on to the objects;
ii. Simple construction of a pair of cilia arrays and vibrators.

The driving principle of the CV actuator, the fabrication process of the cilia array, and the anisotropy characteristics of the cilia friction are described as well as the performance evaluation of both a macro and a miniature model of the CV actuator. (Khidir E.A et. al, 2007).