UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## Faculty of Information and Communication Technology

# OPTIMIZATION OF PHYSICAL VAPOUR DEPOSITION COATING PROCESS PARAMETERS USING GENETIC ALGORITHM

**Mu'ath Ibrahim Mohammad Jarrah**

**Master of Computer Science**

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# OPTIMIZATION OF PHYSICAL VAPOUR DEPOSITION COATING PROCESS PARAMETERS USING GENETIC ALGORITHM

**MU'ATH IBRAHIM MOHAMMAD JARRAH**

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## DECLARATION

I hereby declare that this project report of master project entitle **"Optimization of Physical Vapour Deposition Coating Process Parameters Using Genetic Algorithm"** is the result of my own research except as cited in the references. The report of master project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……………………..…………………

Name : Mu'ath Ibrahim Mohammad Jarrah

Date : ……………………..…….…………….

# APPROVAL

“I/WE* hereby declare that I/WE* have read through this thesis and in my/we* opinion this thesis is sufficient in terms of scope and quality for the award for the degree Master of Computer Science (**Software Engineering and Intelligence**).

Signature: ………………………………...

Name: Dr. Abdul Syukor Mohamad Jaya

Date: ………………………………...

# ABSTRACT

Optimization of thin film coating parameter is an important task to identify the required output. In the process of physical vapor deposition (PVD), two main issues of the PVD process are cost of manufacturing and customization of the cutting tool properties. In general, a proper choice of the coating process parameters is very important to find the best characteristics of coating and towards less material usage, reduced trial in experiment and less machine maintenance. The aim of this study is to identify optimal PVD coating process parameters. Three process parameters were selected which are nitrogen gas pressure ($N_2$), argon gas pressure (Ar) and turntable speed (TT), while thin film grain size of titanium nitrite (TiN) was selected as an output response. In order to get output result, the three parameters were used to develop a polynomial quadratic equation that was designed using response surface methodology (RSM). Then, in order to optimize the coating process parameters, genetic algorithms (GAs) were used for the optimization work. The results showed that the optimized coating process parameters have lower grain size value compared to the actual experimental data and RSM with (≈6%) ratio and (≈0.03%) ratio, respectively.

# ABSTRAK


Pengoptimuman parameter salutan filem nipis adalah satu tugas yang penting untuk mengenal pasti output yang diperlukan. dalam proses pemendapan wap fizikal (PVD), dua isu utama proses PVD adalah kos pembuatan dan penyesuaian ciri-ciri alat pemotong. Secara umum, pilihan yang betul bagi parameter proses salutan adalah sangat penting untuk mencari ciri-ciri salutan yang terbaik dan ke arah penggunaan kurang bahan, mengurangkan percubaan dalam eksperimen dan kurang penyelenggaraan mesin. Tujuan kajian ini adalah untuk mengenal pasti parameter proses PVD salutan yang optimum. Tiga parameter proses yang telah dipilih ialah tekanan gas nitrogen ($N_2$), tekanan gas argon (Ar) dan kelajuan meja putar (TT), manakala saiz bijian filem nipis titanium nitrit (TiN) telah dipilih sebagai respon output. Dalam usaha untuk mendapatkan hasil output, tiga parameter digunakan untuk membangunkan persamaan kuadratik polinomial yang direka menggunakan metodologi respon permukaan (RSM). Kemudian, untuk mengoptimumkan parameter proses salutan, algoritma genetik (GAs) telah digunakan untuk kerja-kerta pengoptimuman. Hasil kajian menunjukkan bahawa parameter proses salutan yang dioptimumkan mempunyai nilai saiz bijian yang lebih rendah berbanding dengan data eksperimen sebenar dan RSM, masing-masing dengan nisbah (≈6%) dan nisbah (≈0.03%).

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| | | |
|---|---|---|
| ABC | - | Artificial Bee Colony |
| ACO | - | Ant Colony Optimization |
| ANOVA | - | Analysis of Variance |
| Ar | - | Argon |
| CVD | - | Chemical Vapor Deposition |
| GAs | - | Genetic Algorithms |
| PSO | - | Particle Swarm Optimization |
| PVD | - | Physical Vapor Deposition |
| RSM | - | Response Surface Methodology |
| $N_2$ | - | Nitrogen |
| SA | - | Simulated Annealing |
| TiN | - | Titanium Aluminum Nitrite |
| TT | - | Turntable Speed |

# CHAPTER I

# INTRODUCTION

## 1.1 Introduction

In today more technology based society, product manufacturers look for more cares to their products manufacturing systems in order to be as much as possible marketable, and thus competitive enough within their markets sector. And achieving a great level of surface quality on polished surface requires sufficient engineering creativity for such operational processes with in order to reach any desired specifications and result on the finished products. In common practice, modern manufacturers manage to obtain such result quality level based on past experience, published researchers work's guidelines to determine the machining parameters.

However, the processes generally involve choosing from various technical tools and methods. For instance, Taguchi parameter design and regression analysis help predict and optimize the surface roughness and metal removal rate in turning operations, whereas chemical vapor deposition (CVD) cutting tool is an example of tools associated with the implementation of this technique. The advancement in knowledge based machinery-tools or knowledge aided computer has contributed to the modern manufacturing works from various perspective. But, yet, the change in technologies and consumer's requirements make the perfection quality improvement an endless process to the responsibility of engineers.

One of the difficult tasks in engineering manufacturing works is the choice of optimal cutting parameters involved into a process planning of metal parts. That is due to the many solutions or design associated with a piece of art, including the variety of tools. However, genetic algorithms (GAs) are among common method used to improve many solutions of optimization complex problems. Apart from the existence of different tools and techniques that can execute a same work, there is also a need for understanding the features level for each of them in the matter of their use into process performance optimization. This project reviewed the ideal selection of coating parameters in turning operation of work material using physical vapor deposition (PVD) coated tool with GA.

Choosing correct optimal cutting parameters for every metal cutting process is not an easy task. Such parameters, which determine the cutting result quality requires an accurate control. Generally, a hand-out provides users with cutting parameters from the machining databases. But, the range that is given in these sources is actually only starting values, and is not for the optimal values. Therefore, coating parameters optimization is a crucial aspect to identify the output of chief importance, as closer to the designed optimization objectives. Many reasons behind the associated difficulty include the required: knowledge of machining; empirical equations relating the tool life, forces, power, surface finish, to develop realistic constrains; specification of machine tool capabilities; development of an effective optimization criterion; and knowledge of mathematical and numerical optimization techniques.

The benefits of coating process are obviously inherent to the main reason of optimization process. From above statements, a proper choice of coating parameters optimization is so important because this better help identify the output of a complex piece of art to its nearer designed optimization objectives. For instance, fewer mistakes, increased durability, and keeping its original polished look, are example of positive effect of coating powder in an object cutting process (Sharma *et al*. 2013), and (Adinarayana *et al*. 2014). In general, the characteristics of coating benefits are "less material usage, reduced trial in experiment, multi-purpose for same process and material enabled, and less maintenance required" (Jaya 2013).

However, different machining aspects in turning operation such power consumption, surface roughness, material removal rate, etc., are reviewed and discussed for GA used in the process. This chapter will cover the project objectives, study significance and the expected outcome as deliverable, including further detail on the study problem and a brief detail on the work methodology.

## 1.2 Problem Background

Machining cutting tool performance can be enhanced by implementing PVD coating process with the tools features. In general, the implementation of PVD coating process brings about manufacturing and cutting tool properties' customization costs (Jaya 2013). This author also cited (Niazi *et al*. 2006) and (Bradbury and Huyanan, 2000) in asserting that the required cares for tool and equipment, material usage, labor; and the need of decreasing machining time are broadly the justification of such manufacturing costs. Also, coated cutting tools' properties customization for usages like in milling, drilling and turning respectively cited here respectively as Weber *et al.*(2004), Settineri and Faga (2006), and Bouzakis *et al.*(2007) are some of common customization leading requests. However, the best coating characteristics have no direct formulas but are defined only out of trial and error in testing series (Zain 2010) and (Adinarayana *et al*. 2014).

In similar study, Zain (2010) in his work mentioned that "in formulating constraint values of the optimization technique, his study assumes that the optimal cutting conditions from the single system could be improved when they are integrated with other results of modeling and optimization techniques". Likewise, performance optimization of machining cutting needs a combination of at least one of related techniques if to maximize the occurrence of the expected improvement. Making use of mixed methods is almost in all practice: additional experiments are usually required to compare optimum values and their corresponding characteristics (Ozcelik *et al*. 2005).

In the best of works processes planning, a predictive model that includes the necessary coating parameters and characteristics is a more convenient method. That is so fine (for less experienced users) as it can help quickly locate the significant coating parameters, which let establish a relationship between both the parameters and the characteristics of coating process. Besides lot of discussions on existing approaches, theoretical background is necessarily a prerequisite knowledge for interested users intending to find relationship between parameter and characteristic of coating. However, RSM method is the most advisable due to its wide application over various research areas; (Jaya 2013) and citing (Chatterjee *et al.*, 2008; Karnik *et al.*, 2008) and (Kumar and Khamba, 2010; Md. Nizam *et al.*, 2010; Zhang Junwei *et al.*, 2010).

More as recommendation RSM technique is probe to gather less data with good designed experiments; and it can match and mapped out the input vs. output interaction in result forecasting (Md. Nizam *et al.*, 2010).

As concluding point overall discussed point in surveyed literatures, machinist's skills or working routines have never being enough to establish an everlasting machining process using a coated cutting. For human is subject to fatigue' influence inherent to impact poorly his/her intelligence over time. Therefore the use of an appropriate algorithm (e.g. GA) or any relevant study's method is necessary in technique design for machining process applying coated cutting system. And in today's information age, this can be developed and supported by an AI base knowledge to monitor the work processes.

## 1.3 Problem Statement

Manufacturing works common issues in machining process that combines coating with cutting tool is the need for accurate and convenient models in order to minimize the risks associated with the cost of using and adopting PVD coating system for such a purpose (Adinarayana *et al*. 2014). The benefits of using the method are huge and there are various methods and tools. However, the main challenges are the definition of an adequate algorithm to assist effectively and efficiently the works processes, while ensuring both coating optimum control and the finished objects with a desired result quality.

In fact, a good machining process using a coated cutting tool can be mainly achieved through the use of some friendly, trusted and accurate models. That is because of their efficiency and effectiveness link to the overall processes cost. Moreover, such models must be designed to enable the use of less of available data and offer good capabilities of controlling coating process to its preferable performance with low time demand. Relatively to the research scope, the aim of this study is to mainly learn how to develop PVD coating process models using GA for performance optimization in manufacturing works. Therefore, the following questions will be the most interesting to remember while carrying out this project chapters' coverage:

- Which parameters in PDV coating process are the most important with greater influence on this process?
- Which available modeling methods offer faster learning for the problem solving process?

Commonly in practice, machining coating process for cut object is learnt out of trial series, whose accuracy's quality is technically relative to the designer's skills. Thus it is necessary to have some models as guide for inexperienced machining users in order to well-predict a machining performance maximum outcome.

GA is among such great methods to determine coating better fit procedures. Obtaining a good algorithm for machining coating will be the marginal cost to avoid the actual finance's costs usually involved with experimental procedure (time, raw materials and execution requirements).

Many research works have produced and published some great coating and cutting performance optimization processes. But at least the need for continuous knowledge learning is one of the targets that support the motivation for undertaken this project study. Yet, proposing a new method is often among studies' practice; but attempt to solving this project's problem using GA is also interesting at least to the exposure in learning steps. To produce a complete research study for this topic is inapplicable under this study scope. Therefore, this is more about getting exposed to solving issues when using GA for the stated problem solution, according to the proposed objectives

## 1.4 Objectives

The main objective of this study is to study coating process. And coating methods aim at decreasing the cutting cost and the process of manufacturing time, increasing the effectiveness of cutting, as well as the tool's life and the quality of the machined product. Therefore, referring to the previous sections, namely the project background and problem statement, the study objectives can be summarized into the following three points:

i. to develop a mathematical model to represent relationship between PVD process parameters and TiN coating grain size using RSM approach.

ii. to optimize the PVD magnetron sputtering coating process using Genetic Algorithms (GAs) approach.

iii. to validate the developed model using actual testing data.

Due to study allocated time constraints and other reasons, with permission, this study will use existing experimental dataset from (Jaya 2013) works for model development and validation.

## 1.5 Research Scope

This project study's scope will be as stated bellow.

a) The study will concentrate more on the coating process rather than the cutting process.

b) Considering the project's completion time constraints, this study also will focus of the design aspects in order to maximize the greater chance for more knowledge discovery. And in attempt to real exposure, the validation stage will apply a historical dataset borrowed from an outstanding research works as stated in above research objectives section.

c) And from the above two points, our study will attempt to comply narrowly with some scope's points under (Jaya 2013) works of which agreement is made for dataset reuse in study process result validation.

## 1.6 Study Significance

The foremost significance of this project work is to apply my knowledge into and learn more from studying a process of coating by applying GA in this case. To a wide extent, this study is intended to increase learning about reducing trial and error experiments in PVD magnetron sputtering coating process using when applying GA. In future study program, the current work outcome will probably serve as good preliminarily study for a fast move forward to achieve a complete research work problem’s solution in similar or other real-life manufacturing issues. It will be also helpful at least as a good theoretical design for other students’ study project.

The overall gained knowledge on PVD magnetron sputtering coating process using GA study will be a great input as well a strong motivation for my involvement in other industry research works due to being exposed, and having explored to some extents the complexity of such research works. Hence, the resulting learning throughout this project will lead to a possible good management. And beyond, it will be a great satisfaction in completing my study program.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Introduction

This chapter opens up on Section 2.2 with a brief introduction to coating process, with focus on PVD process parameters linked to coating and come modelling essential technique. Also some important coating are analysed; and the chapter ends with some related works' reviews.

## 2.2 PVD Magnetron Sputtering Process

In this process, an inert gas is used to produce high pressure sufficient to bombard and fuse the material's surface. The material fusion takes place into an empty room under high pressure, which actually enables the coating process by bombing the ions. Argon is known as the most applicable gas in this system.

Figure 2.1, shows a sample scenario into such a process. The different colours and arrows' direction illustrate the complex phenomenon occurring during the process, but their details are beyond the scope of this study.

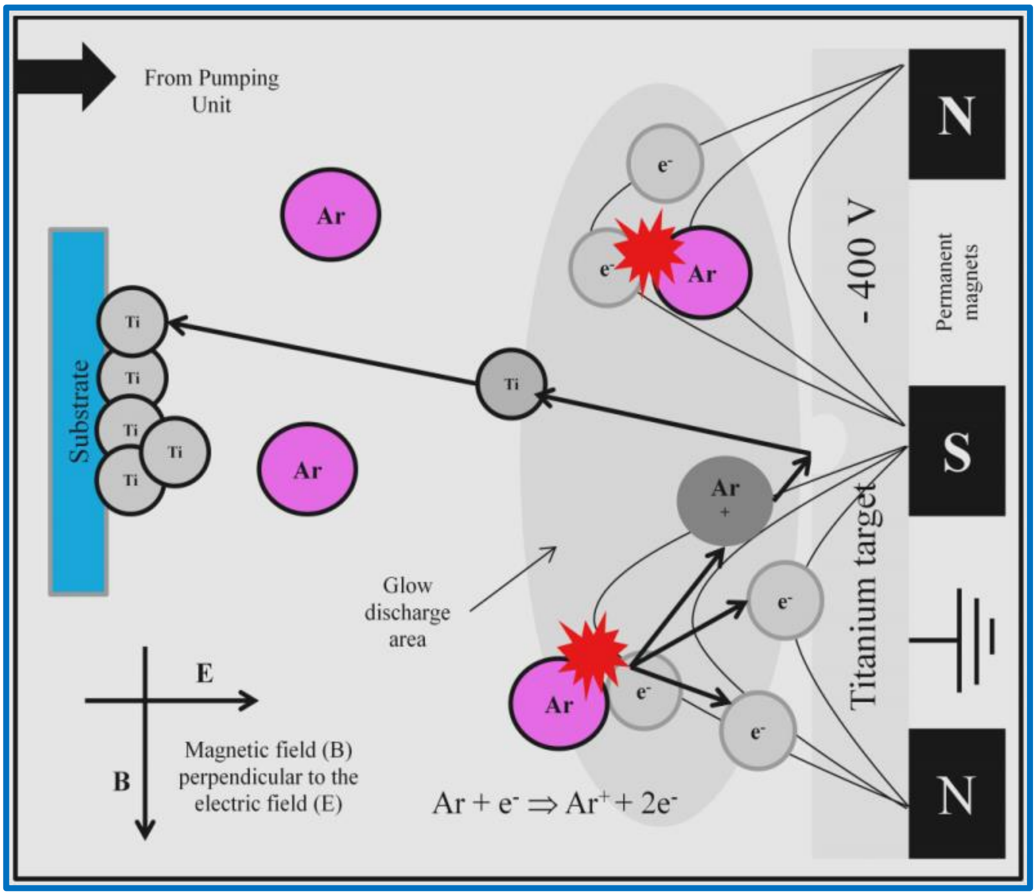


Figure 2.1 : Magnetron Sputtering Process Illustration

### 2.2.1 Magnetron Sputtering Significant Parameters

By definition, coating or shortly covering layer refers to a layer of a substance spread over a surface for protection or decoration. During magnetron sputtering – i.e. the magnetic technique to trap electrons, which will collide with Ar to form $Ar^+$; then $Ar^+$ will pump the negative Ti (Titanium) target to release Ti atom, and Ti atom will coat the substrate. In the process, three coating parameters are important to be controlled such as: $N_2$ gas pressure, Ar gas pressure and turntable speed.