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JUDUL: ANALYSIS OF REFRIGERATION SYSTEM WORKING WITH NANOLUBRICANT

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OPTIMIZATION OF ABRASIVE MACHINING OF DUCTILE CAST IRON USING WATER BASED ZnO NANOPARTICLES: A SUPPORT VECTOR MACHINE APPROACH

MOHD SYAH WALIYULLAH AD-DAHLAWI BIN MAT RAZALI

Report submitted in partial fulfillment of the requirements for the award of Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
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UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Optimization of Abrasive Machining of Ductile Cast Iron using Nanoparticles: A Support Vector Machine Approach*" is written by *Mohd Syah Waliyullah Ad-Dahlawi Bin Mat Razali*. I have examined the final copy of this project and in my opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

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

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Special thanks to my parents who always believe and support me and

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ABSTRACT

This project presents the optimization of abrasive machining of ductile cast iron using water based ZnO nanoparticles. This study were carried out to investigate the performance of grinding machine of ductile cast iron based on response surface methodology (RSM), to develop optimization model for grinding parameters using support vector machine (SVM) and to investigate the effect of water based ZnO nanoparticles in grinding machine. Analysis of variance has been carried out to check the adequacy of the experimental results. The mathematical modeling has been developed using response surface methodology to investigate the performance of grinding machine of ductile cast iron. The optimization model of grinding parameter was developed and the effect of water based ZnO nanoparticles was investigated. From the obtained results, the optimum parameter for grinding model is 30m/min table speed and 40µm depth of cut. The quality of product was determined by output criteria that are minimum temperature rise, minimum surface roughness and maximum material removal rate. Based on prediction data from RSM shows that 2^{nd} order gives the good performance of grinding machine with the significant p-value of analysis of variance that is below than 0.05 and support with R-square value nearly 0.99. Based on the support vector machine (SVM) results, high depth of cut and low table speed gives high quality of product. It shows that SVM result is acceptable since the results was the same as obtained results from response surface methodology (RSM) and can be used to optimize the grinding machine. The results also shows that water based ZnO nanoparticles as a nanocoolant give impact to the temperature rise. It gives temperature rise almost zero compared to conventional coolant. High temperature rise will affect the surface roughness of product, so that it is very efficiency to choose water based ZnOnano particles as a nanocoolant. As the conclusion, the results obtained from this project can be used to optimize the precision grinding machine to get high quality of product using water based ZnO nanoparticles.

ABSTRAK

Tesis ini adalah tentang mengoptimumkan parameter pemipisan besi tuang mulur dengan menggunakan air yang berdasarkan nanopartikel ZnO. Kajian telah dibuat untuk menyiasat prestasi pemipisan mesin besi tuang mulur berdasarkan kaedah respons permukaan (RSM), untuk membangunkan model pengoptimuman untuk parameter mengisar menggunakan pendekatan sokongan vector mesin (SVM) dan untuk mengkaji kesan air berdasarkan nanopartikel ZnO dalam pemipisan mesin. Analisis varians telah dilakukan bagi memastikan kesahihan data yang diperolehi. Matematik model telah dibuat dan kesan air berdasarkan nanopartikel ZnO. Daripada ujikaji tersebut, optimum parameter bagi model pemipisan adalah 30m/min kelajuan meja dan 40μm kedalaman potongan membolehkan mempunyai kualiti produk yang terbaik. Kualiti produk telah ditentukan oleh beberapa kriteria. Kriteria tersebut ialah kenaikan suhu minimum, kekasaran permukaan minimum dan kadar pemipisan bahan maximum. Berdasarkan data ramalan daripada RSM menunjukkan bahawa persamaan tahap kedua memberikan prestasi mesin pemipisan yang baik dengan nilai p dibawah 0.05 dan sokongan R kuasa dua hampir 0.99. Berdasarkan keputusan mesin sokongan vektor, kedalaman pemotongan yang tinggi dan kelajuan meja yang rendah akan menghasilkan produk yang bermutu tinggi. Ini telah menunjukkan bahawa SVM boleh diterima pakai disebabkan keputusan yang diperolehi sama dengan keputusan RSM dan boleh digunakan untuk mengoptimumkan mesin pemipisan. Keputusan yang diperolehi juga menunjukkan bahawa air yang berdasarkan nanopartikel ZnO telah memberikan kesan terhadap kenaikan suhubahan. Kenaikan suhu yang tinggi akan menyebabkan kerosakan pada produk, oleh itu dengan menggunakan air yang berdasarkan nanopartikel ZnO adalah memuaskan. Sebagai kesimpulan, keputusan keseluruhan yang diperolehi daripada projek ini boleh diguna pakai untuk mengoptimumkan mesin pemipisan untuk mendapatkan hasil produk yang berkualiti tinggi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

ϕ	volume concentration in percentages (%)
ω	weight in percentages (%)
ρ_w	density of water
ρ_p	density of nanoparticles
ΔV	amount of distilled water
V_1	volume nanoparticles
ϕ_1	old concentration
ϕ_2	new concentration

LIST OF ABBREVIATIONS

TS	Table speed
DOC	Depth of cut
T	Temperature rise
R_a	Arithmetic average surface roughness
MRR	Material removal rate

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Nowadays, the grinding process is widely used especially in mechanical engineering field. Grinding is a material removal and surface generation process used to shape and finish components made of metals and other materials (Shen et al., 2008). The precision and surface finish obtained through grinding can be up to ten times better than with either turning or milling. Temperature also can give effect to workpiece. Such high temperatures can cause thermal damage to the workpiece, which affects the workpiece quality and limits the process productivity (Malkin and Guo, 2007). The input parameters (types of wheel, types of coolant and depth of cut) can improve the quality of the product. The output parameters in order to choose the best quality of product produced that are surface roughness, tool wear, thermal temperature and material removal rate (MRR).

Coolant is the liquids use to keep surface of the work piece cool. It also can enhance cutting process such as quality of the product. Nanofluids have the potential to be next generation of coolants due to their significantly higher thermal conductivities (Zhang et al., 2009). The nanofluids with various concentrations using grinding machine to optimize the grinding machine of ductile cast iron when using water based ZnO nanoparticles as a coolant. The experiment on conventional coolant in order to compare the result with water based ZnO nanoparticles as a coolant. Ductile cast iron frequently referred to as nodular or spheroid graphite iron is a recent member of the family of cast irons. It contains spheroid graphite in the as cast condition, through the addition of nucleating agents such as cerium or magnesium to the liquid iron. Ductile cast iron is essentially a family of materials with a wide verity of properties which are satisfactory for different engineering requirements. Currently, the ductile cast iron usually in many automotive components, where strength needs surpass that of aluminum but do not necessarily requires steel. Furthermore, ductile cast iron also can be found as a pipe where ductile cast iron is much stronger than other pipe, requires less support and provide greater flow. Therefore ductile cast iron is considered as a workpiece material.

1.2 PROBLEM STATEMENT

The quality of surface finish is an significant requirement for many grinded workpieces. The choice of optimized cutting parameters is very important for controlling the required surface quality. Grinding is the most precise machining process that is used to improve surface roughness of the work piece. It has tactile contact where when it touches the surface of the object can feel the surface roughness, waviness, texture and other scratches. Besides that the effect of coolant very important because to reduce surface cracking and subsurface damage. Nanofluids are formed by dispersing nanoparticles in base fluids such as water. It has been reported that the thermal conductivities of nanofluids increase dramatically due to the high thermal conductivity of solid particles suspended in the heat-transfer fluid (Chen et al., 2008). The suitable parameters needs because it can affect the surface texture been rougher, and the surface is not shining. The parameters that should be optimized are types of coolant, table speed and depth of cut. The results of experiment must consider in different perspective of a parameter to obtain accurate results. The manufacturing industry will have an alternative method in saving the cost of production and increasing production. By determining the optimum parameters for abrasive machine, the industry could use the method to optimize the parameters such as depth of cut, table speed and types of coolant. In normal situation, workers who handle an abrasive machine must have specific experience and skills. This study helps the non-experience worker to handle the abrasive machine in the obtaining optimum parameters used, on the other hands, by using nanofluid as a coolant in order to get the best-quality surface roughness and good dimension of product. Thus, further study is needed in order to accomplish the vision and within given the limitation.

1.3 OBJECTIVES OF PROJECT

The objectives of this project are as follows:

1) To investigate the performance of grinding machine of ductile cast iron based on response surface method.
2) To develop optimization model for grinding parameters using support vector machine technique.
3) To investigate the effect of water based ZnO nanoparticles in the precision surface grinding.

1.4 SCOPES OF PROJECT

This study focus on optimization of abrasive machining of ductile cast iron using water based ZnO nanoparticles. Therefore, the scopes of the project are needed as a guide in order to achieve the objectives. There are several scopes as follows:

1) Design the experiment for grinding process and preparation of 0.1% water based ZnO nanoparticles.
2) Perform experiment on grinding machine utilizing abrasive grinding wheel, water based ZnO and ductile cast iron.
3) Perform surface roughness and material removal rate analysis.
4) Analysis data using response surface methodology and support vector machine approach.

1.5 ORGANIZATION OF PROJECT

Chapter 2 is about the literature review that will be focused on recent past studies related to the effect of grinding process parameters. Chapter 3 presents the methodology that will be conducted for this process by the design of experiment, setup of machine, selection of parameters, experiment layout and others. Chapter 4 is about the MRR, surface roughness and G–ratio when increasing the depth of cut, types of wheel and grinding direction in order to get the best and optimum parameters should be used to get the best product. Chapter 5 is about the conclusion of this project from all the experiment conducted. This chapter also will summarize the findings and recommendation for the future work.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter briefly explains about the grinding, ductile cast iron, nanoparticles, response surface method and support vector machine. Grinding is widely used as the finishing machining process for components that require smooth surfaces and precise tolerances. A large volume of grinding fluid is most commonly used to flood the grinding zone, hoping to achieve tangible productivity targets while often neglecting the seemingly less tangible environmental and safety hazards. In addition, the inherent high cost of disposal or recycling of the grinding fluid becomes another major concern, especially as the environmental regulations get stricter. Minimizing the quantity of cutting fluid is desirable in grinding (Shen et al., 2008). Grinding is a very important finishing process in the automotive industry and often requires close tolerance and high surface finish. Material removal rates in grinding are limited because of chatter and other problems such as thermal damage (Walsh et al., 2002).

In material removal operations, the role of grinding process is indispensable, especially in finishing operations that demand close tolerances, for application such as bearings, pin joints, shafts, etc. Grinding is an abrasive process, where the workpiece is forced against the grinding wheel. As a result of abrasive wear, the process generates chips that are removed from the workpiece surface (Shen et al., 2008). During grinding, most of the input energy is converted into heat, causing high temperatures particularly at the wheel-workpiece interface (the small portion of the grinding wheel actually in contact with the workpiece). Such high temperatures can cause thermal damage to the workpiece, which affects the workpiece quality and limits the process productivity

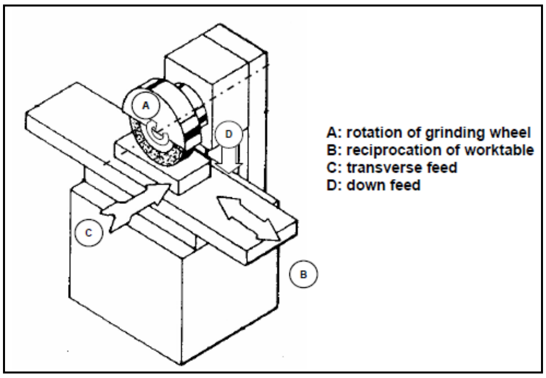
(Malkin et al., 2007). Grinding wheel wear is also a major concern. To control heat and wheel wear or to improve the grinding performance, a heavy amount of grinding fluids (coolant) is used. The conventional cutting fluids used in grinding are considered a problem, as these substances can cause a large amount of mist, which is environmentally challenging and is expensive (Silva et al., 2005).

The machining processes have an important place in the traditional production industry. Cost-effectiveness of all machining processes has been eagerly investigated. This is mainly affected selection of suitable machining parameters like cutting speed, feed rate and depth of cut according to cutting tool and workpiece material. The selection of optimum machining parameters will result in longer tool life, better surface finish and higher material removal rate (Cakir, 2007). During machining process, friction between workpiece-cutting tool and cutting tool-chip interfaces cause high temperature on cutting tool. The effect of this generated heat decreases tool life, increases surface roughness and decreases the dimensional sensitiveness of work material. This case is more important when machining of difficult-to-cut materials, when more heat would be observed. Various methods have been reported to protect cutting tool from the generated heat. Choosing coated cutting tools are an expensive alternative, and generally, it is a suitable approach for machining some materials such as titanium alloys, heat resistance alloys (Cakir, 2007).

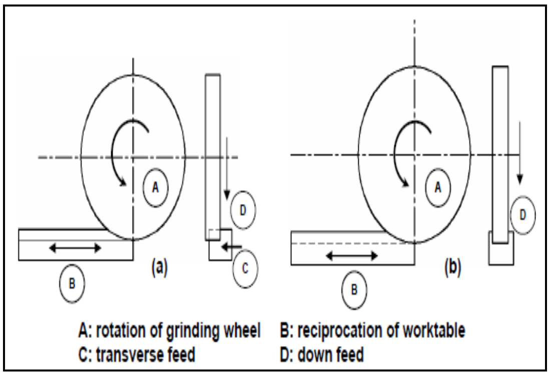
2.2 TYPES OF GRINDING MACHINE

There are many type of grinding machine use to obtain high accuracy along with high class of surface finish on the workpiece. Conventional grinding machines can be broadly classified as surface grinding machine, cylindrical grinding machine, internal grinding machine, and tool and cutter grinding machine.

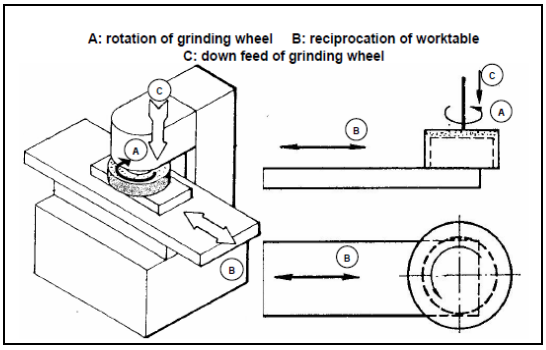
Surface grinding Machine: This machine may be similar to a milling machine used to grind flat surface. However, some types of surface grinders are also capable of producing contour surface with formed grinding wheel. There are four different types of surface grinding machines. Figure 2.1(a) shows this machine with various motions required for grinding action. A disc type grinding wheel performs the grinding action with its peripheral surface. Figure 2.1(b) shows that both traverse and plunge grinding can be carried out.



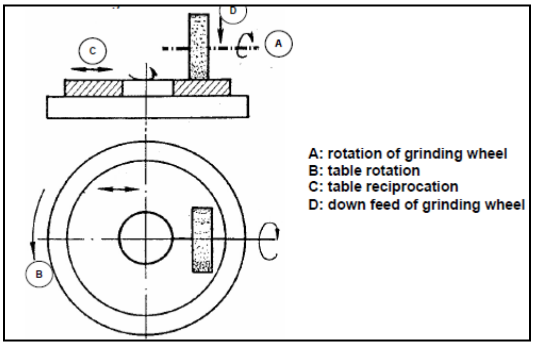
(a) Horizontal spindle reciprocating table



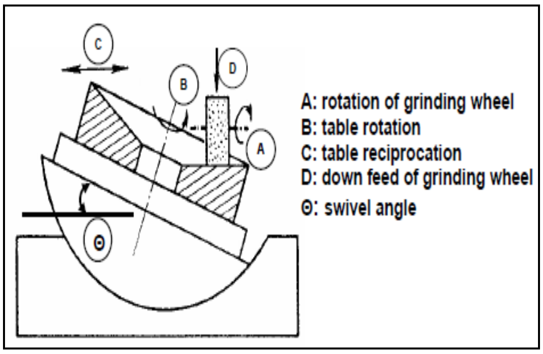
(b) Surface grinding



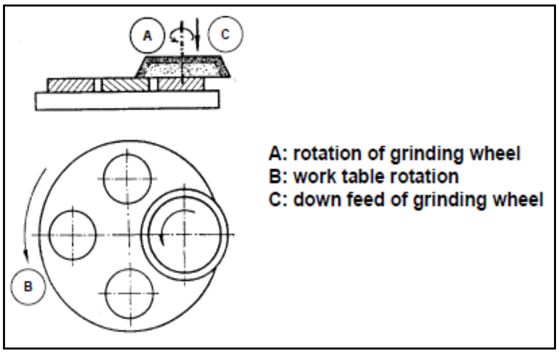
(c) Vertical spindle reciprocating table



(d) Horinzontal spindle rotary table



(e) Horinzontal spindle tapered surface



(f) Vertical spindle rotary table

Figure 2.1: Various types of grinding machine.

Figure 2.1(c) shows that the grinding operation is similar to that of face milling on the vertical milling machine and shows that in this machine a cup shaped wheel grind the workpiece over its full width using end face of the wheel. This bring more grits in action at the same time and consequently a higher material removal rate (MRR) may be attained than for grinding with a peripheral wheel. The principal of this machine is similar as that for facing on the lathe. This machine has a limitation in accommodation of workpiece and therefore does not have wide spread use. However, by swiveling the worktable, concave or convex or tapered surface can be produced on individual part as illustrated in Figure 2.1(d) and 2.(e). This machine is only suitable for small size of workpieces but in large quantities. This primarily production type machine often uses two or more grinding heads thus enabling both roughing and finishing in one rotation of the work table as shows in Figure 2.1(f).

Creep Feed Grinding Machine: This machine enables single pass grinding of a surface with a larger down feed but slower table speed than adopted for multi-pass conventional surface grinding. This machine is characterized by high stiffness, high spindle power, recirculating ball screw drive for table movement and adequate supply of grinding fluid.

High Efficiency Deep Grinding Machine: The concept of single pass deep grinding at a table speed much higher than what is possible in a creep feed grinder has been technically realized in this machine. This has been made possible mainly through significant increase of wheel speed in this new generation grinding machine.

Cylindrical Grinding Machine: This machine is used to produce external cylindrical surface. The surfaces may be straight, tapered, steps or profiled. There are three different types of the cylindrical grinding machines. Figure 2.2 illustrates schematically plain center type cylindrical grinder machine and various motions required for grinding action. The machine is similar to a centre lathe in many respects. The workpiece is held between head stock and tailstock centres. A disc type grinding wheel performs the grinding action with its peripheral surface. Both traverse and plunge grinding can be carried out in this machine as shown in Figure 2.3. Universal cylindrical grinder is similar to a plain cylindrical one except that it is more versatile. In addition to small worktable swivel, this machine provides large swivel of head stock, wheel head slide and wheel head mount on the wheel head slide. This allows grinding of any taper on the workpiece. Universal grinder is also equipped with an additional head for internal grinding.

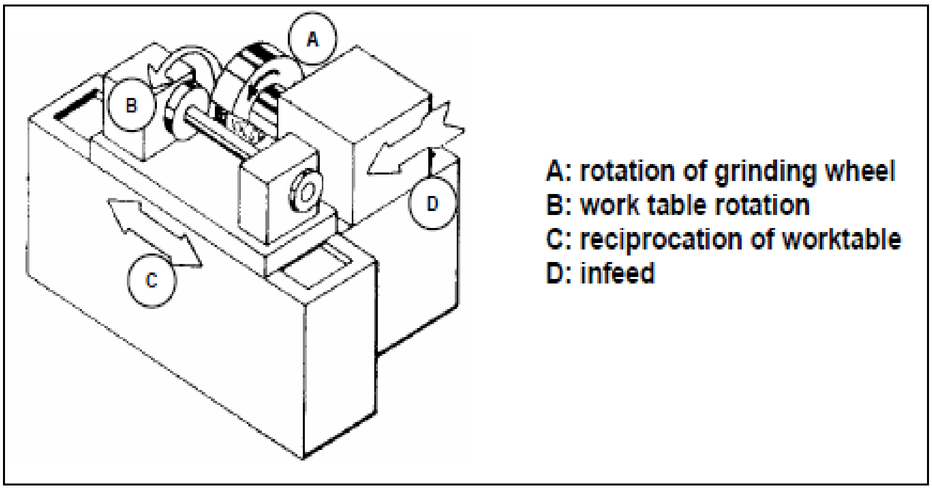


Figure 2.2: Plain center type cylindrical grinder machine

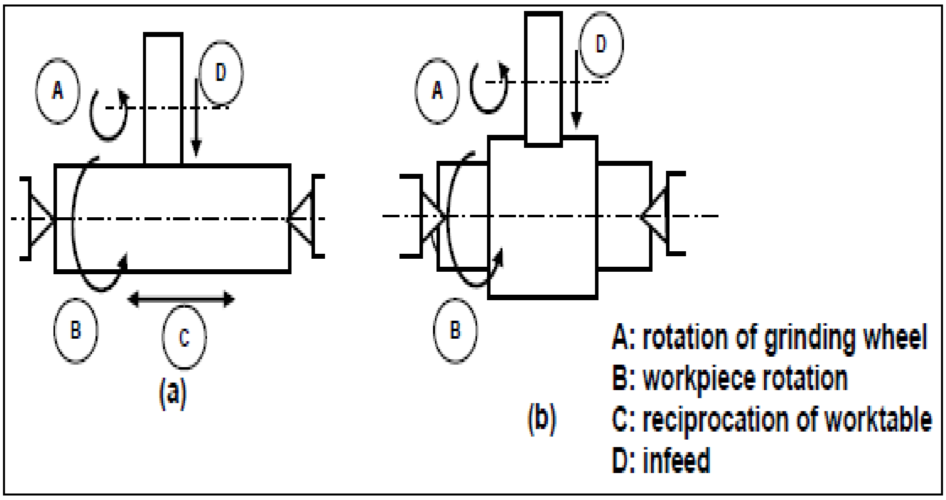


Figure 2.3: Cylindrical (a) Traverse grinding (b) Plunge grinding

Schematic illustration of important features of this machine is shown in Figure 2.4. External centreless grinder is grinding machine is a production machine in which outside diameter of the workpiece is ground. The workpiece is not held between centres but by a work support blade. It is rotated by a regulating wheel and ground by the grinding wheel. In a through-feed center less grinding, the regulating wheel revolving at a much lower surface speed than grinding wheel controls the rotation and longitudinal motion of the workpiece. The regulating wheel is kept slightly inclined to the axis of the grinding wheel, and the workpiece is fed longitudinally as shown in Figure 2.5.

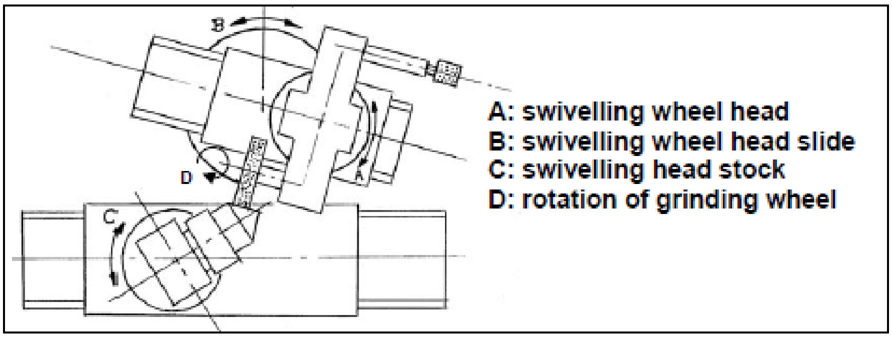


Figure 2.4: Important features of universal cylindrical grinding machine.

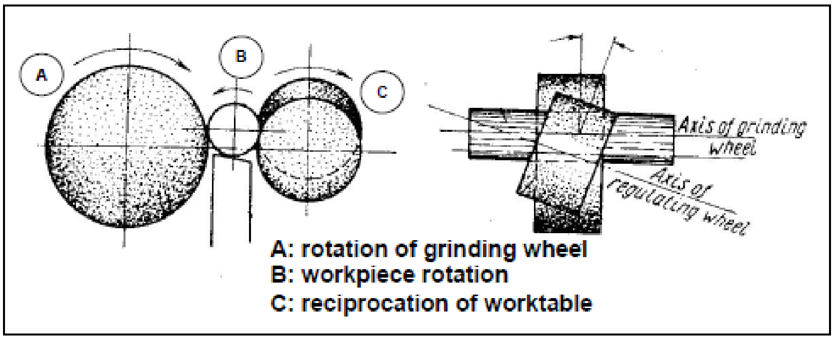


Figure 2.5: Center less through fees grinding

Parts with variable diameter can be ground by Center less in feed grinding as shown in Figure 2.6 (a). The operation is similar to plunge grinding with cylindrical grinder. End feed grinding shown in Figure 2.6 (b) is used for workpiece with tapered surface. The grinding wheel or the regulating wheel or both require to be correctly profiled to get the required taper on the workpiece.

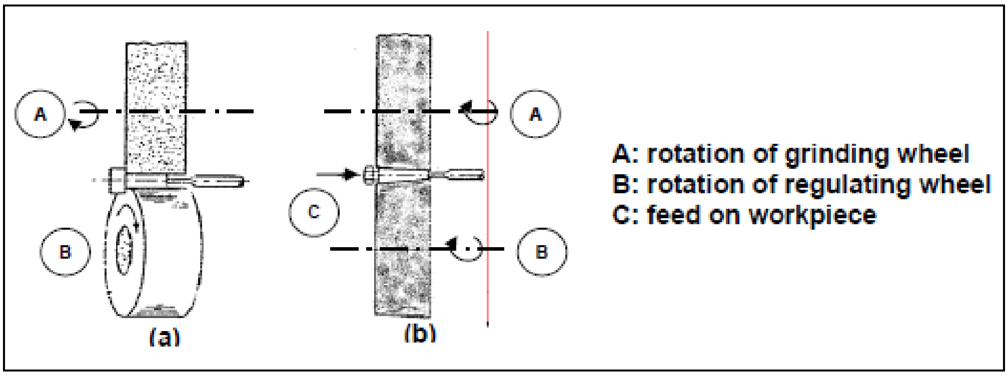


Figure 2.6: Center less (a) In feed; (b) End feed grinding

Internal Grinding Machine: This machine is used to produce internal cylindrical surface. The surface may be straight, tapered, grooved or profiled. Broadly there are three different types of internal grinding machine as follows:

Figure 2.7(a) illustrates schematically chucking type internal grinder machine and various motions required for grinding action. The workpiece is usually mounted in a chuck. A magnetic face plate can also be used. A small grinding wheel performs the necessary grinding with its peripheral surface. Both transverse and plunge grinding can be carried out in this machine as shown in Figure 2.7(b). Planetary internal grinder is used where the workpiece is of irregular shape and cannot be rotated conveniently as shown in Figure 2.8. In this machine the workpiece does not rotate. Instead, the grinding wheel orbits the axis of the hole in the workpiece.

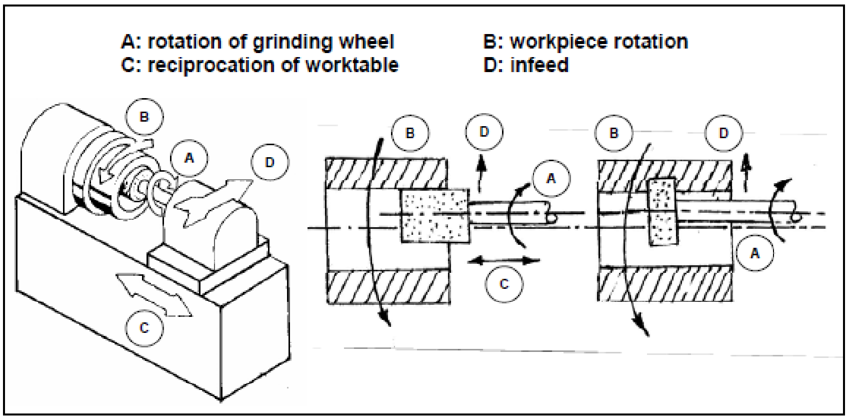


Figure 2.7: (a) Internal Center less grinder (b) Internal (traverse grinding and plunge grinding)

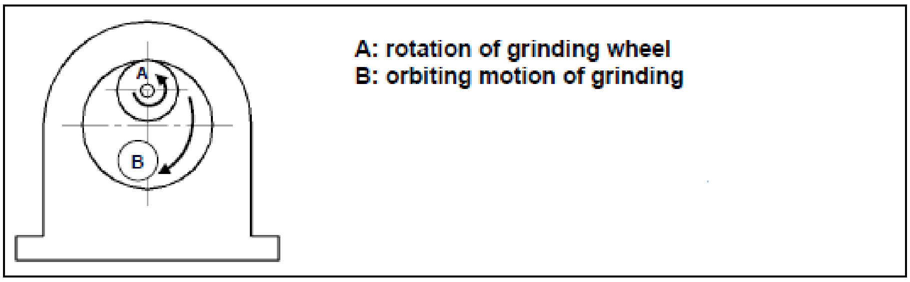


Figure 2.8: Internal grinding in planetary grinder

Center less internal grinder machine is used for grinding cylindrical and tapered holes in cylindrical parts. The workpiece is rotated between supporting roll, pressure roll and regulating wheel and is ground by the grinding wheel as illustrated in Figure 2.9.

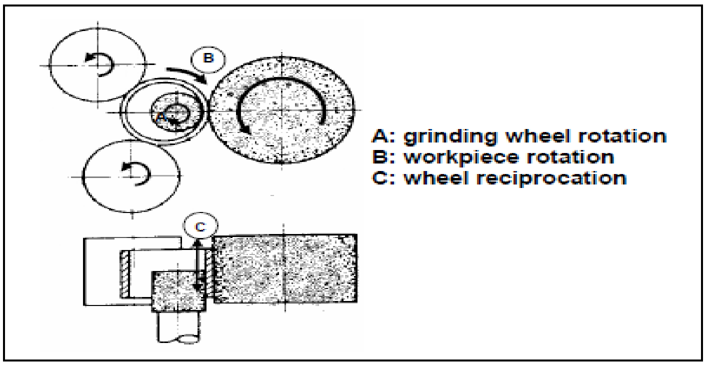


Figure 2.9: Internal center less grinding

Tool and Cutter Grinder Machine: Tool grinding may be divided into two subgroups: tool manufacturing and tool resharpening. There are many types of tool and cutter grinding machine to meet these requirements. Simple single point tools are occasionally sharpened by hand on bench or pedestal grinder. However, tools and cutters with complex geometry like milling cutter, drills, reamers and hobs require sophisticated grinding machine commonly known as universal tool and cutter grinder. Present trend is to use tool and cutter grinder equipped with CNC to grind tool angles, concentricity, cutting edges and dimensional size with high precision.

2.3 SELECTION OF PROCESS PARAMETERS

The productivity, accuracy and cost of grinding processes depend to a considerable extent on the correct choice of process parameters, as the advantages of a good machine and a correct wheel can be lost by operating them under unfavorable conditions. The wheels used in precision grinding operations are normally not self-dressing, wheel wear in grinding is quite small and the cutting efficiency tends to gradually decrease. This means that the wheels should be dressed periodically to restore cutting efficiency and accuracy. Since considerable time and wheel wear is involved in dressing, it is necessary to optimize conditions in such a way as to maximize the period between dressings. These factors that lead to frequent dressings:

Loss of Cutting Efficiency: The cutting efficiency of a wheel is its ability to remove material at a sufficiently fast rate without causing problems of burns, cracks or excessive deflections. The cutting efficiency of a wheel is maintained by the process of abrasive fracture and exposure of fresh cutting edges. Rapid loss of cutting efficiency due to wheel glazing can be combated by increasing the severity of the operation, i.e. by increasing the feeds, depth-of-cut, etc. In extreme cases it may be necessary to use a softer wheel and simultaneously use a coarser grit size if the finish is not a criterion. Quite often, loss of cutting efficiency is accompanied by the appearance of chatter marks on the job surface, after grinding a few pieces. This is sometimes due to a hard wheel. However, the presence of chatter marks immediately after dressing indicates that the wheel is not balanced properly.

Loss of Form and Accuracy: When grinding profiled jobs, the wheel is dressed to the required form. This form is gradually distorted due to uneven wear and necessitates redressing. In such cases, the frequency of dressing can be minimized by reducing the grinding allowance and the severity of the operation. It should be appreciated that the frequency of dressing is always more when profiled jobs are ground, and this is unavoidable. A few specific problems that occur in precision grinding are discussed below:

Dressing: A point which should be noted is that wheel wear in dressing is substantially more than wheel wear in grinding. Most operators have a tendency to dress the wheel more than is necessary and these only results in reduced wheel life. It is recommended to remove only about 0.1 mm radial depth in dressing by taking two or three cuts of 0.02 - 0.03 mm depth after the diamond dressing tool touches the wheel throughout its width. An important aspect of the dressing operation is that it can be modified, to alter the cutting efficiency of the wheel and surface finish off the job. Thus, coarse dressing with a diamond traverse rate of 400-500 mm/min will result in a wheel with fast cutting action and a rough finish, while fine dressing with a traverse rate of 100-200 mm/min will result in a better finish. It is also possible to make a number of diamond passes at rates of 50-100 mm/min without in feed to produce a wheel-condition giving a fine finish. The latter approach is particularly useful when only a few special parts have to be made to the best surface finish in a tool room or maintenance shop. An important corollary to the above statements is that fine dressing should not be done when a free cutting wheel is required for production grinding. The influence of dressing has been discussed earlier. A typical study showed that a 46-grit cylindrical grinding wheel produced a surface finish of 30 micro inches CLA when dressed at a diamond traverse rate of 500 mm/min. Reduction of the traverse rate to 100 mm/min resulted in a 12 micro inch CLA finish.

Balancing: Proper balancing of the grinding wheel is an essential prerequisite if good results are to be obtained in precision grinding. This is because an imbalanced wheel rotating at high speeds causes severe vibrations of the spindle and leads to chatter marks on the job, damage to spindle bearings, etc. Modern machines are sometimes equipped with automatic balancing devices. However, static balancing stands are still widely used. Experience has shown that much time is lost on balancing if operators are not trained in correct balancing techniques.

Surface Finish: One of the main considerations in the choice of precision grinding processes is the required surface finish on the job. There is a widespread belief that jobs should always be ground to a very fine finish. This is totally unwarranted and can be compared to a statement that all parts should be ground to a tolerance of, say, 5microns. Such arbitrary job specifications only create difficulties during manufacture without contributing to the functional quality of the parts. The problems are further compounded by the absence of reliable evaluation methods on the shop-floor and the consequent dependence on the subjective views of the operator. It is extremely important to specify surface finishing quantitative terms, i.e., in microns R_a or micro inches CLA, so that a proper evaluation can be made on the relevant instruments at least on a sampling basis. Quite often, problems are encountered on the shop-floor in achieving the desired finish. This parameter is no doubt considered when choosing the wheel specification, but the end result is dependent on the operating conditions. The factors affecting surface finish are discussed below.

Spark-Out: It is found that the surface finish is inversely proportional to the depth-of-cut in grinding, low depth-of-cut results in a better finish and vice-versa. Therefore, the obvious way to improve finish is to reduce the depth-of-cut to a minimum value. However, in practice, the machine-tool feed mechanisms cannot give very low in feed values owing to various design constraints. This problem can be overcome by the process of spark-out. During grinding, the entire system is subjected to deformations under the action of the cutting forces. Thus, the job deflects considerably in cylindrical grinding, and the wheel spindle deflects appreciably in internal grinding. Even if wheel in feed is stopped at a given moment, material removal continues due to a gradual reduction in the deflections of various parts. This process is called spark-out. As the deflections are quite small, the corresponding depth-of-cut during spark-out is also small and gradually reduces to zero. This explains why spark-out is extremely effective in improving surface finish.

Cutting Parameters: Beside the depth-of-cut, surface finish is also influenced by other cutting parameters. The finish can be improved somewhat by reducing the job speed and reducing the traverse feed

Cutting Fluids: The influence of cutting fluids on surface finish is relatively small and, in general fluids with greater lubricating action impart a somewhat better finish. The more important point is to ensure proper filtration of the fluid because suspended particles of abrasive and metal can cause deep scratches. Isolated scratch marks are a sure sign of dirty fluid. The remedy in such cases is to clean the tank and use magnetic separators at frequent intervals.

2.4 PARAMETERS THAT AFFECTING SURFACE FINISH

Grinding machine can give the best surface finish to product. However, there are parameters that can highly affect surface finish to workpiece. Parameters that can affect surface of workpiece are grinding forces, dressing mode, cutting fluid and depth of cut.

Grinding Force: As is well known, grinding force is one of the most important parameters in evaluating the whole process of grinding. Generally, the grinding force is resolved into three component forces, namely, normal grinding force F_n, tangential grinding force F_t and a component force acting along the direction of longitudinal feed which is usually neglected because of its insignificance. The normal grinding force F_n has an influence upon the surface deformation and roughness of the workpiece, while the tangential grinding force Ft mainly affects the power consumption and service life of the grinding wheel. Figure 2.10 shows the force plays an important role in grinding process since it is an important quantitative indicator to characterize the mode of material removal (Agarwal and Rao, 2007).

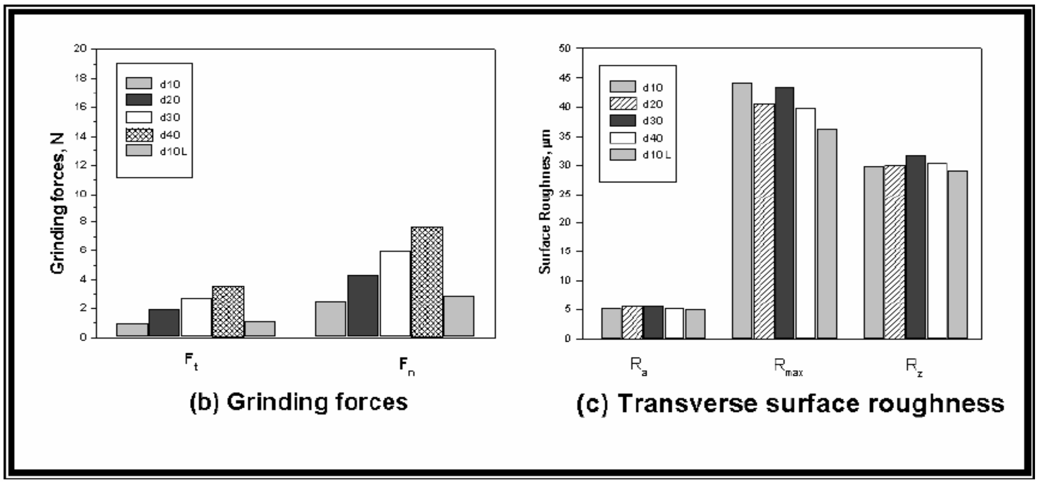


Figure 2.10: Grinding force versus depth of cut graph

Grinding parameters such as the grinding velocity, traverse speed or wheel depth of cut affects the grinding force which in turn can cause fracture, rounding on few overlying grits thus, bringing more number of underlying grits into action. This change in topographical feature of single layer wheel, in various levels, affects the surface roughness of the workpiece. Grinding force increases with decrease in grinding velocity while the same increases with increase in table speed and depth of cut. Accordingly a trend is observed on decrease of surface roughness with decrease in grinding velocity and increase of both traverse speed and wheel depth of cut.

Cutting Fluids: A coolant is a fluid that flows through a machine in order to prevent it from overheating. The best coolant has high thermal capacity, low viscosity, low-cost, non-toxic, and chemically inert, neither causing nor promoting corrosion of the cooling system (Cakir, 2007). The cutting fluids applied in machining process basically have three characteristics. These are:

Cooling effect: The cooling effect of cutting fluids is the most important parameter. It is necessary to decrease the effects of temperature on the cutting tool and machined workpiece. Therefore, a longer tool life will be obtained due to less tool wear and the dimensional accuracy of machined workpiece will be improved (Cakir, 2007).

Lubrication effect: The lubrication effect will cause easy chip flow on the rake face of cutting tool because of low friction coefficient. This would also result in the increased by the chips. Moreover, the influence of lubrication would cause less built-up edge when machining some materials such as aluminum and its alloys. As a result, better surface roughness would be observed by using cutting fluids in machining processes (Cakir, 2007).

Taking away formed chip from the zone: It is also necessary to take the formed chip away quickly from cutting tool and machined workpiece surface. Hence the effect of the formed chip on the machined surface would be eliminated causing poor surface finish. Moreover part of the generated heat will be taken away by transferring formed chip (Cakir, 2007). Cast iron cast group of materials are brittle during machining they break into small size chips. The friction between cutting tool and chip is less due to small size chip formation. It was proposed that using emulsion cutting fluids increases surface finish quality and prevents dust formation during machining. The concentration of emulsion cutting fluid should be kept around 12% – 15% to decrease oxidation (Cakir, 2007). These are the types of machining process, workpiece materials and cutting tool materials. The combination of these three influential factors would provide basic information for selecting the suitable cutting fluid. The regeneration methods of used cutting fluids would also provide various advantages such as reducing cutting the fluids cost, disposals cost of used cutting fluids and nearly eliminating environmental pollution.

Depth of Cut: Methods for determining depth of cut are recommended for determining feeds. In roughing, the cut should be as deep as the grinding wheel will stand, without crowding or springing the work. The depth of cut also depends on the hardness of material. Generally a cut of 0.001 to 0.003 inch in depth is used, depending on the size and condition of the grinding machine. In finishing, the depth of cut is always slight, generally from 0.0005 inch to as little as 0.00005 inch (Cakir, 2007).

Work Speed: Surface grinding machines usually have fixed work speeds of approximately 50 SFPM or have variable work speed ranges between 0 and 80 SFPM. As with cylindrical grinding, the higher work speeds mean that more material is being cut per surface foot of wheel rotation and therefore more wear is liable to occur on the wheel (Fundamentals of Machine Tools, Headquarters Department of the Army, Washington, DC, 29 Oct. 1996). The feed of the grinding wheel is the distance the wheel moves laterally across the workpiece for each revolution of the piece in cylindrical grinding or in each pass of the piece in surface grinding. The feed should be proportional to the width of wheel face and the finish desired. In general, the narrower the face of the wheel, the slower must be the traverse speed; the wider the wheel faces the faster can be the traverse speed. For roughing, the table should traverse about three quarter the wheel width per revolution or pass of the workpiece. For roughing, the table should traverse about three quarter the wheel width per revolution or pass of the workpiece In surface grinding with wheels less than 1 inch in width, the table traverse speed should be reduced about one half (Fundamentals of Machine Tools, Headquarters Department of the Army, Washington, DC, 29 Oct. 1996).

2.5 NANOPARTICLES

Nanostructured materials have received much attention because of their novel properties, which differ from those of bulk materials. Control of dimension and morphology of materials has aroused the interest of researchers in the design of functional devices due to the optical and electronic properties of nanometer- and micrometer-sized materials, which determine their applications, can be adapted by varying their size and shape.

Water based ZnO Nanofluids: Zinc oxide (ZnO), a versatile semiconductor material, has been attracting attention because of the commercial demand for optoelectronic devices operating at blue and ultraviolet regions. ZnO is a wurtzite-type semiconductor with band gap energy of 3.37 eV and it has very large excitation binding energy (60 meV) at room temperature. Recently, special attention has been devoted to the morphology, as ZnO can form different nanostructures. Thermal stability, irradiation resistance and flexibility to form different nanostructures are the advantages that expedite its potential wide applications in photodetectors, surface acoustic wave devices, ultravioletnanolaser, varistors, solar cells, gas sensors, biosensors, ceramics, field emission, and nanogenerator. Since the discovery of conductance in conjugated polymers, a great interest has been paid to these materials and has been extensively explored as alternative to metals or inorganic semiconductors in fabrication of optoelectronic, microelectronic and micro electrochemical devices.

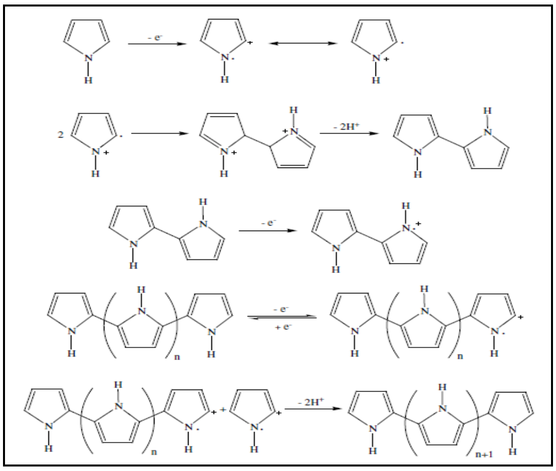


Figure 2.11: Mechanism of formation of PPy

Polypyrrole (PPy), one of the important conducting polymers, have potential applications in drug delivery, sensors, and corrosion protection. The procedure continues until PPy is formed as shown in Figure 2.11 (Chen et al., 2008)**.** Based on its semiconductor properties PPy has been exploited as the electronic component in electronic devices, e.g., photo electrochemical devices, organic light-emitting diodes, and rectifying devices. PPy also shows physicochemical properties which impart to various applications in DNA sensors, actuators, and immune sensors. The chemistry of conducting polymers has been significant development since Diaz et al. demonstrated in 1977 the depositing thin films of PPy using electro-oxidation. PPy have a linear structure and it linked only through and 1 positions of pyrrole ring. Pyrrole is oxidized to form radical cation which reacts with another pyrrole radical to form dimer. The dimer undergoes future oxidation and conjugation with pyrrole radicals.

Nanofluid Application: Nanofluid have the potential to be used as cooling fluids since the nanoparticles suspensions are not abrasive and will not clog mechanical components. These fluids have also shown to exhibit substantially higher thermal conductivities compared to the conventional heat transfer fluids. Some useful applications for nanofluid are as alternative coolants, greases, or lubricants in automotive applications, coolants for microelectronics and others. Besides that few example where nanoscale heat transfer can also be used in diverse areas such as biotechnology, nanotechnology energy conversion and power generation systems such as heat exchanger systems, photovoltaic conversion and thermoelectric energy conversion system, optoelectronics and, in general, every application that involves miniaturization as an objective.

Nanofluid is can be considered as one of excellent coolant working fluid due to its capability of heat transfer. Still, there are advantages and disadvantages of using nanofluid. The good thing of using nanofluid is, nanofluid have great capability to act as heat transfer enhancement since the particles that used in nano size which very small. Thus, the shear stress between the particles and the wall can be neglected. Thus, its works nearly as perfect heat transfer enhancer. However, nanofluid is hard to be manufacture. Only minority of the industries becomes its manufacturer, thus, the price is overwhelming. To use it in industrial as application, some of the financial manager would say that it is impractical and not economical. Besides that, nanofluid production faces some major challenges such as agglomeration of particles in solution and the rapid settling of particles in fluids.

2.6 PREPARATION OF NANOFLUID

Mixing nanoparticles with a fluid where the nanoparticles remain in suspension for a long time are termed as ‘nanofluids’ and understand as nanoparticles in suspensions. Several studies, including the earliest investigations of nanofluids, used a two-step method in which nanoparticles or nanotubes are first produced as a dry powder and then dispersed into a fluid in a second processing step. In contrast, the one-step method entails the synthesis of nanoparticles directly in the heat transfer fluid.

Two-step method: The preparation of nanofluids begins by direct mixing of the base fluid with the nanomaterials. In the first step, nanomaterials are synthesized and obtained as powders, which are then introduced to the base fluid in a second step. This is because the concentration and size distribution can be controlled. Changing the pH value of the suspension, adding surfactants or a suitable surface activator, or using ultrasonic or microwave vibration, are all techniques that have been used with two-step method to have better disperse and more evenly distribute the nanoparticles in the base fluid and maintain the stability of the suspension (Sobhan, 2010). Theoretically, as nanoparticles used are small, the weight to volume ratio is suitable, and the dispersion methods applied correctly, the nanoparticles will be very well dispersed and suspension will be stable for several days. However, majority research paper reported that the suspension sample can be maintained in a homogenous stable state for no more 24 hours.

One-step method: The one step method is the method where nanoparticles are produced directly in the base fluid to obtain suspension. The drawbacks of this technique however, are that the use of low vapor pressure liquids are essential and only limited quantities can be produced.

2.7 RESPONSE SURFACE METHODOLOGY

Response surface methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes. The most extensive applications of RSM are in the particular situations where several input variables potentially influence some performance measure or quality characteristic of the process. Thus performance measure or quality characteristic is called the response. The input variables are sometimes called independent variables, and they are subject to the control of the scientist or engineer. The field of response surface methodology consists of the experimental strategy for exploring the space of the process or independent variables, empirical statistical modeling to develop an appropriate approximating relationship between the yield and the process variables, and optimization methods for finding the values of the process variables that produce desirable values of the response. In this report we will concentrate on the second strategy: statistical modeling to develop an appropriate approximating model between the response y and independent variables x_1, x_2... x_k.

In general, the relationship is expressed by Eq. (2.1).

$$y = f\left(x_1, x_2, \ldots, x_k\right) + \varepsilon \tag{2.1}$$

Where the form of the true response function f is unknown and perhaps very complicated, and ε is a term that represents other sources of variability not accounted for in f. Usually ε includes effects such as measurement error on the response, background noise, the effect of other variables, and so on. Usually ε is treated as a statistical error, often assuming it to have a normal distribution with mean zero and variance σ^2 (Carley et al., 2004).

In fact, successful use of RSM is critically dependent upon the experimenter's ability to develop a suitable approximation for f. Usually, a low-order polynomial in some relatively small region of the independent variable space is appropriate. In many cases, either a first-order or a second order model is used. The first-order model is likely to be appropriate when the experimenter is interested in approximating the true response surface over a relatively small region of the independent variable space in a location where there is little curvature in f. For the case of two independent variables, the first-order model in terms of the coded variables is in Eq. (2.2).

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \tag{2.2}$$

The form of the first-order model in Eq. (1.2) is sometimes called a main effects model, because it includes only the main effects of the two variables x_1 and x_2. If there is an interaction between these variables, it can be added to the model easily as follows:

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 \tag{2.3}$$

This is the first-order model with interaction. Adding the interaction term introduces curvature into the response function. Often the curvature in the true response surface is strong enough that the first-order model (even with the interaction term included) is inadequate. A second-order model will likely be required in these situations. For the case of two variables, the second-order model is in Eq. (2.4).

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 \tag{2.4}$$

This model would likely be useful as an approximation to the true response surface in a relatively small region. The second-order model is widely used in response surface methodology for several reasons: The second-order model is very flexible. It can take on a wide variety of functional forms, so it will often work well as an approximation to the true response surface. It is easy to estimate the parameters (the β's) in the second-order model. The method of least squares can be used for this purpose. There is considerable practical experience indicating that second-order models work well in solving real response surface problems. In general, the first-order model is in Eq. (2.5).

$$\eta = \beta_0 + \beta_1 x_q + \beta_2 x_2 + \ldots + \beta_k x_k \tag{2.5}$$

The second-order model is expressed as Eq. (2.6).

$$\eta = \beta_0 + \sum_{j-1}^{k} \beta_j x_j + \sum_{j=1}^{k} \beta_{jj} x_j^2 + \sum_{i<} \sum_{j=2}^{k} \beta_{ij} x_i x_j \tag{2.6}$$

In some infrequent situations, approximating polynomials of order greater than two are used the general motivation for a polynomial approximation for the true response function f is based on the Taylor series expansion around the point x_{10}, $x_{20} \ldots x_{k0.}$ Finally, let's note that there is a close connection between RSM and linear regression analysis. For example, consider the model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + \varepsilon \tag{2.7}$$

The β's are a set of unknown parameters. To estimate the values of these parameters, we must collect data on the system we are studying. Because, in general, polynomial models are linear functions of the unknown β's, we refer to the technique as linear regression analysis (Myersand Montgomery, 2002).

2.8 ARTIFICIAL NEURAL NETWORKS

One type of network sees the nodes as 'artificial neurons'. These are called artificial neural networks (ANNs). An artificial neuron is a computational model inspired in the natural neurons. Natural neurons receive signals through synapses located on the dendrites or membrane of the neuron. When the signals received are strong enough, the neuron is activated and emits a signal though the axon. This signal might be sent to another synapse, and might activate other neurons. The complexity of real neurons is highly abstracted when modeling artificial neurons. These basically consist of inputs, which are multiplied by weights and then computed by a mathematical function which determines the activation of the neuron. Another function computes the output of the artificial neuron. ANNs combine artificial neurons in order to process information as shows in Figure 2.12.

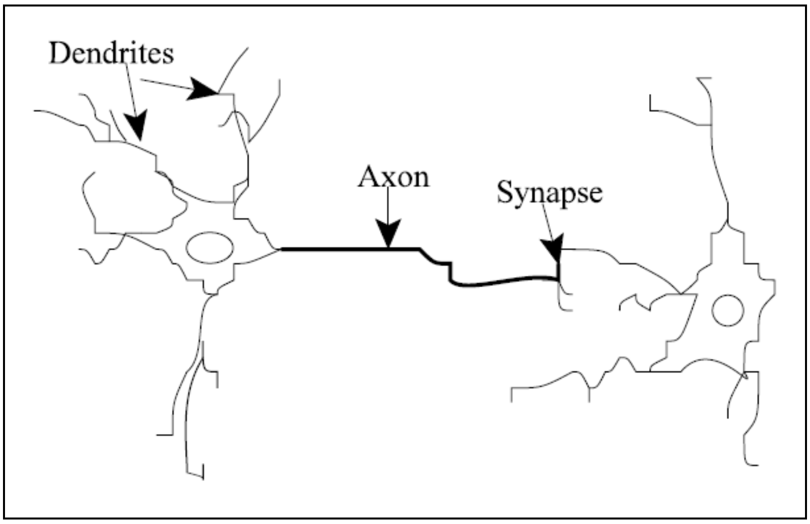


Figure 2.12: Natural neurons.

The higher a weight of an artificial neuron is, the stronger the input which is multiplied by it will be. Weights can also be negative, so we can say that the signal is inhibited by the negative weight. Depending on the weights, the computation of the neuron will be different. By adjusting the weights of an artificial neuron we can obtain the output we want for specific inputs as shows in Figure 2.13. But when we have an ANN of hundreds or thousands of neurons, it would be quite complicated to find by hand all the necessary weights. But we can find algorithms which can adjust the weights of the ANN in order to obtain the desired output from the network. This process of adjusting the weights is called learning or training. The number of types of ANNs and their uses is very high. The differences in them might be the functions, the accepted values, the topology, the learning algorithms, etc.

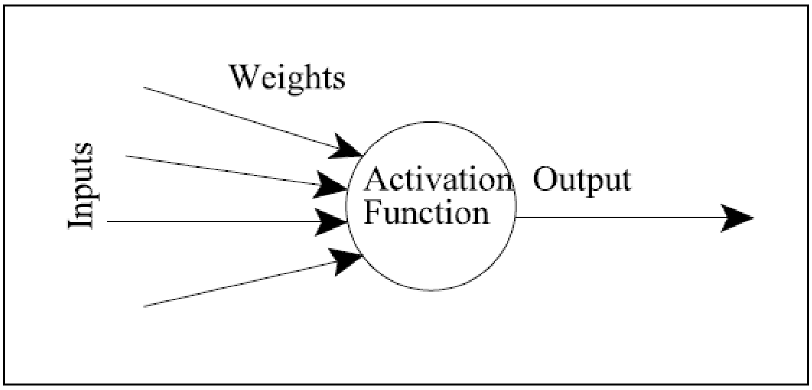


Figure 2.13: An artificial neuron

Since the function of ANNs is to process information, they are used mainly in fields related with it. There are a wide variety of ANNs that are used to model real neural networks, and study behavior and control in animals and machines, but also there are ANNs who are used for engineering purposes, such as pattern recognition, forecasting, and data compression.

Support vector machines (SVMs) have been researched in the data mining and machine learning communities for the last decade and applied to applications in many domains. SVMs are used for learning classification, regression, or ranking functions, for which they are called classifying SVM or ranking SVM. Two special properties of

SVMs are that SVMs achieve high generalization by maximizing the margin and support an efficient learning of nonlinear functions by kernel trick (Chapelle, 2007).

The main techniques are stochastic gradient ascent, Newton's method, conjugate gradient descent, and primal-dual interior point method. The naive method to find optimal for a given set of training examples is stochastic gradient ascent. The algorithm described in Chapelle (2007) simply updates one at a time, and loops until the termination criteria are met. Since it only deals with one example at a time, it has virtually no memory requirements. Unfortunately, this method has no convergence guarantees either. The Newton method used by Chapelle (2007) is a one-step solution to finding the optimal vector.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The method used in this project is being described in detail. Besides that, this chapter includes the work flow, information on preparation workpiece, information on preparation of nanofluid solution that is 0.1% water based ZnO nanoparticle, the flow of experiment done using the suitable apparatus and method used. The experiment is about the optimization of grinding of ductile cast iron using water based ZnO nanoparticles. There are several parameters that can affect the quality of the product such as grinding force, feed rates, cutting speed, depth of cut, coolant and etc. The depth of cut will set to be 10μm down feed, next is table speed, it take from the grinding machine from higher to the lower table speed. (Nazwa and Hashim, 2010), types of coolant used are conventional and 0.1% ZnO nanocoolant in order to compare the result to each other, grinding pattern – single pass and multiple pass while feed rates are constant due to the lack of grinding machine used. Figure 3.1, the flow of the experiment can clearly be understood that the experiment starts with preparation of workpiece at desired volume by using milling machine and bend saw machine. The experiment will be examined from two types of coolant that are 0.4 ethylene glycol coolant and 0.1 water based ZnO nanoparticles. The input parameters table speed (TS), depth of cut (DOC), types of coolant and grinding pattern are considered based on previous researcher. After that, run the experiment and the best quality of product can be determine based on its output parameters such as surface roughness (R_a), material removal rate (MRR) and temperature rise (T) due to friction between workpiece and wheel. Figure 3.1 illustrated the detail methodology throughout this project. The experiment will be examined from two types of coolant that are ethylene glycol coolant (5% soluble water based) and 0.1% water based ZnO nanoparticles.

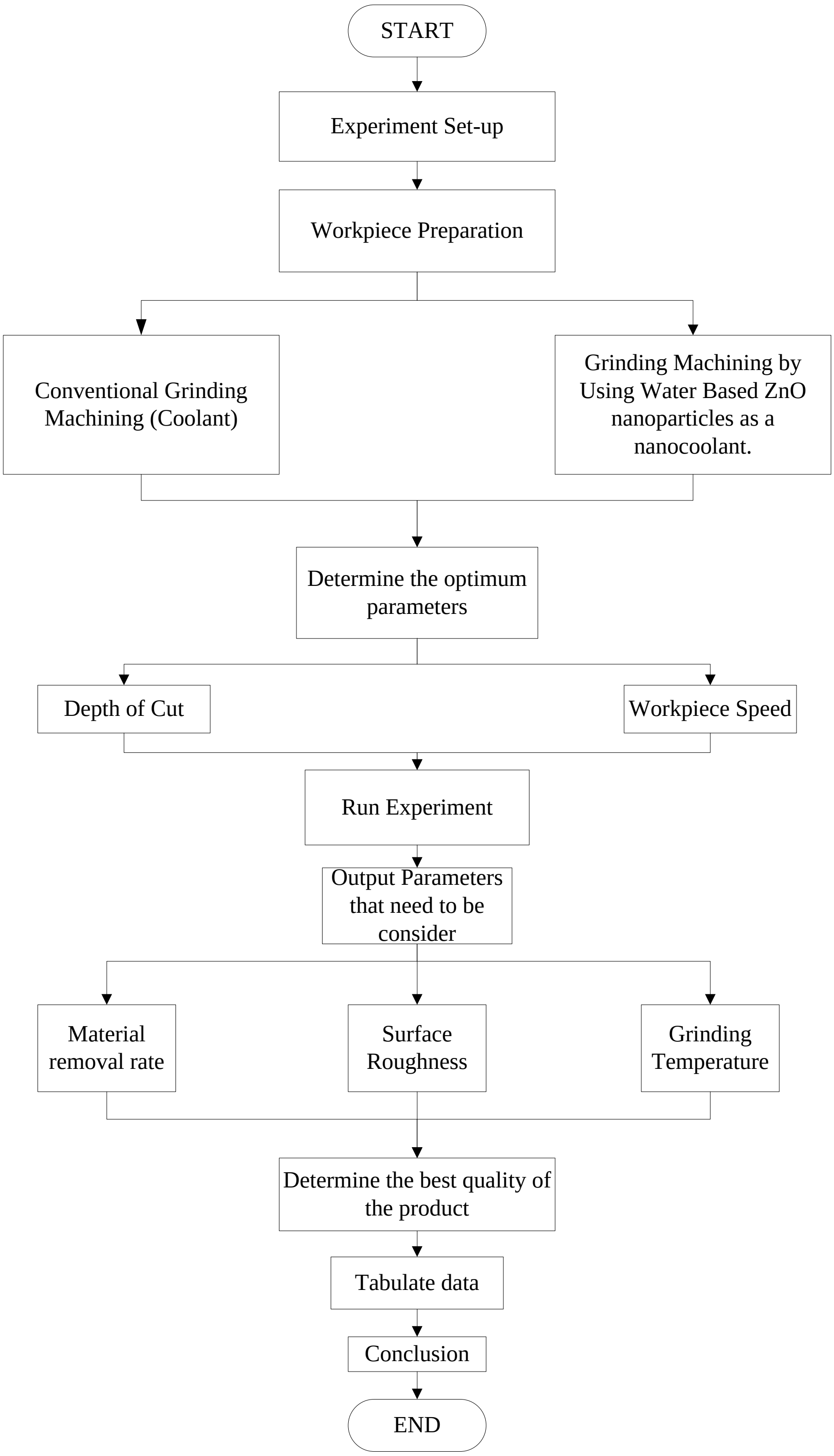


Figure 3.1: Flow Diagram of Experiment

3.2 PREPARATION OF WORKPIECE

In order to acquire the desired volume of workpiece, theier need to used milling machine and bend saw machine. Milling machine is used to get a square shape of workpiece, while the bend saw machine is used to cut the workpiece. Milling machine is used for preparing workpiece because there is no ductile cast iron that already made like hollow, bar or rod. The ductile cast iron takes from foundry lab, and the ingot shape before it go to milling machine process as shown in Figure 3.2 and Figure 3.3. In order to get an appropriate view of workpiece, the ingot's condition will be squaring by using milling machine. Milling machine is the best machine that can cut the ingot's condition workpiece into square condition. However, it took a lot of time to get a square workpiece.

(a) Side view (b) Front view

Figure 3.2: Workpiece view

Figure 3.3: Bend Saw machine

3.3 COMPOSITION OF THE WORKPIECE

After the preparation of workpiece, the author goes to foundry lab to check workpiece composition by using spectrometer as shows in Figure 3.4. First of all, the author needs to get smooth surface of the workpiece before start checking composition. The sand paper is used to get smooth surface of workpiece. After that, the workpiece will be checking its composition by using spectrometer.

Figure 3.4: Spectrometer

3.4 PREPARATION OF ZnO NANOPARTICLES

There are several equipment and material needed to dilute nanocoolant such as distilled water, stirrer, ZnO nanoparticles and basin. Since there is only need a small amount of nanocoolant, so the solution is using one-step method to prepare nanocoolant. For this project, the author only need 0.1% concentration of nanoparticles, so that there is an equation (Eq. (3.1)) to determine the volume of distilled water and how much should the author use to get the accurate concentration.

$$\phi = \frac{\omega \rho_w}{\frac{\omega}{100}\rho_w + \left(1 - \frac{\omega}{100}\right)\rho_p} \tag{3.1}$$

where:

$\phi =$ volume concentration in percentages (%)

$\omega =$ weight in percentages (%)

$\rho_w =$ density of water

$\rho_p =$ density of nanoparticles

$$\Delta V = V_1\left(\frac{\phi_1}{\phi_2} - 1\right) \tag{3.2}$$

where:

$\Delta V =$ amount of distilled water

$V_1 =$ volume nanoparticles

$\phi_1 =$ old concentration

$\phi_2 =$ new concentration

3.5 DESIGN OF EXPERIMENTS

Based on the input parameters, the author has design the level of input as shown in Table 3.1:

Table 3.1: Design of levels

Level	-1	0	+1
Table Speed (m/min)	20	30	40
Depth of Cut, DOC (µm)	20	40	60

Next are the outputs parameters that has considered are:

- Surface Roughness (*Ra*) - Minimize
- Temperature Rise (*T*) - Minimize
- Material rate removal (*MRR*) – Maximize

In designing the experiment, the parameters were based on the precision surface grinding machine. Four variables input parameters that are table speed (TS), depth of cut (DOC), types of coolant, and grinding pattern. The machine only can change the speed of wheel, depth of cut, coolant used and grinding pattern. Rotational speed of grinding wheel constant and cannot be control. The problem has been solving by using Tachometer as illustrated in Figure 3.5.

Figure 3.5: Tachometer

By using Tachometer, the speed of table can be increase and decrease on desired speed. Its minimum speed is 20m/min and maximum speed is 40 m/min. Based on Najwa and Hashim (2010), three speed of table were selected that are 20, 30 and 40 m/min and depth of cut also a parameters that has been decide base on Shen (2008). Three different depth of cut were selected that are 20 μm, 40 μm and 60 μm. After that, silicon carbide wheel was used to grind workpiece. The grinding patterns are single and multiple pass grinding. For multiple pass grinding, the workpiece was grind about ten times. Last parameter that decided was types of coolant. There are two types of coolant used in this experiment that are ethylene glycol coolant 5% solution water based and 0.1% water based ZnO nanoparticles. From these all parameters, the experimental data was collected.

3.6 EXPERIMENTAL DETAILS

The apparatus used in this project are the precision surface grinding machine, weight balance, Mahr Perthometer S2, scanning electron microstructure (SEM), thermocouple, tyachometer and clamping. For the first run, 5% of water based solution ethylene glycol as a coolant and after that goes through with 0.1% water based ZnO nanoparticles as a nanocoolant. The surface grinding machine was operated based on the flow chart in Figure 3.6. The quantity of coolant was checked in order to make sure that the quantity of coolant enough to run. Then, the experiment was started as the precision surface grinding was on. The workpiece was clamped using mini clamper because of the ductile cast iron cannot be hold by magnetic table. The mini clamp is as illustrated in Figure 3.7.

Before start the experiment, the workpiece was measured its weight using analytical weight balance. After that, the workpiece with the clamper was placed on magnetic table then the magnetic force switch, coolant switch, and grinding wheel was pressed. Before start the surface grinding, the speed of table was adjusted and the speed of table was measured using Tachometer. Then, the grinding wheel went down to the work piece and make sure that there is spark out. As soon as grinding started, the grinding temperature was taken. The grinding movement is constant that is zip zap. The workpiece was grind according to it grinding pattern whether single or multiple pass (Figure 3.8).

The times also take as soon as the grinding started to grind until the single pass done and for multiple pass. The time was taken from the grinding starts and stop until ten passes. After that, the entire switches were switched off. The workpiece with it clamper took out and then the workpiece took out from the clamper. After that, the weight of workpiece was measured after the grinding using the analytical weight balance. Next, the structure of workpiece was taken by using Scanning Electron Microscope (SEM) in order to check it microstructure. After that, workpiece arithmetic average surface roughness (R_a) was collected by using Mahr Perthometer S2. Lastly, the workpiece was grinded again with various depth of cut, table speed, types of coolant and grinding pattern.

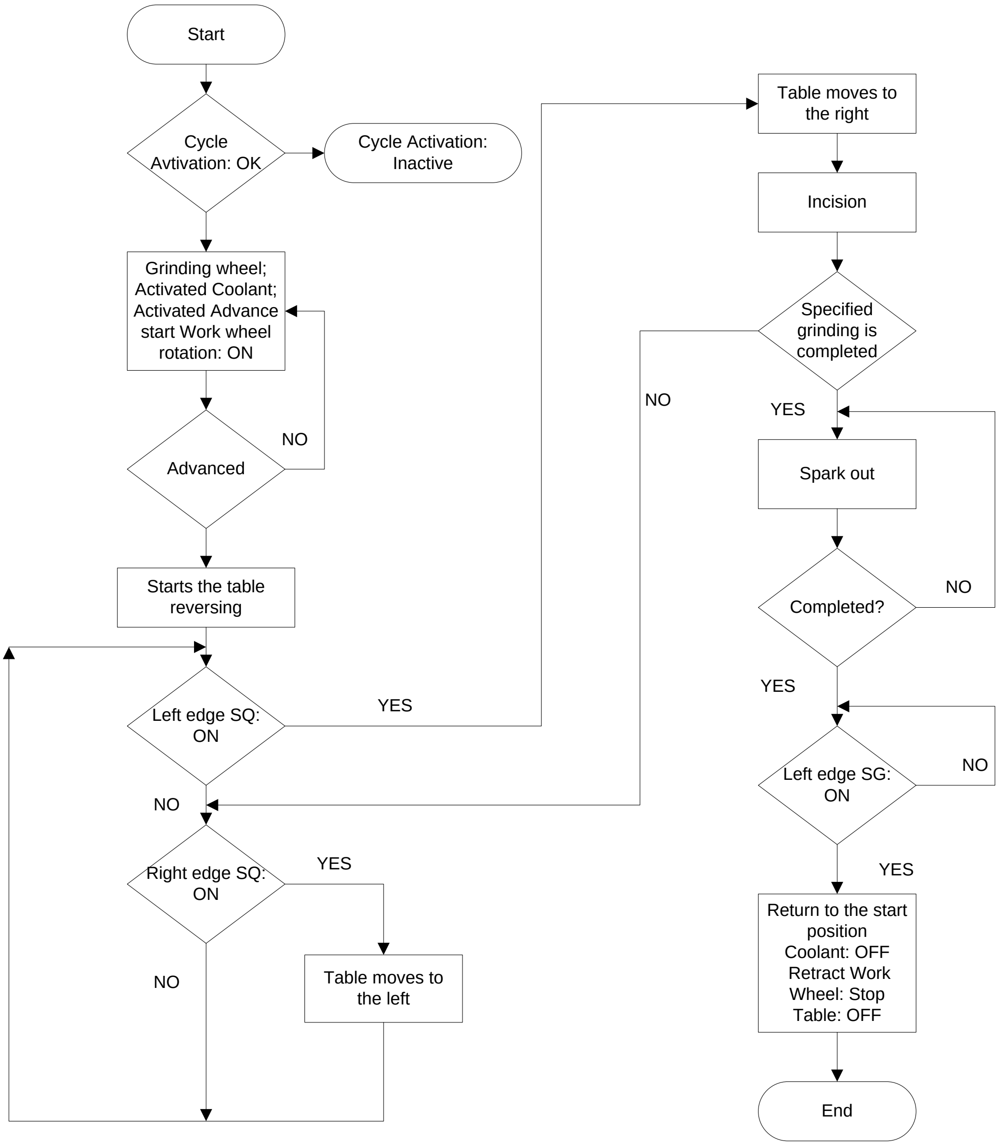


Figure 3.6: Flow chart of surface grinding

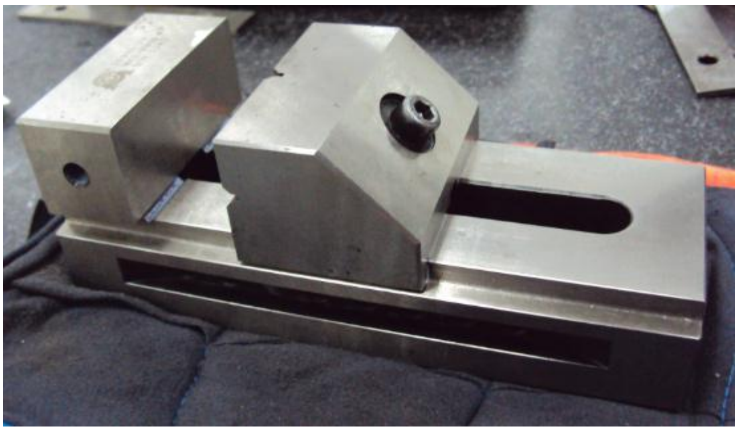


Figure 3.7: Mini Clamp

Figure 3.8: Spark Out

3.7 ARITHMETIC AVERAGE SURFACE ROUGHNESS

Surface roughness was taken using Mahr Perthometer S2. It was taken three times and takes the average value. The acceptable value for surface roughness (R_a) is below 0.8 µm. The testing actually was doing at different place but in random. The equation that the author uses to take the average is expressed by Eq. (3.3):

$$\text{Surface Roughness} = \frac{Ra_1 + Ra_2 + Ra_3}{3} \tag{3.3}$$

3.8 MATERIAL REMOVAL RATE

Material removal rate is weight remove per time needed. The equation for material removal rate is expressed as Eq. (3.4):

$$\text{Material removal rate} = \frac{\text{Weight remove}}{\text{Time needed}} \tag{3.4}$$

3.9 RESPONSE SURFACE METHODOLOGY

In the response surface methodology, design parameters are changed to formulate an approximate equation by the design of experiment. An approximate sensitivity calculation of multicrestedness problem can be performed using convex continuous function and applied to optimization. The Box-Behnken Design is normally used when performing non-sequential experiment. These designs allow efficient estimation of the first and second order coefficient. Because Box-Vehnken designs have fewer design points, they are less expensive to run Box-Behnken than central composite designs with the same number of factors. Box-Behnken designs do not have axial points, thus we can be sure that all design points fall within the safe operating zone. Box-Behnken designs also ensure that all factors are never set at their high levels simultaneously (Box and Behnken, 1960; and Box and Draper 1986). The proposed linear model correlating the responses and independent variables can be represented by Eq. (3.5):

$$y = C + a\mathrm{TS} + b\mathrm{DOC} + \mathrm{d}(\mathrm{TS} \times \mathrm{DOC}) \tag{3.5}$$

where y is the response; C, a, b and d are the constant. *TS* is table speed and *DOC* is depth of cut.

Eq. (3.5) can be rewrite for linear equation by Eq. (3.6).

$$y = \beta_0 x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \tag{3.6}$$

where y is the response, x_0=1(dummy variable), x_1=table speed and x_2=depth of cut. β_0, β_1, β_2 and β_3 are the model parameters. The second order model can be expressed as shown in Eq. (3.7):

$$y'' = \beta_0 x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{11} x_1 x_2 + \beta_{12} x_1 x_2 + \beta_{14} x_2 x_3 \tag{3.7}$$

3.10 SUPPORT VECTOR MACHINE APPROACH

Support vector machines (SVM) represent an extension to nonlinear models of the generalized portrait algorithm developed by Vapnik and Lerner (1963). The SVM algorithm is based on the statistical learning theory and the Vapnik-Chervonenkis (VC) dimension (Kadirgama et al., 2009). The nonlinear feature function j combines the input space into the feature space, which can even have an infinite dimension as shown in Figure 3.9 (Kadirgama et al., 2009).

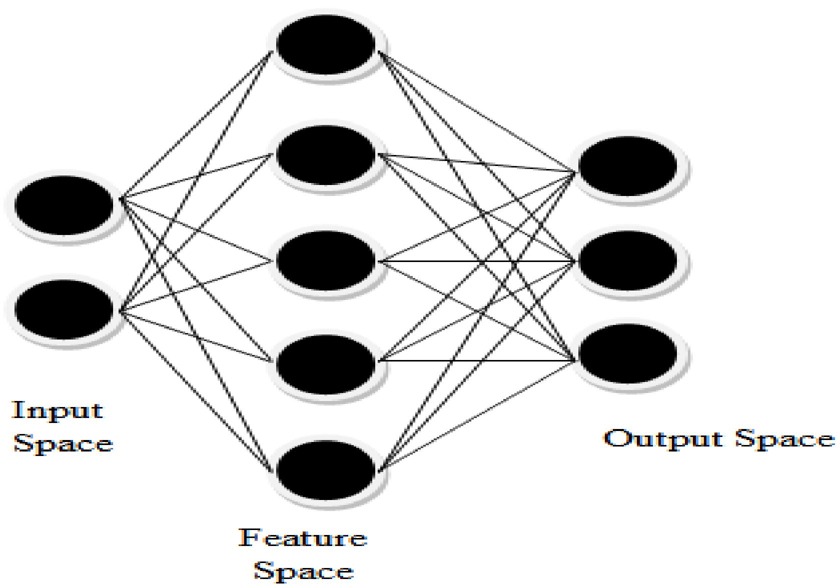


Figure 3.9: Support vector machines map the input space into a high-dimensional feature space.

Because the feature space is high dimensional, it is not practical to use directly feature functions *j* in computing the classification hyperplane. Instead, the nonlinear mapping induced by the feature functions is computed with special nonlinear functions called kernels. Kernels have the advantage of operating in the input space, where the solution of the classification problem is a weighted sum of kernel functions evaluated at the support vectors. Note that in pattern recognition, descriptors are usually called “features”, but in SVM, “features” have another meaning, so one must make a clear distinction between “descriptors” and “features”. A descriptor can be any experimentally measured or theoretically computed quantities that describes the structure of a pattern, including, for example, spectra and composition for chemicals, agricultural products, materials, biological samples; graph descriptors and topological indices; indices derived from the molecular geometry and quantum calculations; industrial process parameters; chemical reaction variables; microarray gene expression data; and mass spectrometry data for proteomics. An n-dimensional pattern x has n coordinates, x = (x_1, x_2... x_n), where each x_i is a real number, x_i € R for i = 1, 2, …, n. Each pattern x_j belongs to a class y_j € {-1, +1}. Consider a training set T of m patterns together with their classes, T = {(x_1, y_1), (x_2, y_2)…(x_m, y_m)} Consider a dot product space S, in which the patterns x are embedded, x_1, x_2…x_m Î S. Any hyperplane in the space S can be written as Eq. (3.8):

$$\{\{\mathrm{x} \in \mathrm{S} \mid \mathrm{w.x} + \mathrm{b} = 0\}\}, \mathrm{w} \in \mathrm{S}, \mathrm{b} \in \mathrm{R} \tag{3.8}$$

The dot product w.x is defined by:

$$\mathrm{w.x} = \sum_{i=1}^{n} \mathrm{w}_{\mathrm{i}} x_i \tag{3.9}$$

A hyperplane w.x + b = 0 can be denoted as a pair (w, b). A training set of patterns is linearly separable if at least one linear classifier exists defined by the pair (w,b), which correctly classifies all training patterns. All patterns from class +1 are located in the space region defined by w.x+b>0 and all patterns from class -1 are located in the space region defined by w.x+b<0. Using the linear classifier defined by the pair (w, b), the class of a pattern xk is determined with:

$$\mathrm{class}(\mathrm{x}_{\mathrm{k}}) = \begin{cases} +1, & \mathrm{w.x}_{\mathrm{k}} + b > 0 \\ -1, & \mathrm{w.x}_{\mathrm{k}} + b < 0 \end{cases} \tag{3.9}$$

The distance from a point x to the hyperplane is defined by Eq. (3.10):

$$\mathrm{d}(\mathrm{x};\, \mathrm{w}, \mathrm{b}) = \frac{|\mathrm{w.x} + \mathrm{b}|}{\|\mathrm{w}\|} \tag{3.10}$$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents about the result obtained from the experiment. Besides that, the development of mathematical modeling using response surface methodology (RSM) and artificial neural network predicting modeling using support vector machine have been discussed elaborately. The sensitivity analysis of ANN model also discussed in this chapter.

4.2 MATHEMATICAL MODELLING

After conducting the experiment, the collected data output variables that are arithmetic average surface roughness (R_a), temperature rise (T) and material removal rate (MRR) are used to find the parameters appearing in the postulated first order model. The first order linear equation used to predict the output variables (MRR, SR and T) are expressed as follows:

$$MRR = 0.0278027TS + 0.035209DOC + 0.0120959TS \times DOC \qquad (4.1)$$

$$Ra = 0.01866667TS + 0.05966667DOC + 0.0145TS \times DOC \qquad (4.2)$$

$$T = 1.16667TS + 0.333333DOC + 0.25TS \times DOC \qquad (4.3)$$

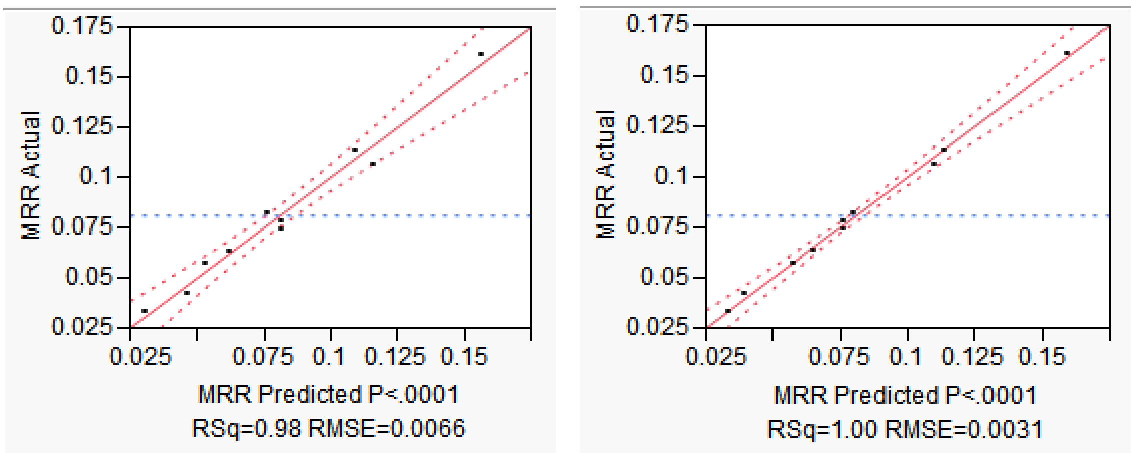
where MRR is material removal rate; R_a is arithmetic average surface roughness; T is temperature rise; TS is table speed; DOC is depth of cut.

Table speed is the most dominant factors on the T, but depth of cut is the most dominant factors on the MRR and R_a respectively. Hence, a fine quality of product can be produced with the combination of high depth of cut and low table speed. The relationship between the table speed and depth of cut is significant with the probability values for lack of fit more than 0.05 as shown in Table 4.1. Normal plot is shown in Figure 4.1 shows the normal plot, it can be seen that the experimental value closely near to the normal line and there is no outlier value. Due to the data point roughly follow the straight line, the p-value is over 0.05, and it can conclude that the data are from a normally distributed population. The second order quadratic equation used to predict the output variables is expressed as follows:

$$MRR = 0.075633717 + 0.0278027TS + 0.035209DOC + 0.01209TS \times DOC + 0.00972878TS^2 + -0.000930325DOC^2 \tag{4.4}$$

$$Ra = 0.231714 + 0.0186667TS + 0.0596667DOC + 0.0145TS \times DOC + 0.0665714TS^2 + -0.000428571DOC^2 \tag{4.5}$$

$$T = 2.35714 + 1.166667TS + 0.33333DOC + 0.25TS \times DOC + -0.314286TS^2 + 0.1857143DOC^2 \tag{4.6}$$



(a) Single Pass (b) Multiple Pass

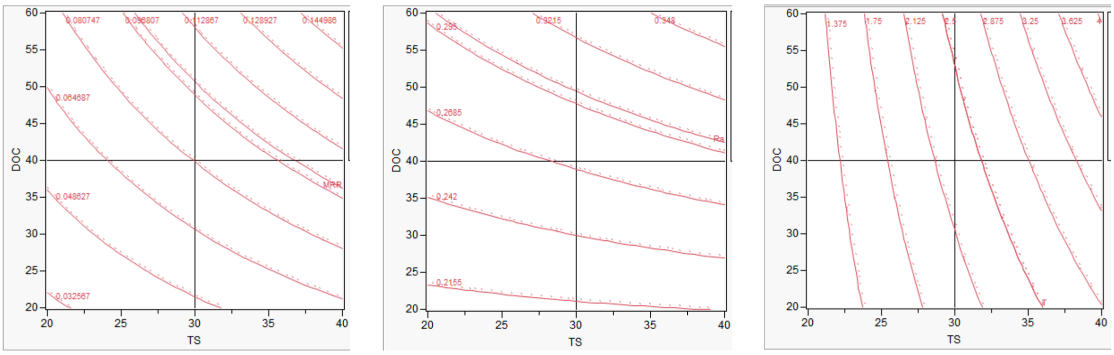
Figure 4.1: Normal plot

Table speed and depth of cut also significant since the probability values less than 0.05. It is observed that high depth of cut and low table speed produce fine quality of product whereas this finding same with first order. The second order model is fit since the probability value for lack of fit higher than 0.05. Furthermore, second order exhibits the better agreement.

Table 4.1: Analysis of variance (ANOVA)

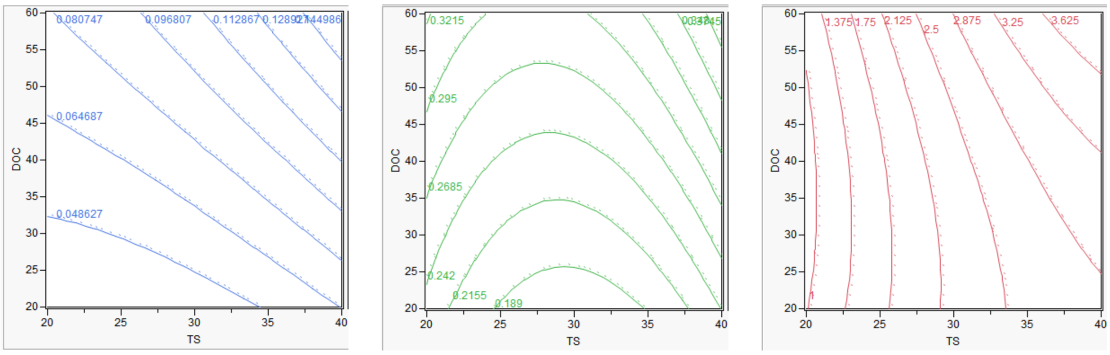
Single Pass Conventional Coolant					
Source	Degree of Freedom	Sum of Squares	Mean Square	F ratio	Prob>F
Model	3	0.0127	0.00422		
Error	6	0.0003	4.3E-05		
C.Total	9	0.0129		97.68	<.0001
Lack of Fit	5	0.0003	0.00005		
Pure Error	1	8E-06	8.4E-06		
Total Error	6	0.0003		5.997	0.3
Max RSq = 0.9994					
Multiple Pass Conventional Coolant					
Source	Degree of Freedom	Sum of Squares	Mean Square	F ratio	Prob>F
Model	5	0.0129	0.00258		
Error	4	4E-05	9.3E-06		
C.Total	9	0.0129		276.6	<.0001
Lack of Fit	3	3E-05	9.6E-06		
Pure Error	1	8E-06	8.4E-06		
Total Error	4	4E-05		1.151	0.58
Max RSq = 0.9994					

Contour plot shows the relationship between variables. Figure 4.2 and 4.3 show the relationship with each variable. It can be seen that the combination of high depth of cut and low table speed produce high quality of product. Combinations with high depth of cut produce high *MRR*, high *Ra* and constant temperature. The most important output variable in term of quality is arithmetic average surface roughness. Lower value of R_a means high quality of product. The contour plot shows the clear picture of relation between the variables and it is easy to be used by other unskilled machining operators.



(a) *MRR* (b) R_a (c) *T*

Figure 4.2: Contour plot – single pass

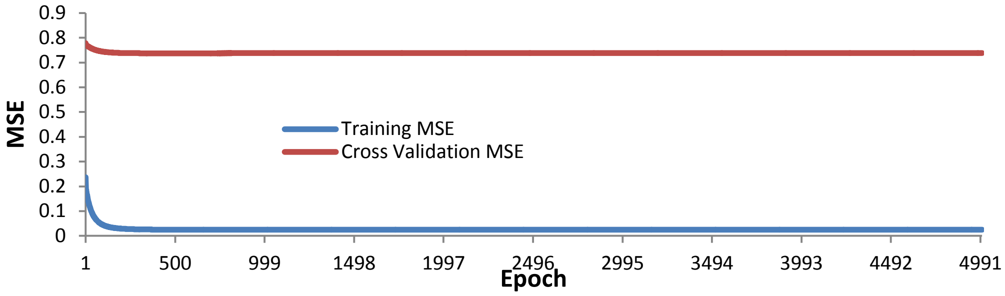


(a) *MRR* (b) *Ra* (c) *T*

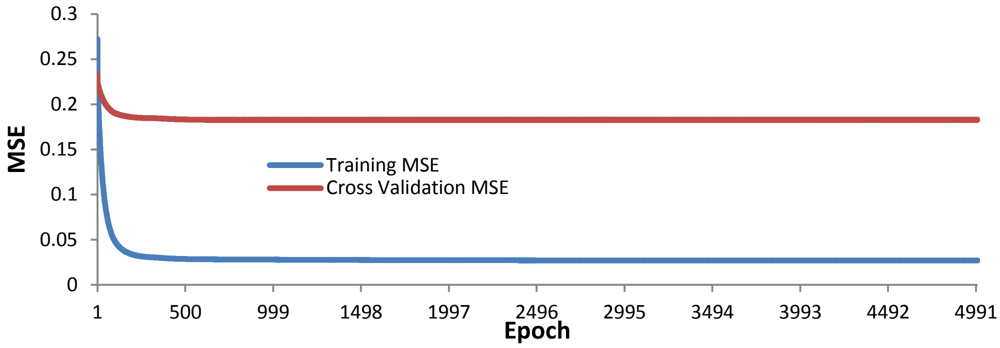
Figure 4.3: Contour plot – multiple pass

4.3 SUPPORT VECTOR MACHINE METHOD

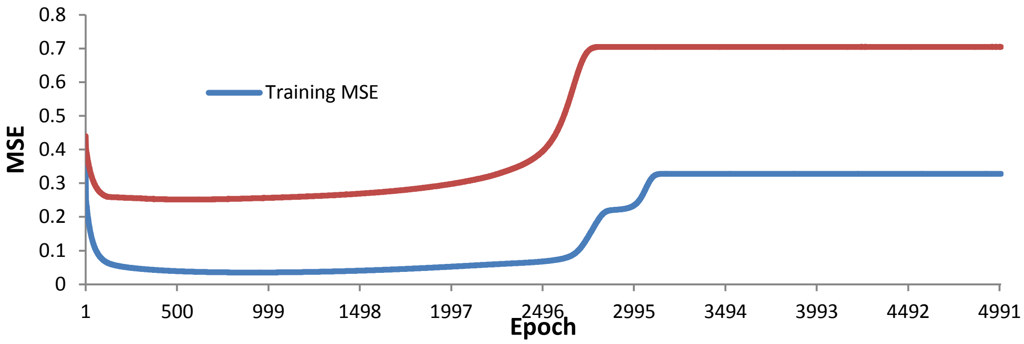
The experimental data collected is analyzed using support vector machine approach to developing the artificial neural network model. Figure 4.4 shows the MSE versus Epoch. It can be observed that the collected data is acceptable since the training MSE and cross validation MSE is conversed and similar patterns observed. Therefore, the collected data are valid for further analysis. Figure 4.5 shows the desired output and actual network output. From this figure, it can support Figure 4.4 validate the collected data is acceptable to be analyzed. The desired, and actual network output shows are very close to each other.



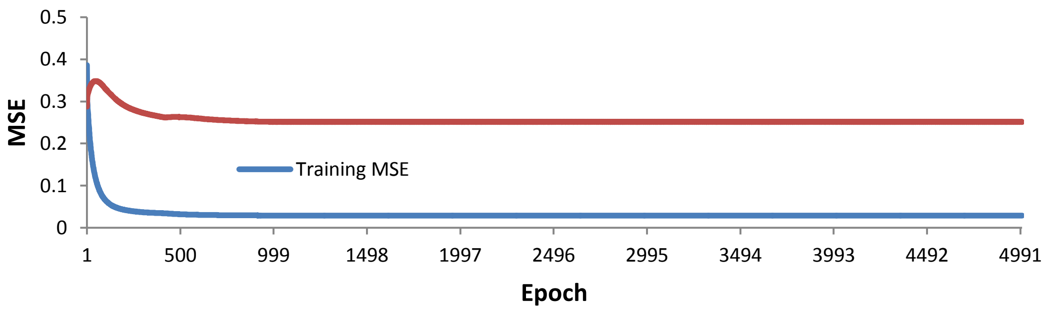
(a) Conventional coolant and multiple pass data



(b) Conventional coolant and single pass data



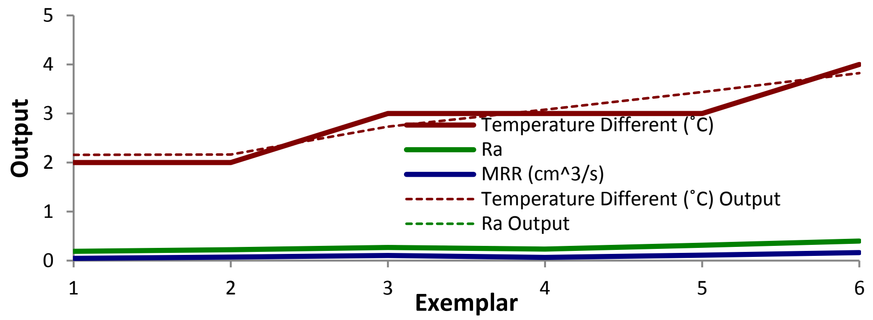
(c) ZnO nanoparticles and multiple pass data



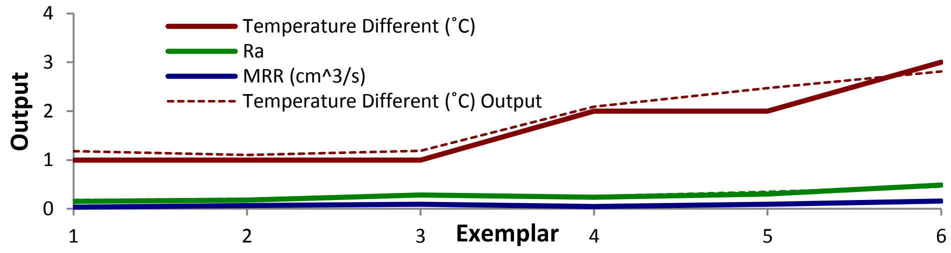
(d) ZnO nanoparticles and single pass data

Figure 4.4: MSE versus Epoch

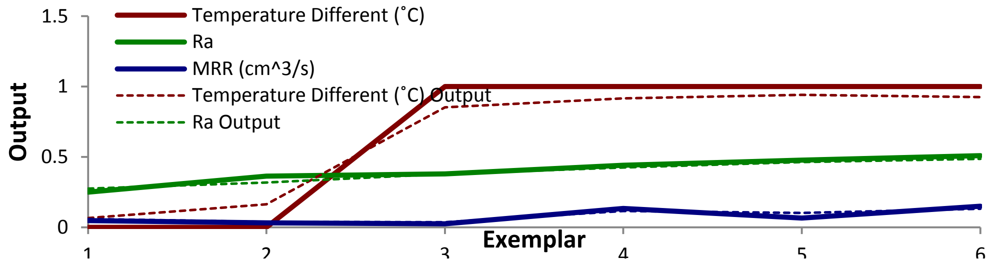
Figure 4.5 shows the desired and actual output of obtained results. As illustrated in graph, it shows the deviation between desired and actual output is much closed to each other. For R_a and MRR, there are no high deviations of desired and actual output. However for the temperature rise, it shows that temperature rise has bigger deviation if compared to R_a and MRR. Figure 4.5 (a) and (b) are conventional coolant, while (c) and (d) are water based ZnO nanoparticles.



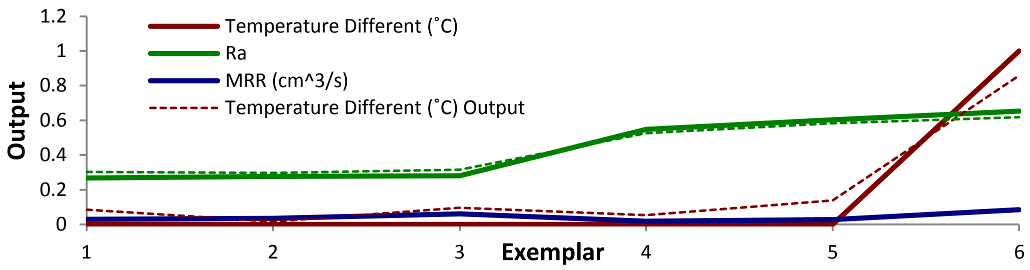
(a) Conventional coolant and multiple pass data



(b) Conventional coolant and single pass data



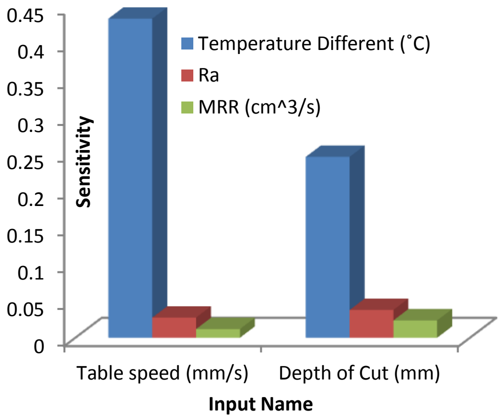
(c) ZnO nanoparticles and multiple pass data



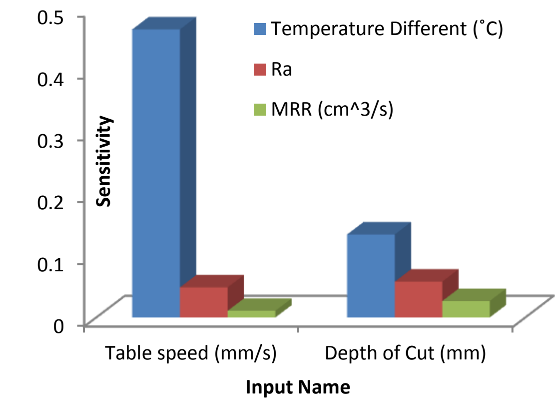
(d) ZnO nanoparticles and single pass data

Figure 4.5: Desired and actual network output

Figure 4.6 shows the bar chart of sensitivity of about the mean. It clearly shows that table speed and depth of cut give higher impact to the temperature rise but only small amount to R_a and *MRR*. Figure 4.6(b)(ii) shows slightly the different that is table speed gives higher impact to R_a. The results give higher impact to temperature rise same as others because of the ZnO nanoparticles has been mixed together with other material. The variation of inouts on outputs from the network are shown in Figure 4.7 and Figure 4.8 for conventional and ZnO nanocoolant respectively. From overall graph show that as the table speed and depth of cut increase, temperature was increased drastically compared to R_a and MRR. From overall collected data using SVM shows that model were in acceptable area. Thus, the optimization grinding model was developed.

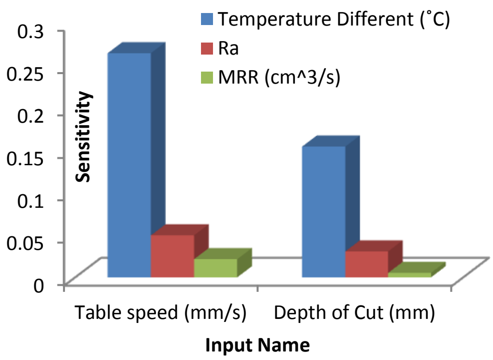


(i) multiple pass

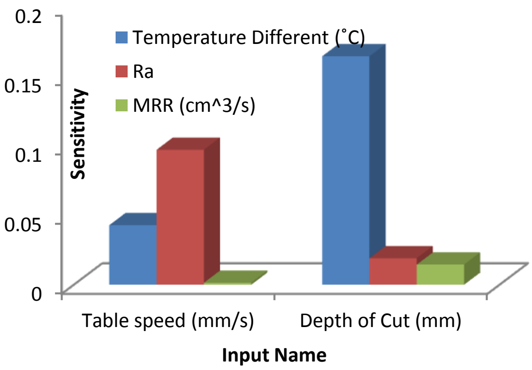


(ii) single pass

(a) Conventional coolant



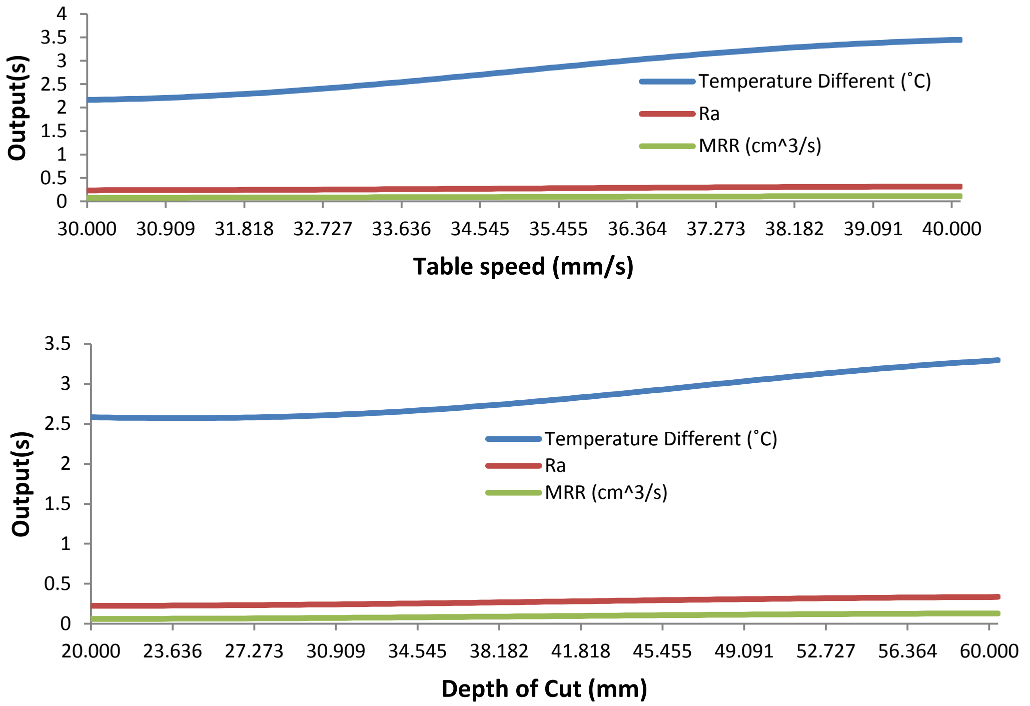
(i) multiple pass



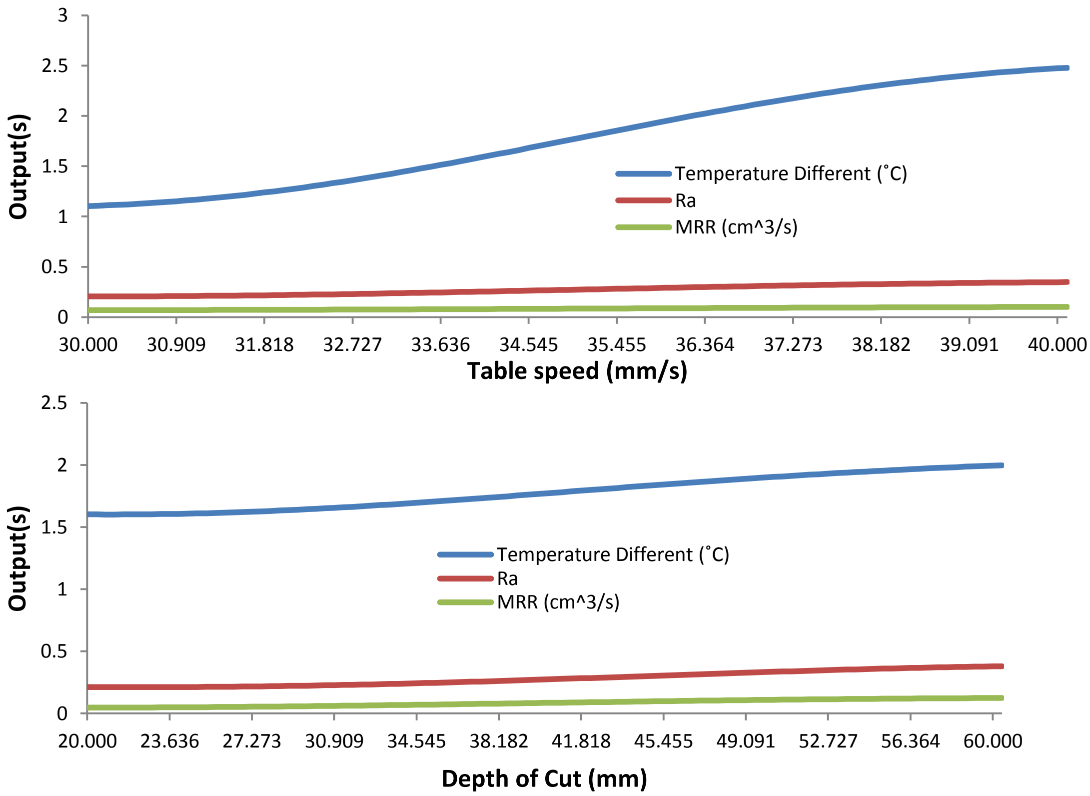
(ii) single pass

(b) ZnO nanoparticles

Figure 4.6: Sensitivity analysis

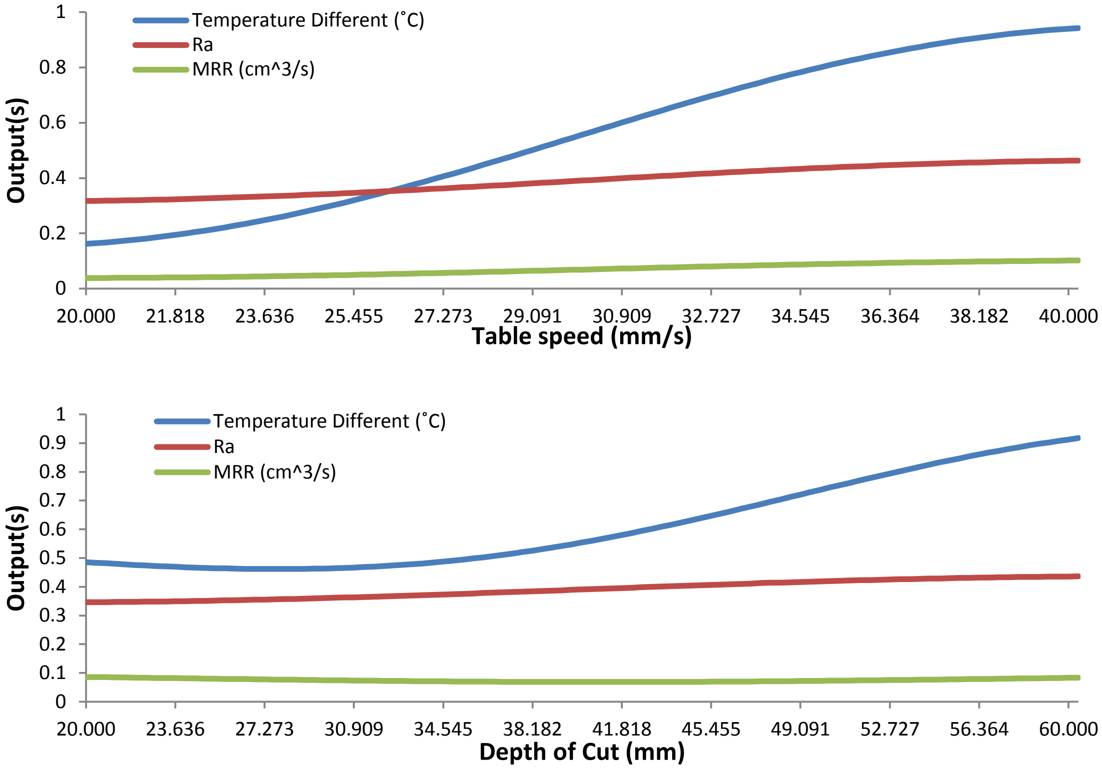


(a) multiple pass

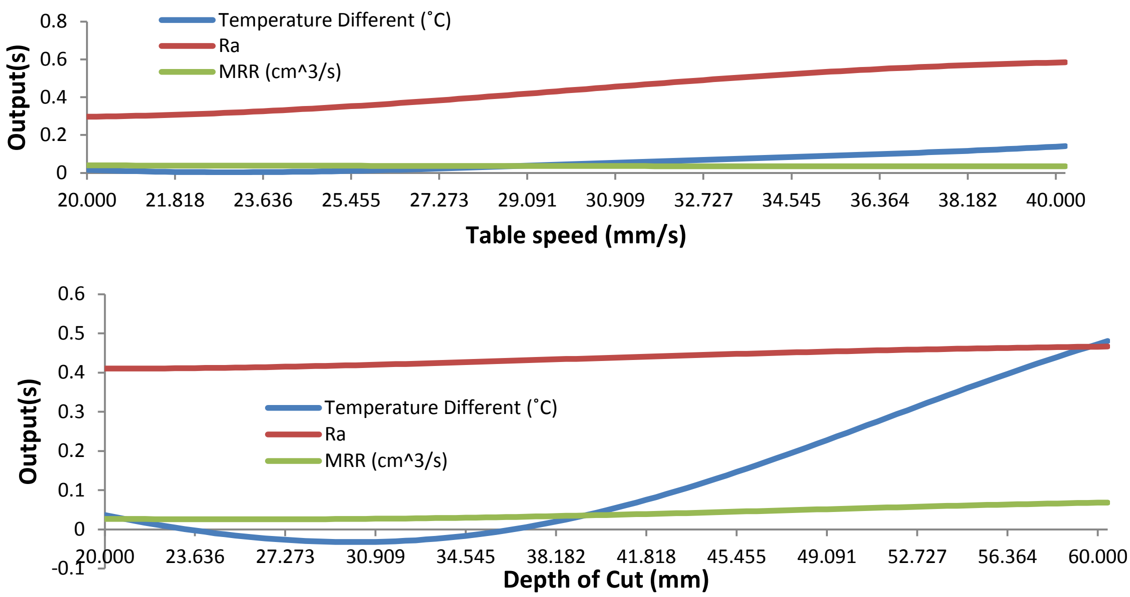


(b) single pass

Figure 4.7: Network output variation for conventional coolant



(a) multiple pass



(b) single pass

Figure 4.8: Network Output(s) variation for ZnO nanoparticles

For overall results, water based nanocoolant with multiple pass was the best obtained result that gives the best quality of the product. Conventional coolant also can give best quality of product but in term of temperature rise, the water based ZnO nanoparticles can overcome it. So that, water based ZnO nanoparticles was selected as the optimum coolant. In term of grinding pattern, it shows that multiple pass can give better quality of product than single pass.

4.4 SCANNING ELECTRON MICROSCOPE ANALYSIS

Figure 4.9 illustrates the comparison of microstructure of surface workpiece after grinding between conventional coolant and ZnO nanoparticles coolant.it can be seen that there are crack, cavity, peak and valley, grinding marks and flat surface. The cracks happen when grinding wheel not dressing well. In order to get high quality of product, grinding wheel is one of the main factor that can affect surface of product. Dressing could help grinding wheel become sharper after used it. Grinding marks causes of grinding direction. In order to minimize the grinding marks, the zip zap direction should be really slow so that, grinding wheel can grind surface perfectly.

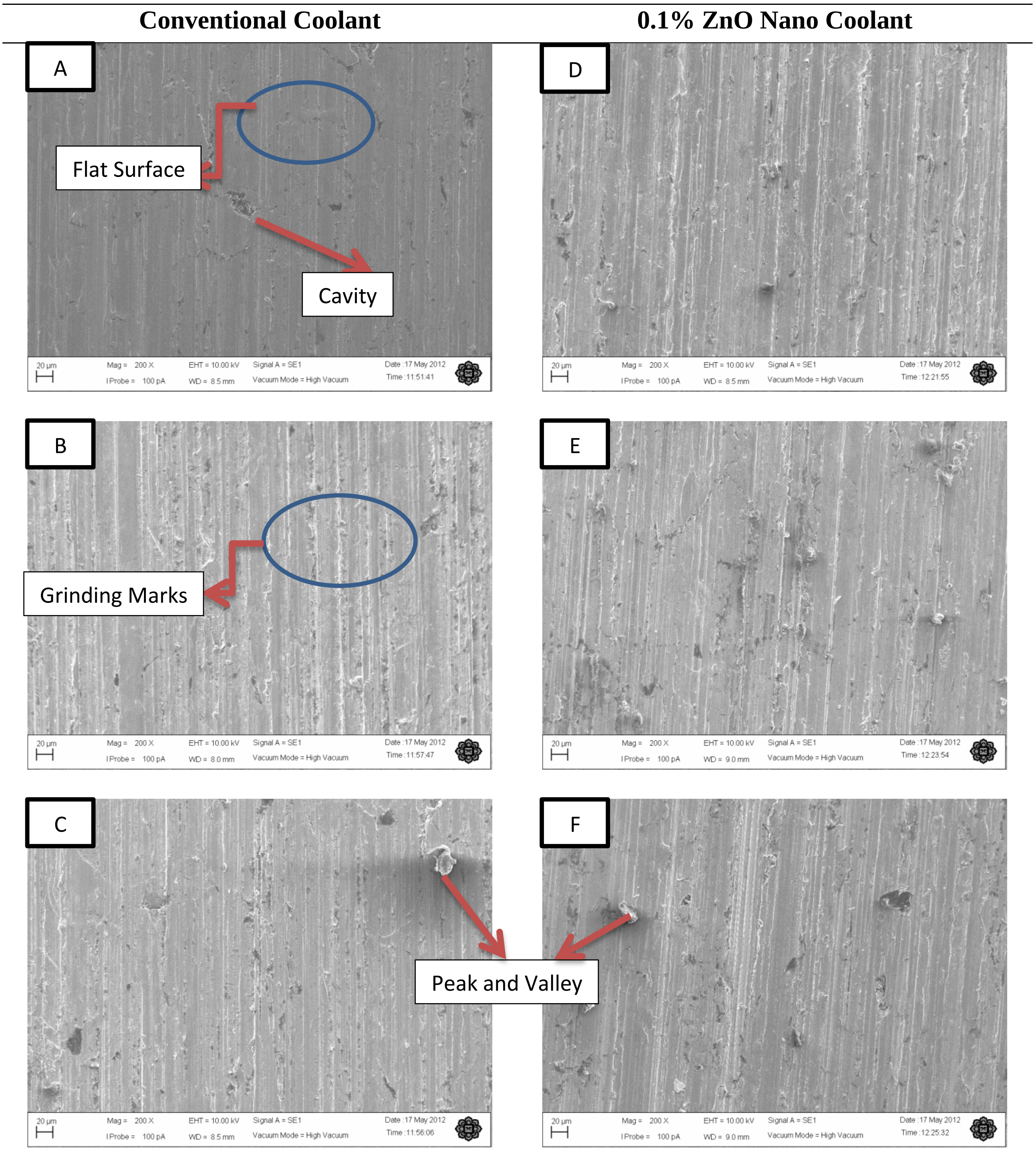


Figure 4.9: Surface microstructure of workpiece

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSIONS

The performance of precision surface grinding machine of ductile cast iron based response surface methodology was investigated experimentally. The first order and second order models to predict the grinding performance were developed. The relationship between input and output variables was determined and performance of precision surface grinding machine was validated. High depth of cut and low table speed can produce high quality of product. The optimization model for precision surface grinding parameters using support vector machine (SVM) was developed. From the SVM, the obtained results show that there is a good agreement with the experimental results. This model can be used for predicting the grinding performance with any range of parameters. It can be seen that the high depth of cut and low table speed can produce high quality of product. The most optimum parameters in the project are 30 m/min of table speed and 40 µm of depth of cut. The optimum parameters were selected based on maximum material removal rate; minimum temperature rise and minimum arithmetic average surface roughness.

Based on obtained results, it shows that water based ZnO nanoparticle is better than conventional coolant in term of temperature rise. High temperature rise can restructure the surface of product. There is high change that the structure of product can restructure the surface of product. Grinding pattern also affect the quality of product. Based on obtained results, it shows that multiple pass is better than single pass since high material removal rate give high quality of product.

In conclusion, the obtained result can used in order to optimize the grinding machine to get higher quality of product. The objectives of study have achieved with the performance of precision surface grinding using RSM has been investigated, optimize using SVM has been developed and the effect of water based zinc oxide has been investigated.

5.2 RECOMMENDATIONS FOR FUTURE WORK

There are several recommendations made based on present study, which is presented as follows:

1) Various types of nanofluids with different concentration need to be experimented to choose the best nanofluids.
2) Nanofluids should be tested in heat transfer enhancement study. Lastly, increase the design level so that the output parameters will be more accurate.
3) Using other method optimization approach such as GA, Fuzzy Logic and PSO.

REFERENCES

Agarwal, S. and Rao, V. 2010. Modelling and prediction of surface roughness in ceramic grinding. *International Journal of Machine Tools & Manufacture*. 50: 1065–1076.

Box, G.E.P. and Behnken, D.W. 1960. Some new three level designs for the study of quantitative variables. *Technometrics*, **2**: 455-475.

Box, G.E.P. and Draper, N.R. 1986. *Empirical model-building and response surfaces*. New York: John Wiley & Son Inc.

Cakir, O. 2007. *Selection of cutting process on machining processes*. Master thesis, Department of Mechanical Engineering, Dicle University.

Carley, K.M., Kamneva, N.Y. and Reminga, J. 2004. Response surface methodology. Carnegie Mellon University, School of Computer Science. CMU-ISRI-04-136

Chapelle, O. 2007. Training a support vector machine in the primal. *Neural Computation*. **19**(5):1155–1178.

Chen, H., Yang, W., He, Y., Ding, Y., Zhang, L., Tan, C., Lapkin, A. A. and Bavykin, D. V. 2008. Heat transfer and flow behaviour of aqueous suspensions of titanate nanotubes (nanofluids). *Powder Technology*. **183**(1): 63-72.

Fundamentals of Machine Tools, Headquarters Department of the Army, Washington, DC, 29 Oct. 1996.

Kadirgama, K., Noor, M.M., Ali, A., Rahman, M.M. and Ghazalli, Z, 2009. Prediction of end of life strategies for household equipments using artificial intelligent. *American Journal of Applied Sciences*. **6**(10): 1838-1844.

Malkin, S. and Guo, C. 2007. Thermal analysis of grinding. *Annals of the CIRP*. **56**(2): 760-782.

Myers, R.H. and Montgomery, D.C. 2002. Response Surface Methodology: process and product optimization using designed experiment. New York: A Wiley-Interscience Publication.

Nazwa, T. and Hashim, U. 2010. Precision surface grinding of silicon carbide with fine grain diamond cup wheel. *Engineering e-transaction*. **5**(1): 19-26.

Shen, B., Malshe, P.A., Kalita, P. and Shih, A.J. 2008. Performance of novel MOS2 nanopartilces based grinding fluids in minimum quantity lubricant grinding. *Transactions of NAMRI/SME*. **36**: 357 – 364.

Silva, L. R., Bianchi, E. C., Catai, R. E., Fusse, R. Y., França, T. V. and Aguiar, P. R. 2005. Study on the behavior of the minimum quantity lubricant – MQL technique under different lubrication and cooling conditions when grinding

ABNT 4340 steel. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*. **27**: 192-199.

Sobhan, M.A., Ams, M., Withford, M.J. and Goldys, E.M. 2010. Ultrafast laser ablative generation of gold nanoparticles: the influence of pulse energy, repetition frequency and spot size. *J. Nanopart.* **12**: 2831-2842.

Vapnik, V. and A. Lerner, 1963. Pattern recognition using generalized portrait method. *Automat. Remote Control*. **24**: 774-780.

Walsh, A.P., Baliga, B. and Hodgson, P.D. 2002. A novel technique to optimize grinding process. *International Manufacturing Leaders Forum*. 101 – 106.

Zhang, H., Andrew, A.O.T. and Xue, Z. 2009. Feasibility study of nanofluid cooling techniques for microelectronic systems. *11th Electronics Packaging Technology Conference,* 619-625.