Faculty of Manufacturing Engineering

PERFORMANCE ANALYSIS OF PRE-SLIDING MOTION USING SLIDING MODE CONTROLLER

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DECLARATION

I hereby declared this report entitled "Performance analysis of pre-sliding motion using Sliding Mode Controller" to be the results from my fieldwork except where mentioned in references.

Signature : ....

Name : SITI NUR SYAZWANI BINTI KUNYAHAMU

Date : 22nd FEBRUARY 2021

APPROVAL

I hereby declared that I had read this thesis. In my opinion, this thesis is sufficient in terms of scope and quality for the award Master of Manufacturing Engineering in Industrial Engineering.

Signature : ……………………………………………

Supervisor Name : DR NUR AIDAWATY BINTI RAFAN

Date : 22nd FEBRUARY 2021

DEDICATION

For loving, helping, and supporting my cherished parents, siblings, and friends

ABSTRACT

Friction is typically defined as motion resistance as two surfaces move against each other. In nature and a wide variety of engineering applications, frictional interactions occur between solids. In manufacturing engineering, the friction force is necessary for the machine to prevent sliding. Still, when too much friction is applied to the device, it will affect the device and decrease the positioning and tracking accuracy in mechanical systems. This study identifies friction activity in pre-sliding motion, which is the compensation of friction force at motion reversal. Compensation methods either compensate for the controller (adaptive) or interference forces to achieve improved output in terms of monitoring and contour errors. Sliding Mode Control (SMC) is a design by using MATLAB software to compensate for friction. The Generalized Maxwell-Slip (GMS) friction model is used for numerical analysis. The controller's performance is measured based on reducing the error in the pre-sliding regime after designing the Sliding Mode Controller using Matlab Simulink software. The SMC parameters Lambda (λ), Gain (K) and Delta (φ) were tuned and the best parameters were selected in accordance with the specifications of the configurations suggested, Configuration 1, Configuration 2 and Configuration 3. The lower variability index value, is Configuration 3 which are 0.3456% and the RMSE values is -0.1628, has been found to have the best tuning parameters for the Sliding Mode Control (SMC) controller. Using the best configuration performance that have been chosen, will be used in the PID Controller simulation to view the different output results of two different controllers using the same configuration performance value. The value of variability index and RMSE of PID is 1.9863% and 0.2710. Based on this analyses it shown that the Sliding Mode Controller (SMC) performed well during the simulations as opposed to the PID controller in this study.

ABSTRAK

Geseran biasanya didefinisikan sebagai rintangan pergerakan kerana dua permukaan bergerak antara satu sama lain. Secara semula jadi dan pelbagai aplikasi kejuruteraan, interaksi geseran berlaku antara pepejal. Dalam kejuruteraan pembuatan, daya geseran diperlukan agar mesin dapat mengelakkan gelongsor. Namun, apabila geseran terlalu banyak digunakan pada peranti, ia akan mempengaruhi peranti dan menurunkan ketepatan kedudukan dan penjejakan dalam sistem mekanik. Kajian ini mengenal pasti aktiviti geseran dalam gerakan pra-gelongsor, yang merupakan pampasan daya geseran pada pembalikan gerakan. Kaedah pampasan sama ada mengimbangi pengawal (adaptif) atau daya gangguan untuk mencapai output yang lebih baik dari segi pemantauan dan kesalahan kontur. Sliding Mode Control (SMC) adalah reka bentuk dengan menggunakan perisian MATLAB untuk mengimbangi geseran. Model geseran Generalized Maxwell-Slip (GMS) digunakan untuk analisis berangka. Prestasi pengawal diukur berdasarkan pengurangan ralat dalam rejim pra-gelongsor setelah merancang Sliding Mode Controller menggunakan perisian Matlab Simulink. Parameter SMC Lambda (λ), Gain (K) dan Delta (φ) diselaraskan dan parameter terbaik dipilih sesuai dengan spesifikasi konfigurasi yang disarankan, Konfigurasi 1, Konfigurasi 2 dan Konfigurasi 3. Nilai indeks kebolehubahan yang lebih rendah, adalah Konfigurasi 3 yang 0,3456% dan nilai RMSE -0,1628, didapati mempunyai parameter penalaan terbaik untuk pengawal Sliding Mode Control (SMC). Menggunakan prestasi konfigurasi terbaik yang telah dipilih, akan digunakan dalam simulasi PID Controller untuk melihat hasil keluaran dua pengawal yang berbeza menggunakan nilai prestasi konfigurasi yang sama. Nilai indeks kebolehubahan dan RMSE PID adalah 1.9863% dan 0.2710. Berdasarkan analisis ini menunjukkan bahawa Sliding Mode Controller (SMC) menunjukkan prestasi yang baik semasa simulasi berbanding dengan PID controller dalam kajian ini

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CHAPTER 1

INTRODUCTION

1.0 Introduction

In this chapter, the study's overall evaluation describes the study's objective, the purpose of the analysis on the study, and the shortcomings of the report. The study field's comprehensive structural analysis is briefly analyzed to obtain a clear visualization of the study's whole scope's successions.

1.1 Background

Control systems nowadays make a significant contribution to virtually every area of our industrial society, with extensive implementations in the home environment and industry. There is a tremendous market in the industry for high speed and high precision machine tools, which means providing good performance in the devices.

One factor relating to their success in a drive system is the strength of the friction forces. On the machine, the friction force is necessary to prevent sliding. Still, if too much friction is exerted on the machine, it may destroy the machine and decrease the mechanical systems' positioning and tracking accuracy.

A phenomenon caused by friction is known as the "spike" and is commonly known as a quadrant glitch, noticeable throughout circular motion at quadrant locations. Quadrant glitches on each axis of a motion device are defined as dynamic non-linear frictional actions at motion reversal or near zero velocity. This study focuses on developing a control technique to counteract the friction force of a drive mechanism to improve the device's precision with the use of a Sliding Mode Controller (SMC).

1.2 Problem Statement

Friction is a force between objects opposing the objects' relative movement. If two objects move in relation to each other, kinetic friction transforms some of the movement’s kinetic energy into heat. High friction in machinery slows down mechanical activity and increases control loop instability, thus reducing finished product output and increasing energy waste.

The friction can be compensated for this problem. Friction arbitration requires operators with different systems. Effective pressure tuning techniques help in increased friction compensation. This study uses the location controller Sliding Mode Control (SMC). This project aims to define friction behavior and design the Sliding Mode Controller to analyze pre-sliding motion using Sliding Mode Control (SMC).

One of the considerations that contribute to the machine tool's precision is the drive mechanism's output monitoring, which is significantly determined by the mechanical structure, friction forces, cutting forces, and workpiece weight (Jamaludin, Brussel and Swevers, 2007). Fortunately, the problems relating to friction in the control field are hard to deal with, owing to its degrading impact on precise monitoring and extremely non-linear low-speed efficiency. Evermore researchers have recognized that the friction effect must be carefully observed in the study of the motion control of the servo feed systems to increase machine tools' accuracy (Mei *et al.*, 2001).

Generally, this study focuses on creating a highly efficient and stable friction compensation controller in the XY machining positioning system. The proposed controller is supposed to compensate for the extremely non-linear friction phenomena in motion reversal while maintaining a stable device. This problem can be overcome by compensating for friction.

Compensation friction has different approaches involving controls. Effective tuning techniques in the controller result in greater tolerance for friction. This study uses the Sliding Mode Control (SMC) position, controller. This study aims to define the machines' friction behavior, define the Sliding Mode Control (SMC) tuning strategies, and evaluate the selected methods' efficacy.

1.3 Objective

The objectives of this study are:

1. To identify friction behavior in pre-sliding motion.
2. To design a position controller with embedded friction compensation function.
3. To analyze the performance of pre-sliding motion using Sliding Mode Control (SMC) in MATLAB Simulink

1.4 Study Question

The followings are study questions for this study:

1. What is the behavior of friction in pre-sliding motion for one axis machine system?
2. What is the different model of friction model?
3. What is the relationship between friction compensation and improvement of control technique at the movement reversal of a drive system that generates quadrant?
4. How to analyze the monitoring efficiency of the proposed friction compensation model?
5. What is the recommendation for future study

1.5 Scope of Research

This study will investigate the behavior of friction in the pre-sliding regime in linear motion. In the case of sliding motion, the friction force relies upon the system speed, but only the friction force in the pre-sliding region will be focused mainly in this study. Where it means it occurs before the breakaway, but it still depends upon the system position. For this study, the control system is designed for the two-axis mechanism machine, such as the XY table machine. The controllers involved in this study are PID and Sliding Mode Controller. The analyses are conducted for the continuous motion numerically for the x-axis only. The software used for this study is the MATLAB Simulink software.

1.6 Significant of Study

This study's main contribution is to design an optimized friction model based on friction behavior in the pre-sliding regime. The effectiveness of this newly designed friction model is tested and verified based on a pre-sliding motion performance study using Sliding Mode Control (SMC)

1.7 Organization of Report

Table 1.1 below shows the chapter-based report organization, which is chapter 1, will cover the background, problem statement, objective, scope, and study significance of the project. Chapter 2 is the Review of the Literature, Chapter 3 Methodology, and Chapter 4 Result and Discussion, and finally, Chapter 5 will cover the conclusion and recommendation.

Table 1.1 Organization of report

Chapter	Subtopic	Description
Chapter 1	Project Background	Develop the background of the study where the topic is covered
	Problem Statement	Describe the problem that leads to the study project
	Objective	Describing the aim of the study
	Scope	The scope involves the scope of study, place, and users.
	Significant of Study	Explaining the importance of study that need to be conducted
Chapter 2	Literature Review	Review the previous study or project that has been done from the source

		• Behavior of friction • compensation methods using friction compensation model • Identification for *x* and *y*-axis machine
Chapter 3	Methodology	Explain the process and the method used for the study • Flowchart of main research activities • System set-up • Tools and software used in this research (MATLAB software).
Chapter 4	Result and Discussion	A detailed explanation on results achieved and the discussion • Identification of parameters needs in the simulation based on the past researcher. • Presents numerical and experimental findings with a concurrent explanation of friction compensation as an output measurement using PID and SMC as controllers.
Chapter 5	Conclusion and Recommendation	To conclude the study and recommendation for the future • The study result ends with a suggestion for future studies.

1.8 Summary

To summarise this chapter, it gives the upper layer of understanding of what this study all about. This chapter provides a rough view of the study and gets the point. This study's importance is the objectives that need to be achieved and the study's scopes to succeed.

CHAPTER 2

LITERATURE REVIEW

The literature review in this chapter explores the dominant themes of studies and research from various published materials. The materials are used as guidance for the next phase of the study, including journals, articles, books, and online resources. Besides, this chapter also discusses the differences identified in the current literature and briefly explained specifics to defend the study.

2.0 Introduction

The friction is usually defined as motion resistance if two surfaces are sliding. Friction is typically a helpful phenomenon that allows many common activities, such as walking and accelerating a vehicle. Friction can also contribute to unintended results. For instance, friction can degrade the system's output with high-precision mechanical motion systems.

High speed and high-precision machine tools have been a huge demand for the industry. Therefore, the high-speed drive system created high friction inside the system, leading to a significant location mistake. An unmistakable effect caused by friction is known as a "spike" that is noticeable at the quadrant's position during circular motion. Clear spikes are commonly regarded as quadrant glitches can refer to in the figure below. These quadrant glitches result from dynamic non-linear motion reversal activity that can strongly impact positioning and tracking performance (Jamaludin, Brussel and Swevers, 2007). Because of this phenomenon, and appropriate management system is required to minimize the error due to frictional forces. Understanding the concept of friction behavior and friction characteristics is also need in this project. The friction actions, friction models, and controllers used to compensate for friction and the linear motion are discussed in this chapter.

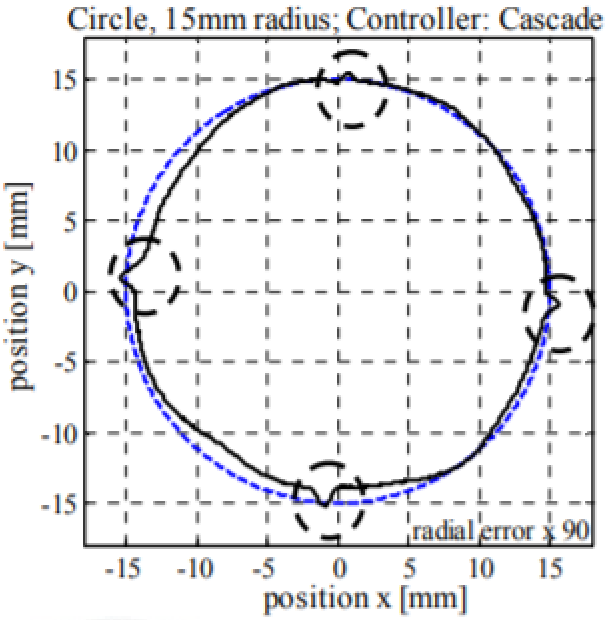

Figure 2.1: Quadrant glitches in circular test (Jamaludin, Brussel and Swevers, 2007)

2.1 Friction Behaviour

Friction is the force to one solid object moving around another, as reliable companies of the macroscopic universe are generally known. To compensate for friction, friction behavior, the quadrant glitches have to be defined and separated, as frictions affect the precision and accuracy of the systems' tracking and positioning. The movement resistance as one solid body slides over another (Al-Bender, 2005). The phenomenon of friction can be defined as two pre-sliding and sliding regions. The friction force depends on the device's speed in sliding region motion and involves Coulomb, stick-slip, Streibeck effect, and viscous friction (Choi, Kim and Han, 2004). Friction is defined as a relatively low speed-moving axis during the pre-sliding time. Besides, in the transition between sliding regimes, a smooth continuous curve is required (Rafan *et al.*, 2014). The frictional force in the pre-sliding area before the breakaway depends basically on the location of the mechanism.

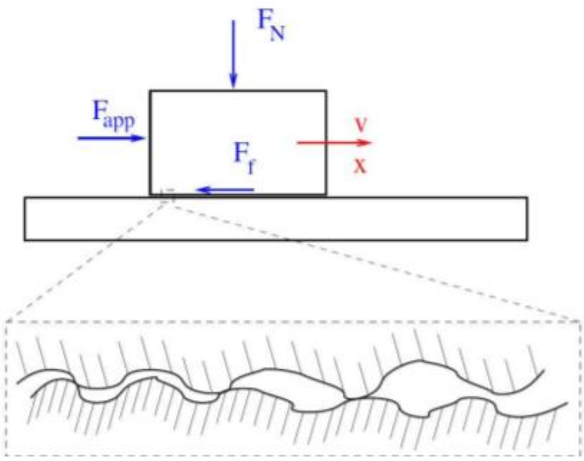

Figure 2.2: Basic friction configuration (Al-Bender and De Moerlooze, 2011)

Given Figure 2.2 shows friction as a mechanical tool, a detailed study of sliding shows two regimes of friction: the pre-sliding regime and the extreme sliding method. Due to the asperity contacts illustration in Figure 2.2, adhesive forces dominate the pre-sliding system, so the friction forces primarily depend on shift and not speed. This behavior explains that the friction junctions elastically deform and thus behave like non-linear hysterical sources (Al-Bender, 2010).

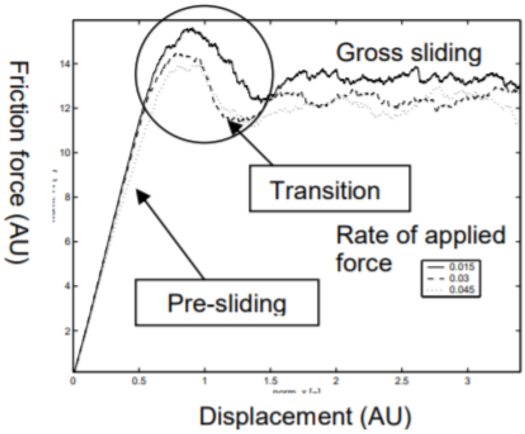

Figure 2.3: Both regimes of friction and their transition (Al-Bender and De Moerlooze, 2011)

2.2 Pre-sliding Behaviour

According to Al-Bender (2010), experiments indicate a hysteretic frictional force based on displacement during minimal changes in the pre-sliding system. Whenever an order is pre-sliding, as shown in Figure 2.3, the force-displacement comportment of the results Figure 2.4 is applied to the column. The location signal is chosen such that an internal loop is present within the external hysteresis loop. For the contrast right and left in Figure 2.5, the resulting friction location curve is frequencies independent.

This means that the traction position curve is independent of the speed of the position signal used. If the inner loop, which is c-d-c, is closed, the outer loop curve a-c-b is observed again to show non-local hysteresis information. The form of hysteresis's function depends on the distribution of asperity, tangential rigidity, and the normal rigidity of the relationship (Al-Bender and De Moerlooze, 2011).

The whole hysteresis behavior comes mainly from the breaking of adhesive contacts, as described below in the Maxwell-Slip model. The role of deformation losses in the bulk material is hysteresis losses, depending on the gravity of this part relative to both the adhesive component and the tangential rigidity of the asperities, which controls the degree of deformation before slipping.