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"OPTIMIZATION OF SURFACE ROUGHNESS ON ALUMINIUM MILLING OPERATION BY PELTIER COOLING EFFECT"

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Abstract

"OPTIMIZATION OF SURFACE ROUGHNESS ON ALUMINIUM MILLING OPERATION VIA PELTIER COOLING EFFECT"

MD. TANZIB EHSAN SANGLAP

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The ultimate goal in the manufacturing of a part is to achieve an economic production plan with precision and accuracy in the first attempt at machining. A physics-based comprehensive modelling of the machining processes is a fundamental requirement in identifying optimal cutting conditions which result in high productivity rates without violating accuracy throughout the part production process. As technology provides smaller devices with greater heat dissipation needs, cooling systems become essential during machining. The results of manufacturing processes, such as roughness structures on machined surfaces, now play a significant role in milling phenomena. The Main vision of this paper is to facilitate improved machinability that also constitute the reduction of surface roughness and decreasing the temperature at the cutting zone. The conventional milling, in both dry condition and cryogenic cooling that have a lack of getting a smooth surface as well as environmental purpose and costs. Thus for getting a complete cost effective and

reliable solution, Peltier cooling effect is conducted for the analysis of the influence of the milling parameters on the surface roughness. This also helps to get improved chip formation and chip morphology. The optimum surface roughness obtained in both low and high RPM. In this paper the effect of cutting condition (cutting speed and feed rate) on surface roughness were studied and analyzed using Peltier cooling effect. And the results suggest that using Peltier cooling effect attains more realistic alternative to conventional coolants for milling applications that is not only reduces surface roughness of the machined surface, but also more eco-friendly, provides better chip formation and increases tool life.

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Nomenclature

SYMBOL	DEFINATION
a	axial depth of cut
c	feed per tooth
D	Cutter Diameter
d	Depth of cut
h	uncut chip thickness
T	Temperature
α	helix angle
$y_{i\,j}$	experimental number in the array operation
Ra	Roughness
n	spindle speed
N	number of teeth on the cutter
CAM	Computer Aided Manufacturing
MRR	Material Removal Rate
AVG	Average

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Finally, we would like to dedicate this work to two our father and mother without whom none of our success would be possible.

CHAPTER 1

1.1 INTRODUCTION

Sustainability – according to definition, sustainable development is the development that meets the needs of the present, without compromising the ability of future generations to meet their own needs [7]. To accomplish this definition our manufacturing industries has to maintain the aim of sustainability in their process. Thus we have to emphasize on the commonly used metal during machining such as Aluminium.

Milling operations are most widely used to more accurately produce net shapes in the manufacturing industry. Applications can be found in the milling of dies and molds, jet engine parts made of heat resistant alloys, aircraft fuselage and wing panels, and biomedical parts. For the manufacturing fact Aluminium is the most vastly used material in manufacturing like automotive, aircraft, insulation etc. If its reliability can be increased and decrease its manufacturing cost that would be more preferable to the manufacturer. In manufacturing process machining is the main part of their business. Most of these operations are done by the CNC milling machine. During machining different types of cutting fluid like oil based machining, chemical based machining, cryogenic cooling synthesis and semi-synthesis machining etc are used in following decades to reduce the temperature of the cutting zone as well as the surface roughness. Thus, the condition of the surface roughness can be amplified more by using advance technology. But using these technologies is not cost effective and reliable to the manufacturers. That’s why it is a must to select a right procedure of machining. There is no mathematical model of integrated machining physics used in the industry. Process planners select cutting conditions, i.e. depths of cut, spindle speeds, and federates based on their accumulated experience, which is gained through trial and error over a period of years. When a part becomes considerably more costly due to cooling systems like liquid coolant, cryogenic coolant, chemical based coolant and may other synthesis and semi synthesis coolant. It is a preferred approach to test the machining operations in a virtual environment and achieve an accurate and economically sound part that has been machined

Method:

To achieve the goal of manufacturer Peltier cooling effect can be the best choice. This paper presents the empirical procedure used to investigate the effects of Peltier cooling on the machinability aluminium alloy for CNC milling operations. In addition, the obtained results from Peltier worked machining are compared with that of traditional dry and wet machining in order to illustrate the effects of Peltier cooling on the machinability of aluminium.

There is no mathematical model of integrated machining physics used in the industry. Process planners select cutting conditions, i.e. depths of cut, spindle speeds, and federates based on their accumulated experience, which is gained through trial and error over a period of years. When a part becomes considerably more costly due to cooling systems like liquid coolant, cryogenic coolant, chemical based coolant and may other synthesis and semi synthesis coolant. It is a preferred approach to test the machining operations in a virtual environment and achieve an accurate and economically sound part that has been machined.

Chapter 2

Literature Review

2.1. Overview

In following decades using conventional cutting fluids is considered as an effective method to withheld the friction and reduce the temperature at the cutting zone, increase tool life and improve surface roughness of the parts to be machined. However, the costs of using conventional cutting fluids is not limited to the purchase and preparation, but also consists of maintenance and disposal costs [1]. Contrary to advancement in machine tool technology and milling tool development, cutting parameters such as spindle speed, feed rate, depth and width of cut are selected conservatively to avoid the risk of damaging costly work pieces and machine tools during manufacturing. There is an increasing demand for virtual process simulators that are capable of predicting performance measures such as cutting forces, tool deflection, work piece, tool vibrations, spindle torque and power demands. Complex parts with many geometric features lead to dynamically changing engagement conditions during machining that require automatic selection of cutting parameters along the tool path to fully exploit the capacities of machine tool and milling cutter. The coolant cost during cutting operation cover an extra variable cost to the manufacture. Hence to reduce that cost and archiving an optimum surface level the foundations to achieve machining studied in the thesis, and the related past research reported in the literature is reviewed in this chapter.

The next type of analysis, which can be used is Analysis of Variance also known as ANOVA. Some steps in this analysis are similar to Regression analysis.

Another method is Response Surface Methodology, which is known from the publication of Kopac and Bahor [18].

The next method which can be used is Taguchi Method Analysis. The Taguchi method is used to identify impact of various parameters on an output and figure out how to control them to reduce the variability in that output.

2.2 AVAILABLE COOLING PROCESES

•Oil‑Based Machine Coolants ‑ Including straight oils and soluble oils.

•Chemical Machine Coolants -Chemical is used with the oil and occurs chemical reaction that reduces the surface temperature.

•Cryogenic cooling ‑ Including Nitrogen based super cooling process.

•Synthesis and semi synthesis coolant –another type of cooling where chemical coolant can be used for several time.

Apart from volumetric approaches, some researchers concentrated on feed rate scheduling using physical constraints. In the early 1990s, Altintas [17] outlined a detailed flow chart of a comprehensive machining simulation and optimization scheme that considers not only the geometric factors but also mechanics and dynamics of milling, controller performance and feed drive dynamics as well as volumetric errors of a machine tool to compensate for machining errors and reduce cycle time by adjusting machining parameters. Over the years, a large number of publications have been produced tackling problems related to individual areas; however, a systematic study of milling process simulation and optimization has not been conducted yet.

Ajitkumar[9] works on peltier effect in refrigeration and air conditioning to decrease the temperature at a certain limit. From his inspiration the format of decreasing temperature we applied the peltier effect on machining process. The decrement of temperature during air-conditioning process can be applied to reduce the cutting zone temperature during milling operatrion

Carlos Henrique Lauro [10] stated that High temperatures in the cutting zone can change microstructure of materials. It also provoke the loss of machined material as well as decrease of tool life. So, high temperatures at the machined surface is responsible for increasing in production costs. He used a process to select the machining parameters that influence for decreasing temperature during the milling of aluminum alloys. From his aspect we generalized this fact of decreasing temperature during machining we applied peltier effect that reduces temperature as well as the surface temperature.

2.2 Dry machining:

Dry cutting is where the coolant is not used for the metal cutting processes The advantages of dry machining include non-pollution of the atmosphere (or water) no residue on the swarf, which will be reflected in reduced disposal and cleaning costs; no danger to health; no injuries to the skin and allergy free.so dry machining is always the best way to sustainability.

Lohithaksha M Maiyara*, Dr.R.Ramanujam investigated the parameter optimization of end milling operation for super alloy with multi-response criteria based on the taguchi orthogonal array with the grey relational analysis. Based on an L9 orthogonal array of Taguchi method were performed a grey relational grade obtained from the grey relational analysis is used to solve the end milling process with the multiple performance characteristics. They expreses a general equation to solve the roughness as $\mathbf{x_{i\,j}}$

$$x_{ij} = \frac{y_{ij} - \min_j y_{ij}}{\max_j y_{ij} - \min_j y_{ij}}$$

Here $\mathbf{y_{i\,j}}$ the experimental number in the array operation. They have done their job in dry machining and got a generalized equation to predict the surface roughness in different condition.

Figure 1: Damage of cutting tool in dry machining during our experiment

The work piece material resulting in the formation of built of edges on the cutting tool, smearing and re-depositing of the chips onto the machined surfaces, thus reducing surface smoothness [4].In figure 1 showing the real view of damage of cutting tool that occurred during our experiment of dry machining without Peltier work.

Beside that the surface roughness and temperature at the cutting tool can be varied with different tool geometry, rack angle, tool setup, work piece and machine vibration, tool wear and degradation etc. Engr. Kaisan Muhammad Usman explained surface roughness can be varied with different rack angle of the cutting tool [9], He included at 20◦ rake angle a good surface finish can be obtained. But it is tough to maintain the absolute 20◦ rake angle in every production.

Kandlikar et al. [14] and Taylor et al. [15] proposed six new roughness parameters that will better describe the surface topography of roughened surfaces for use in fluid flow applications. Three of the presented parameters describe the surface roughness and the other three correspond to the localized hydraulic diameter variations.

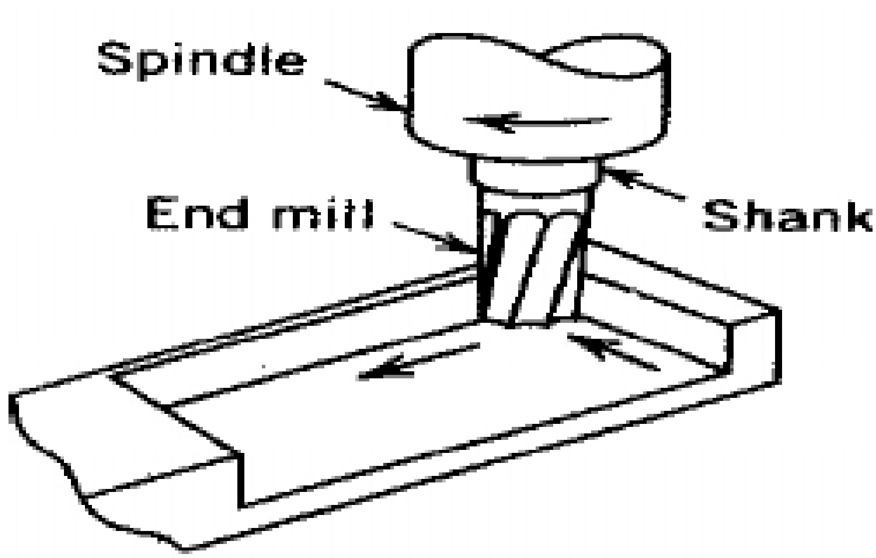


Figure 2: Dry machining during end milling process.

Roughness parameters describe: mean spacing of profile irregularities, maximum profile peak height and the floor distance mean line. The proposed roughness parameter to replace average roughness (Ra) will be further discussed.

Dry machining could be used as an alternative of cutting fluid [4]. But during higher RPM the temperature at the cutting zone become so high. If the temperature is increased to the melting point of the job piece, in some of the case the metal melts down and stuck to the tool. That causes the damage of the cutting tool.

2.3Cryogenic cooling

The application of cryogenic coolants in machining was carried out in the year 1950s.cryogenic cooling is used for effective and fast removal of heat generated during the cutting operations and is used for almost all types of material Cryogenics is the science of very low temperature 100K (-173°C) and absolute zero (0K or -273°C).Cryogenics has been derived from two Greek words, namely ‘cryos’ and ‘genes’, since ‘cryos’ means ice cold and ‘genes’ means born. Today cryogenics deals with temperatures below -153°C or lower. Various cryogenic coolants such as helium, hydrogen, neon, nitrogen, oxygen, argon, krypton, xenon, methane, ethane, propane and carbon dioxide are used but work when referred to cryogenic CO2, LN2 are used for machining. Cryogenic machining is a material removal process where the conventional cutting fluids are replaced with cryogenics such as liquid nitrogen and CO2 etc., in this method usually liquefied gases, is directed into the cutting zone temperature and cool down the tool and/or work piece. The cryogenic medium absorbs the heat from the cutting zone and evaporates into the atmosphere.

Dilip Jerold and Pradeep Kumar, 2011 measures the cutting temperature, chip thickness, surface roughness, cutting forces using the work material as AISI 1045 Steel and used a cutting tool in multicoated carbide the results says that LN2 proved to be a best alternative cutting fluid in terms of reduced cutting temperature cutting forces and better surface finish. Dilip Jerold and pradeep kumar, 2012 made experimental work and compare performance on cryogenic coolant such as LN2 and CO2 measures the cutting temperature, cutting force, tool wear, surface finish, and chip morphology using the work material as AISI 1045 Steel and used a cutting tool in multicoated carbide inserts the results says that when compared to the use of cryogenic LN2 coolant. Tool wear was found to be less on the application of CO2 compared to the wet and LN2 machining conditions.

Yakup Yildz and Muammer (2011)[15] reported that effect of cryogenic cooling in milling process he takes the work material as AISI 304 Stainless Steel and cryogenic cooling is achieved by spraying LN2 to tool, chips and material. And he is measured in cutting forces in dry and cryogenic cooling conditions. And different cutting speed (80, 120, 160, &200m/min) as a result cryogenic cooling and cutting speed are found to be effective on cutting forces

Carbon-Di-Oxide as a coolant was used by V.BALAJI1, S. Ravi [16] they attached with pressure regulator the regulator used for this purpose consists of two dial indicators, one indicating the cylinder pressure and the other indicating the supply pressure Next to the regulator, a carbon dioxide flow meter is attached, to measure the amount of flow of the carbon dioxide coolant. The nozzle tip of the welding torch was pointed towards the cutting zone, to supply carbon dioxide while the machining operation was carried out. But the process was expensive for the manufacturers for their industrial purpose as well as it requires both installing cost and maintaining cost.

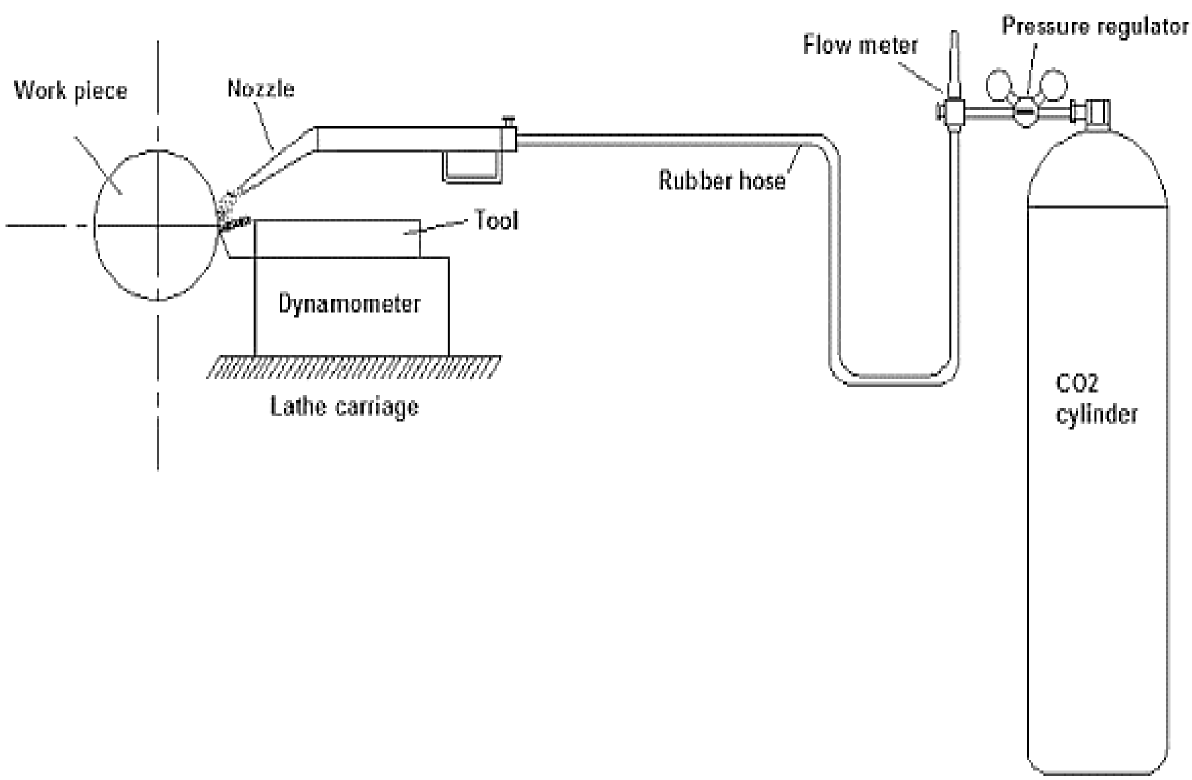


Figure 3: Cryogenic cooling process

Nitrogenous based cooling process is used to decrease the cutting zone temperature. Basically liquid nitrogen is an odorless fluid which is lighter than air. It reduces the temperature of the cutting zone about -120°C [5].But using nitrogenous based coolant is not cost effective to the manufacturer. Hence may have some aspiratory problem of the controller. Additionally, at present it reflects a high complexity in delivering of cryo-fluid to the cutting zone. Therefore the process is still not applied in the industrial environment [6].

2.4 Peltier Chip

The Peltier effect was discovered in 1834 by a French watchmaker and part time physicist Jean Charles Athanase Peltier. Peltier found that the application of a current at an interface between two dissimilar materials results in the absorption/release of heat as seen in Figure n.

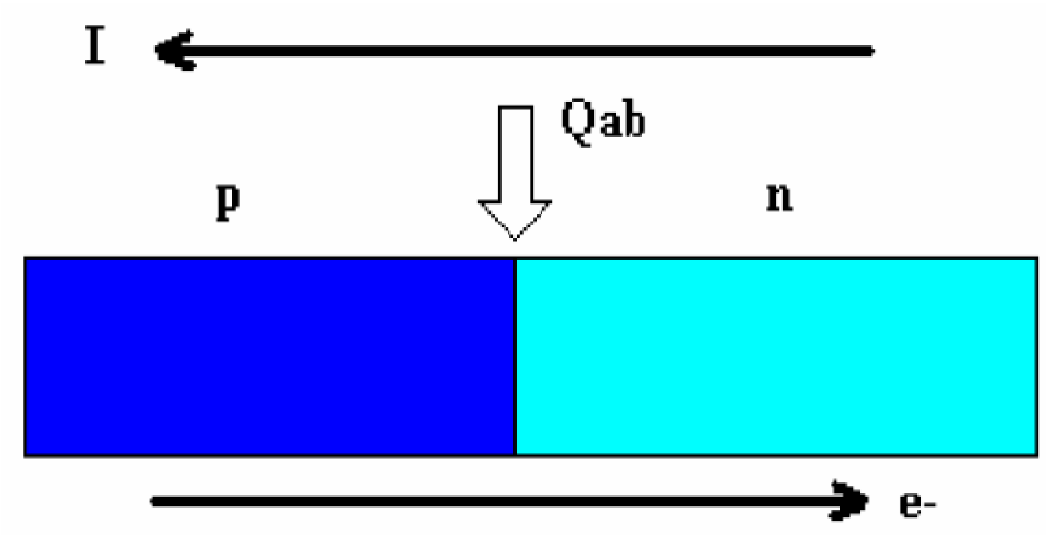


Figure 4: Peltier chips Primary Working principle

Peltier chips has positive and negative sides which are connected to the battery via wire. It contains different ceramic plates at upper and lower side. Inside the Peltier square shaped thermoelectric N, P elements is available which can produce a temperature difference in each blocks.

Basically Peltier elements are solid-state devices with no moving parts; they are extremely reliable and do not require any maintenance and functioned with reverse thermoelectric cooling process creates temperature difference in both side when there is a voltage (12V) is applied. In thermo-electric process, temperature difference at two side of wire is applied and get a voltage as output. In Peltier chip (reverse thermo-electric process), a DC voltage is applied to this semiconductor device, one side gets cold while the opposite side gets hot. As the voltage is higher, the temperature difference become higher. It can make a 15to18 degree Celsius temperature deference on its two side.

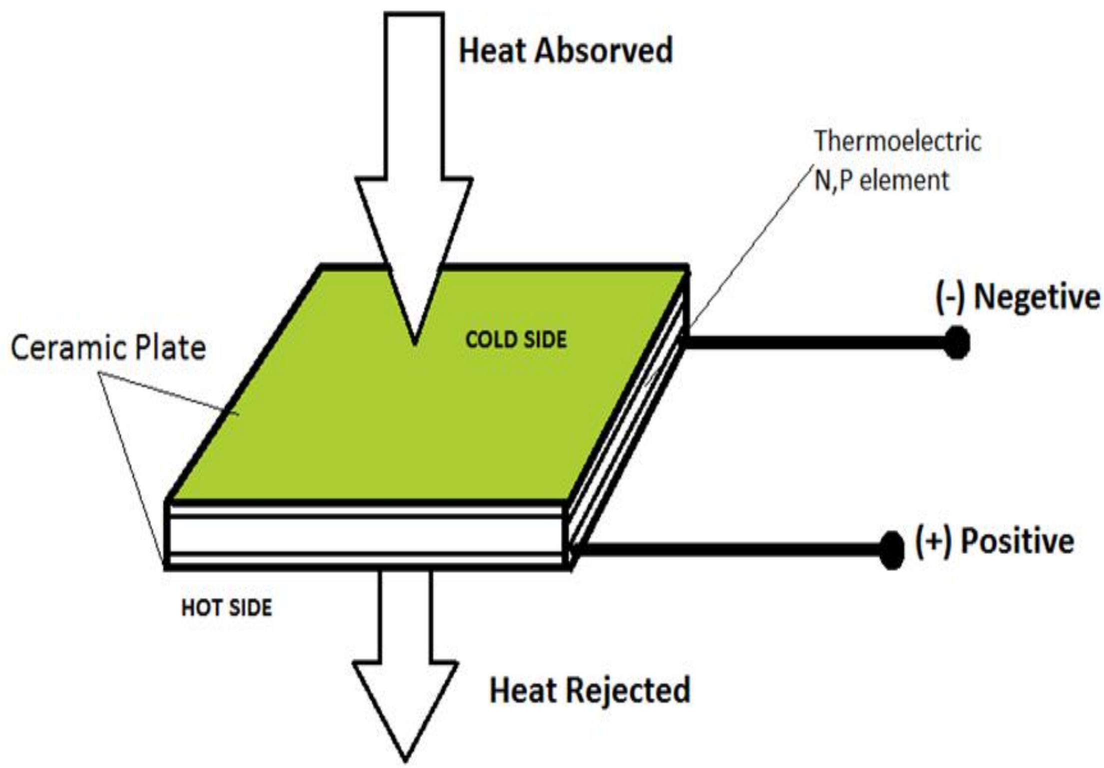


Figure 5: Peltier chip working function

In this paper shows the way to reduce the hot side temperature and to utilize the cold side temperature to decrease the cutting zone temperature.

2.5 Surface Roughness

Surface roughness can be explained by the deviation or the bifurcation of the surface vector from its real value. If the deviation of the surface is more than the real or base line than the surface is rough and if it is are small then the surface is smooth.

The most common surface roughness parameter is relative roughness Ra. This is the currently accepted parameter in industry, and can be found via Equation (Ra)

$$R_a = \frac{1}{n}\sum_{i=1}^{n} |Y_i|$$

Figure 6: Roughness meter

Basically, roughness is just opposite to the smoothness and is the component of surface texture also consist of the waviness and lay. Surface roughness can be measured by the roughness meter. In Figure 3 show a sample view of surface roughness meter.

Difference surface condition criteria, Ra and Rt (expressed in µm)) are often used to denote the roughness. Here, Rt is total roughness (maximum deviation), and Ra is arithmetic roughness (mean arithmetic deviation from the mean line of the roughness).It can be characterized by the equation, Ra $= \frac{\Sigma A + \Sigma B)}{L}$ (H. Yanda et.al. 2010). As shown in Figure 4 in the mean line the deviation is ΣA= ΣB.

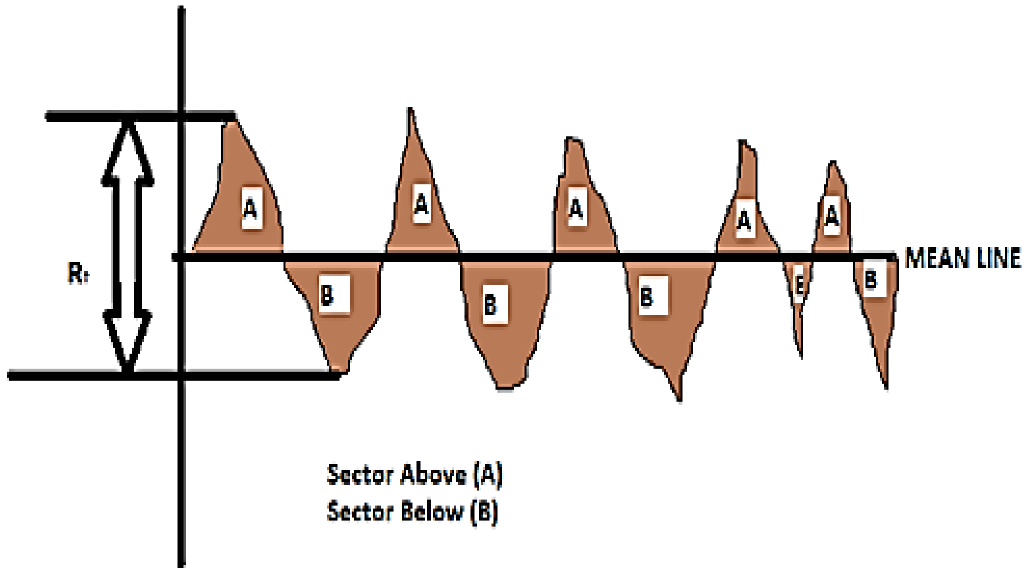


Figure 7: Schematic of the mean arithmetic deviation (Ra) and total roughness (Rt). [H. Yanda et.al, 2010]

The maximum profile peak height, Rp, defines the distance from the mean line to the highest point on the profile. The conjugate of the maximum profile peak height is the maximum profile valley height, Rv. This second parameter represents the distance between the mean line and the lowest point on the profile. Equations (4664) and (18787) show the calculation for these parameters.

Rp = max (z) -Mean Line (4664)

Rv = min (z) -Mean Line(18787)

Different factors are functioned with the surface roughness:

- Different cutting parameters like-feed, cutting speed, depth of cut, MRR etc.
- Angle and sharpness of the cutting edge, corner radius, etc.
- Temperature at the cutting zone.
- Forces applied by the tool
- Types of chip formation

Along all factors we deeply gave emphasis on cutting zone temperature, cutting force, depth of cut and RPM. If these factors stabilizes the surface roughness at different condition the outcome should be more preferable.

CHAPTER 03

3.1 Experimentation set up:

In experiment the Peltier work based machining need only three components- some Peltier chips, a 12V battery, salty ice. Theoretically if we apply more voltage to the Peltier chips it can produce more temperature difference between hot and cold surface of it. But in market only 12V Peltier chips are available that's why 12V battery is use to meet that procurement. In case of industrial purpose it can be modified by the manufacturer to have more efficient product.

Figure 9: Experimental set-up (During the experiment the ices provided in the containers for visualizing clearly only the ice is

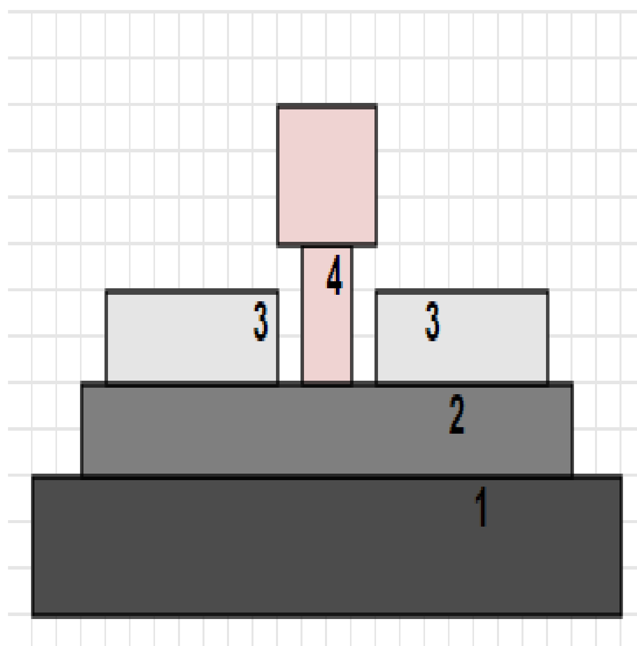
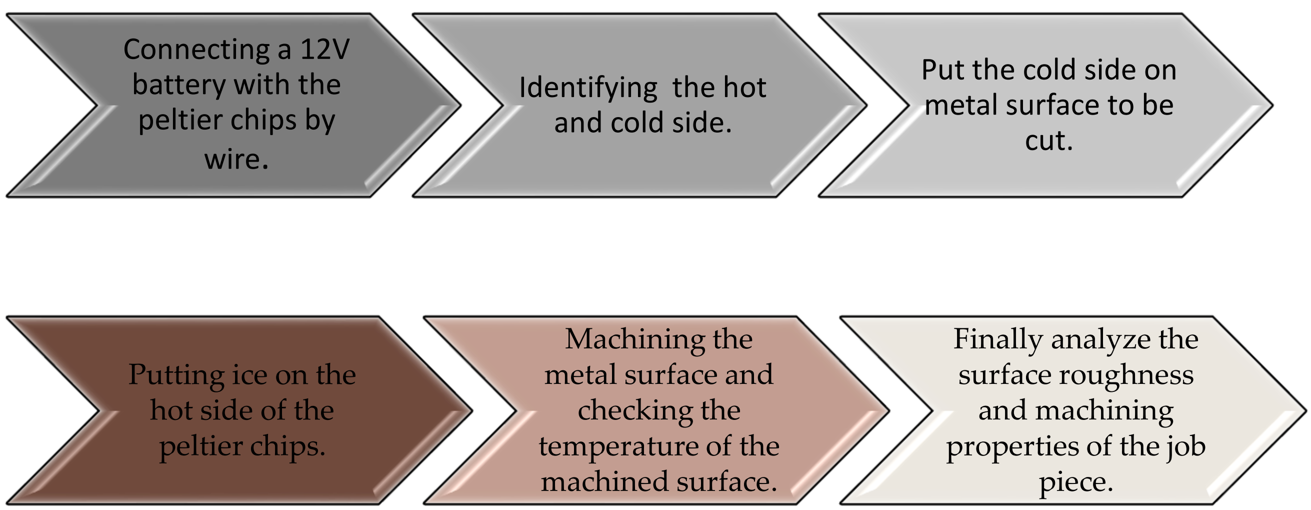


Figure 8: Schematic set-up for Peltier cooling 1-Work table, 2-Workpiece, 3-Peltier Chips, 4-cutting tool

Beside some amount of salt was mixed with the ice. The purpose of mixing salt with ice is- salt can increase the melting time of the ice [8]. Thus this characteristic is used to decrease the melting time of ice. And the ice must be provided in a container. Experimental set up was taken as- the Peltier chips was connected with the 12V battery. Then the hot and cold side of the Peltier chip should be identified, simply by touching two sides. Next, the cold side of the Peltier chip have to put on the surface of the work piece to be cut. And at the hot side the salty ices on container should be put on to decrease the hot side temperature. After setting up all of this, the machining operation can be done. During the operation a clearance must be maintained between Peltier chips and cutting tool.

3.2 Methodology:



During the operation the temperature was measured by the Laser temperature meter. The laser temperature meter can measure the temperature from several distance to the cutting zone. After completing the operation at different RPM the surface roughness has been measured by the surface roughness meter. In table-1 the temperate and the surface roughness is denoted for different RPM.

Chapter 4

4.1 Experimental results

All the experiments was done to meet the manufacturer needs. As the manufacturing the average feed taken by them is ranged between 26-40.Thats why during the experiment the feed was taken fixed as 26 Rev/min and at different RPM the temperature and surface roughness was measured in both Peltier worked machining and without Peltier machining(Dry machining). In table 1 shows the experimental measurements.

Table 1: Temperature and roughness at 0.5 mm depth of cut

RPM	Depth	Temperature (Without Peltier)	Temperature (With Peltier)	Surface Roughness (Without Peltier)	Surface Roughness (With Peltier)
400	0.5	40.20	12.30	2.96	2.06
700	0.5	46.90	15.81	3.64	2.21
900	0.5	50	19.97	3.50	2.36

Table2: Temperature and roughness at 1.5 mm depth of cut

RPM	Depth	Temperature (Without Peltier)	Temperature (With Peltier)	Surface Roughness (Without Peltier)	Surface Roughness (With Peltier)
400	1.5	64	24	5.91	2.66
700	1.5	59	26	5.97	2.81
900	1.5	57	23	6.19	3.12

Table 3: Temperature and roughness at 3 mm depth of cut

RPM	Cutter Diameter (D)	Depth of cut (d)	Roughness		Temperature (^{0}C)	
			With petier	Without peltier	With peltier	Without peltier
400	1.5	3	3.996	5.65	18.6	60.46
500	1.5	3	3.929	5.38	19.5	61.48
600	1.5	3	3.87	4.93	17	56.8
800	1.5	3	3.29	5.85	23.99	55
900	1.5	3	2.69	6.38	21.8	61.7

4.2 Temperature analysis:

The surface roughness can be bought in a suitable range if we can decrease the cutting zone temperature. According to our experimental result shown in table 1 the reddish results are showing with Peltier and blue are without. It can be easily visualized that the temperature at the cutting zone with Peltier is far better than without Peltier. In figure 6 showing, without Peltier all the temperature at different RPM is more than 55°C.It is all most double or triple of with Peltier.

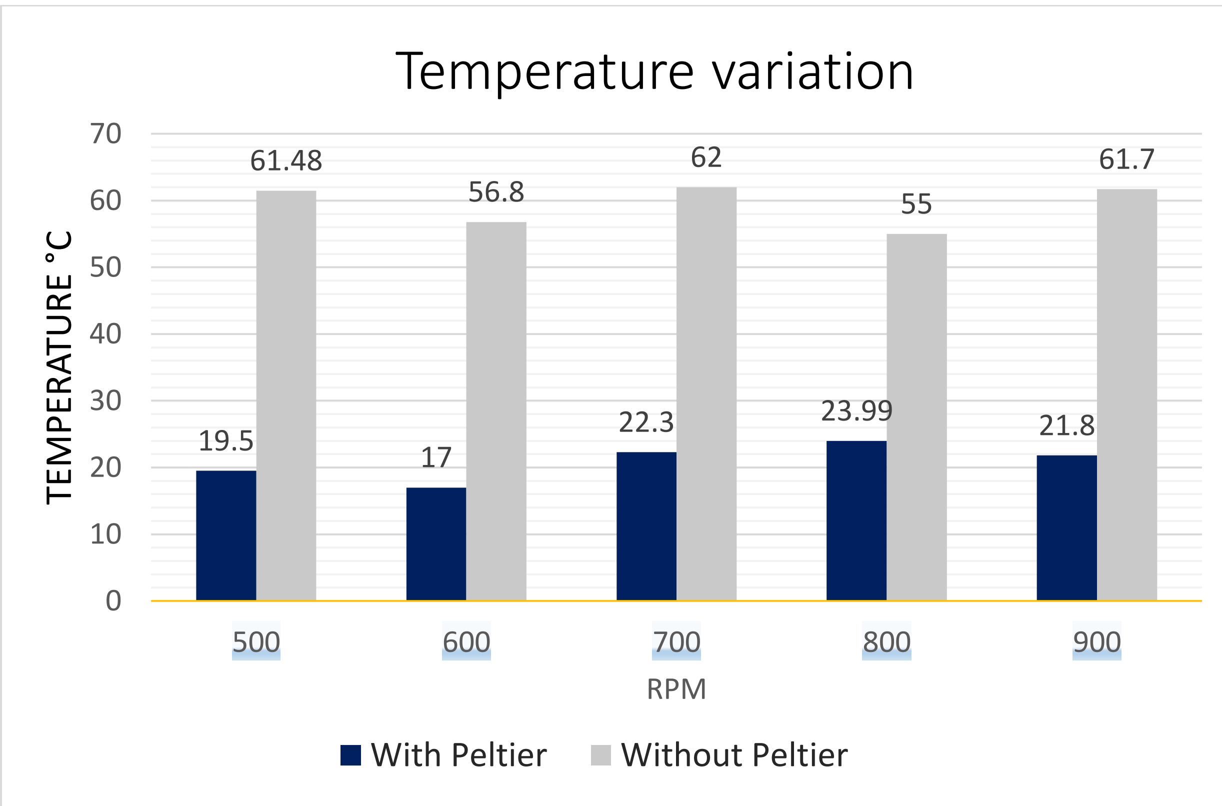


Figure 10: Temperature variation at 3 mm depth of cut

On the other hand, with Peltier the highest temperature is at 800RPM that is 22.3°C.Even the lowest temperature at 500 RPM with Peltier is only 19.5°C.So it is a great advantage for machining to avoid the damage of the tool thus increases the tool life.

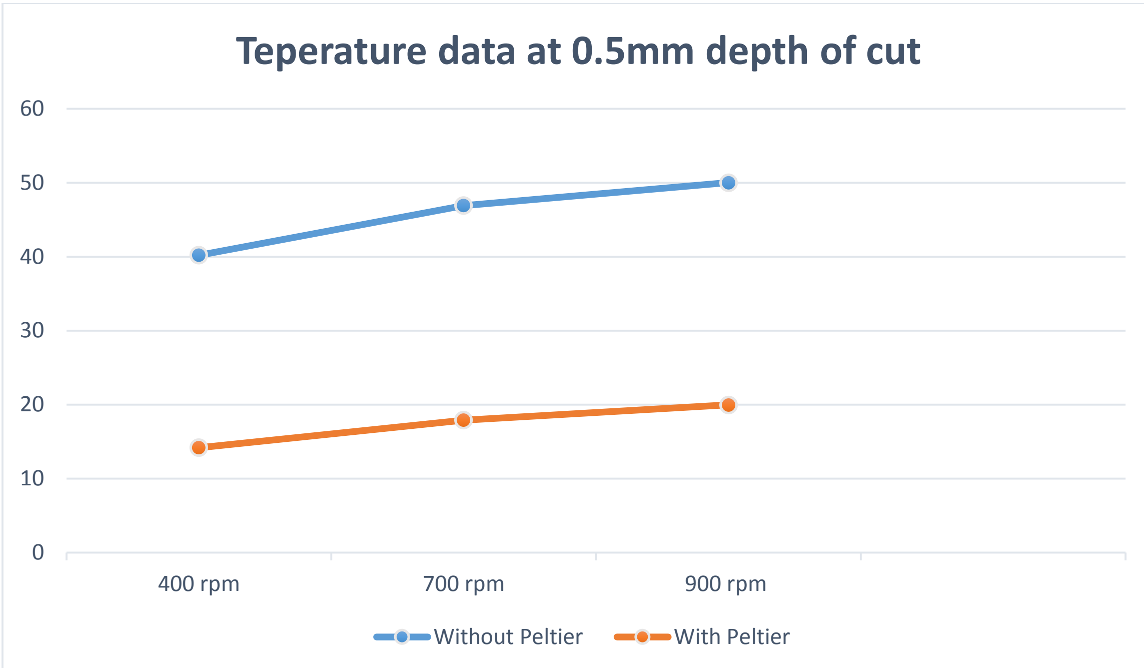


Figure 11: Temperature variation at 0.5 mm depth of cut

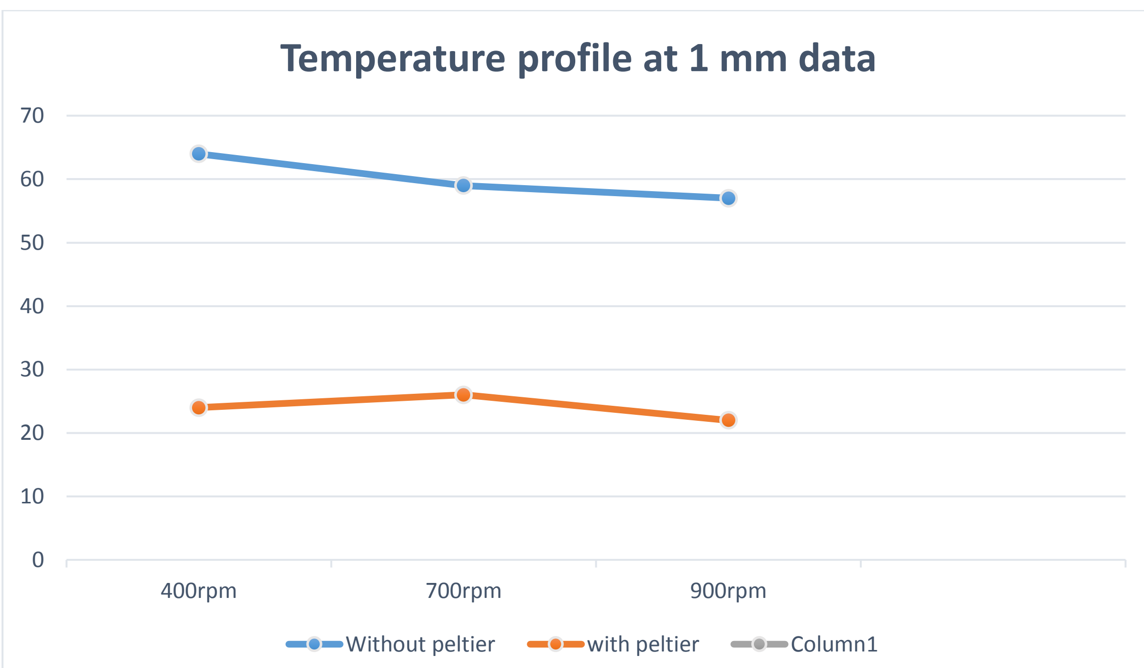


Figure 12: Temperature variation at 1 mm depth of cut

4.3 Surface Roughness Analysis

Roughness can be varied at different RPM during machining. During the experiment the roughness was measured in both with and without Peltier. In Figure 7 showing the variation of roughness at different RPM with and without Peltier work. Firstly, surface roughness is much better in without Peltier machining. At different RPM all the surface roughness without Peltier is over 5.5 µm and with Peltier the value is below 4.2 µm.so the desired advantages achieved in roughness.

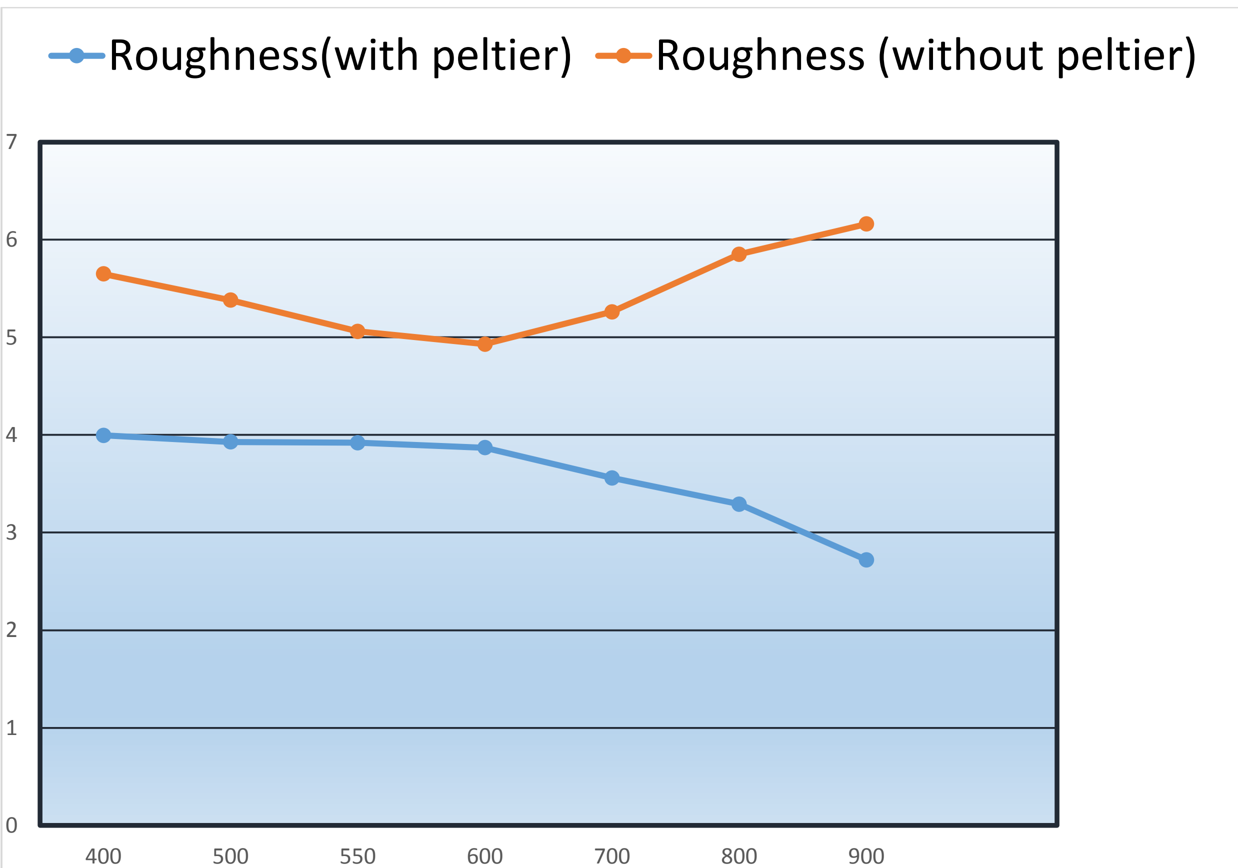


Figure 13: Temperature variation at 3 mm depth of cut

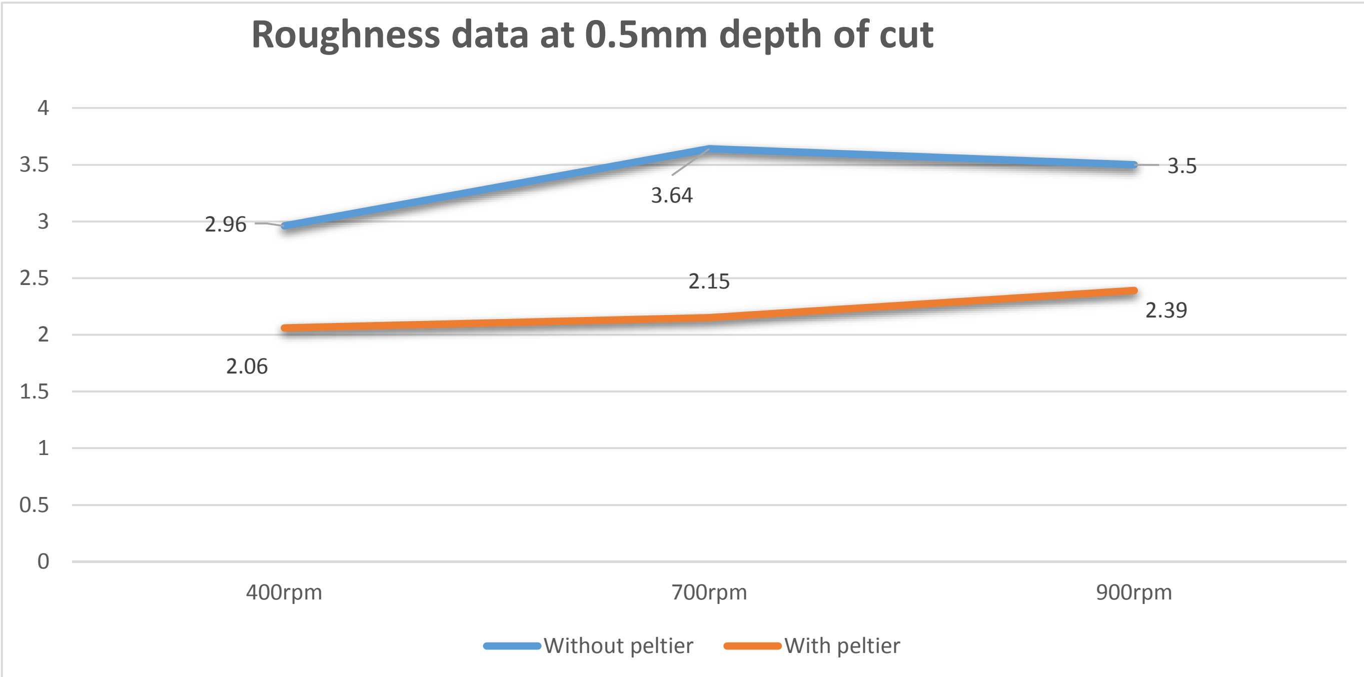


Figure 14: Temperature variation at 0.5 mm depth of cut

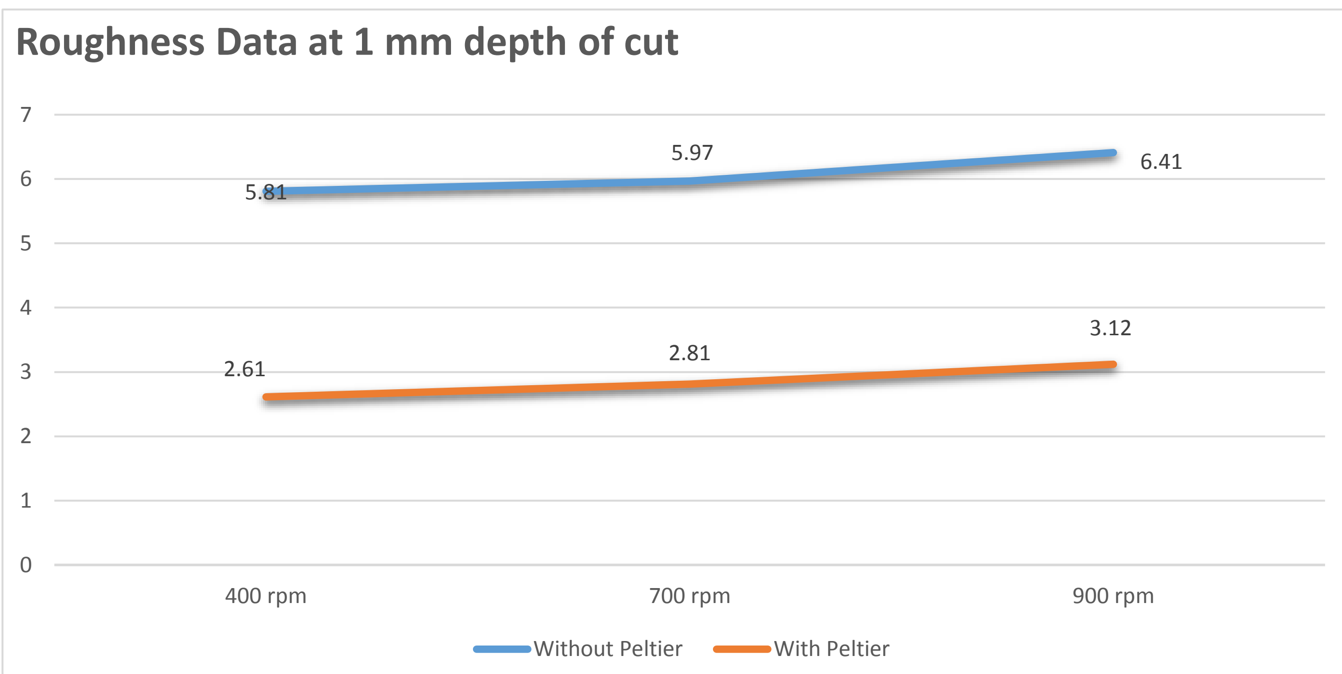


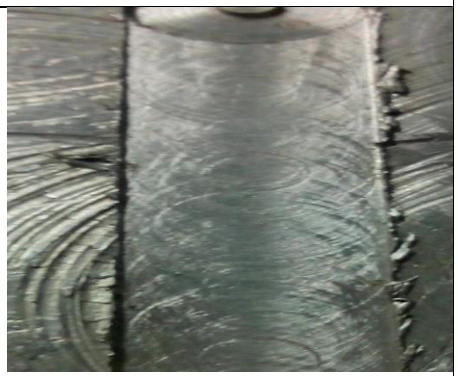
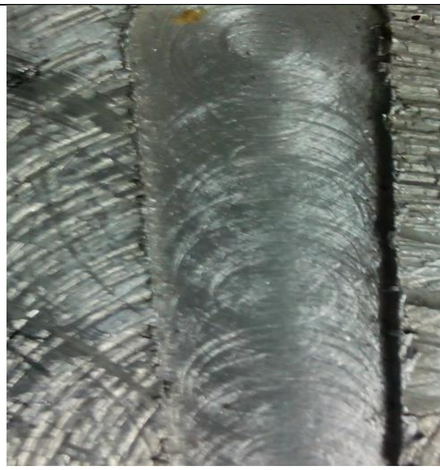
Figure 15: Temperature variation at 1 mm depth of cut

Secondly, Most of the manufacturers prefer to do their machining operation at higher RPM. But it is justified in figure 8 that the higher the RPM at a fixed feed the roughness become higher during without Peltier work. On the other hand, in higher RPM the value of the surface roughness become decreases during with Peltier cooling effect. So, it is a huge advantage for the manufacturer.

4.4. Efect in different Depth of cut & Comparism:

In Figure 9 showing the surface with peltier cooling effect [13] is more reliable than normal condition [14]. Although in cryogenic cooling the surface roughness is smoother but the cost of cryogenic cooling is almost 250% more than the peltier worked. Comparatively, the surface roughness is not so high than the peltier cooled machining relative to its cost

Depth: 0.5mm

RPM	Without peltier	With peltier
400		
700		

900		

Figure Practical view Comparism: at 0.5 mm d

At 1 mm depth of cut

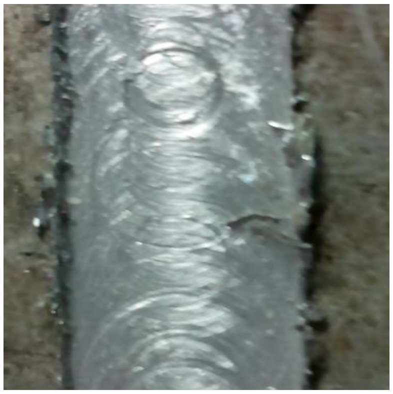
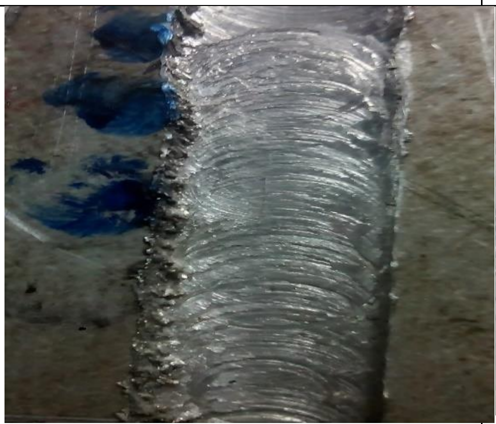
RPM	Without peltier	With peltier
400		
700		
900		

Figure 15:Practical view Comparism at 1 mm d

At 3 mm depth of cut

RPM	WITHOUT Peltier	WITH Peltier
400		
600		

700		
900		

Figure 16:Practical view Comparism at 3 mm d

4.4.1 Experimental Studies in Agreement with Experimental results:

CNC dynamics, i.e. feed and spindle servo systems, change the effective chip loads that directly affects all process states along the tool path. Within the framework of optimizing the machining process, understanding the temperature that occurs during the milling is unessential. The main difficulties in measuring cutting temperature during milling occurs because: (a) the tool is rotating and regularly entering and leaving the work. Piece; (b) the zone affected by the heat moves on the work piece surface, and (c) the chips may hinder the measurement. Moreover, the methods to define the percentage of energy that goes into tool, chip, and work piece vary and depend on each machining, where the main objective is to know the percentage of energy to improve the tool's quality. Nowadays, infrared cameras are commonly used to measure the temperature distribution on machined surfaces. Materials with temperatures above 0 Kelvin show electromagnetic waves. The dynamics of the CNC system must be integrated to the process physics in order to improve the accuracy of the virtual simulation of the machining process and machine tool motion. The experimental trends from this work compare well to the dry machining where the temperature at the cutting zone is relatively higher than using Peltier effect. Corresponding surface roughness is also significantly good. For the manufacturer Roughness parameter is a basic need. According to the experimental result in 0.5mm, 1mm, 3mm depth of cut the surface roughness in increasing when the RPM is increasing gradually. Besides applying Peltier effect is time consuming relative to other processes. For the cryogenic cooling it also a cost effective process.

4.4.2Experimental Studies in Disagreement with Experimental results:

Surface finish is an important factor to indicate the effectiveness of the machining process. In order to explore the effect of different coolants to the surface finish, the surface roughness average values of machined surfaces at three different cooling conditions like RPM, Depth of Cut and feed were recorded and analyzed in table 1 to 4 .During coolant machining based operation the surface roughness Ra is got in a similar results. But by using peltier work the surface smoothness can easily be achieved in that suitable range.Beside that the operation need not look for any other instruments or part to arrange during machining. Just apliying the voltage input switch the operator can have more comfortable operation rather than changing coolant or anything else.

4.4.3 All Results Summary

The processed results from each individual test geometry and test are plotted in Figure 13, 14, 15 and presented in tabular form on the following pages. When available factor is reported for each set of test conditions. It is important to note the error associated with temperature may vary due to environmental temperature at different condition during experimental operation. The tabular form presents relevant geometry and test conditions for completeness to uniquely identify each set of test data.

Chapter 5

Conclusions

5.1 Experimental Conclusions

A novel, physics based virtual milling system is introduced in this thesis. The system receives the NC part program, and the geometry of blank and part from an industry standard Computer Aided Manufacturing (CAM) environment. The part-cutter engagement conditions are identified along the tool path, and used as boundary conditions to simulate the physics of milling operations. The experimental operation and physical results has come into a conclusion by involving the Peltier effect during the CNC milling process. The system allows prediction of cutting performance and possible damage to the part and the machine in a virtual environment so that remedial action can be taken before actual production takes place. In parallel, a series of Peltier chips can be imposed and cutting conditions can be automatically adjusted. The results were analyzed and strong trends within the data found

- All smooth and roughness results were self-consistent
- There appears to be significant chip formation due to the roughness structures tested in the experimental range over different depth of cuts and other counterparts.
- This study shows the interaction between radial depth of cut and feed rate to be the most factor affecting the surface roughness. Machining induced factor contributed to this response.

5.2 Theoretical Conclusion:

This investigation approaches the Peltier cooling effect can be used as an alternative way to conventional coolant as well as different cutting parameters used in CNC milling. Most significant interactions were found between work materials, cutting zone temperature, surface roughness and RPM. Studies documented in the literature section suggest that Peltier effect has demonstrated a vast promising results to improve the machinability of difficult-to-machine materials in milling operation.

Experimental investigations also explored that Peltier cooling is an effective method to eliminate the use of cutting fluids and maintain the surface smoothness of the machined parts. Therefore, Peltier cooling effect can be established as a new tradition to improve machinability. The following are conclusions drawn based on the experimental investigation conducted to determine the optimal level of process parameters.

- According to the data collection clearly it is observed that the increase in RPM tends to improve the roughness thus the cutting zone temperature increases.
- Interestingly the optimal combination process parameters for minimum surface roughness are obtained at 900 RPM.
- When the cutting directions are compared, we can state that up-milling generates higher temperature thus it requires more efficient and relevant peltier work at the cutting surface in the milling of aluminum

Summary of Experimental Results

The experimental results of this work were found to be self-consistent, but deviated from theoretical expectations significantly in temperature data. The temperature data may affected due to the surrounding environmental temperature and surface condition while the machining condition is done. The consistency of the results show that the experimental procedure, data collection method, and interpretation are accurate and reasonable. However, this issue is not limited to the use of hydraulic diameter. Any misinterpretation leading to an invalid negligible axial conduction assumption could explain the behavior of the system.

The overall experiment result showed that the surface finish, cutting forces, and tool wear are related to the heat generated at the cutting zone and the friction between tool and work surface. Peltier Chip effect emulsion is the best cooling process compare with dry machining, Cryogenic cooling as well as compressed cold air. Conventional coolants can be applied in machining of hardened steel while compressed cold air can be used in machining of softer metal like aluminum, mild steel and etc. A better coolant and optimal parameters have been figured out.

Chapter 6

There are remaining key challenges before achieving a fully virtual machining of parts using models with the machine tool and the cutting process. The experimental results in the performed study were self-consistent within reasonable error limits. The results, however, require expanded experimental range before a definitive
Understanding of the effect of roughness, in general, can be obtained.

Recommendation

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