# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# COMPARISON STUDY BETWEEN THE EFFECT OF VORTEX AIR COOLING AND CONVENTIONAL COOLING ON FLANK WEAR AND SURFACE ROUGHNESS

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

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# APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory is as follow:

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# ABSTRAK

Cecair pemotong dalam proses beralih digunakan untuk mengurangkan suhu pemotongan antara mata alat and serpihan. Pemesinan hijau amat disukai, dengan itu penyejukan tiub vorteks adalah diperkenalkan. Penyejukan udara mendorongkan penurunan suhu antara mata alat and serpihan. Cecair pemotong konvensional menyebabkan impak kesihatan, pencemaran dan kos yang tinggi dalam aspek pembelian dan rawatan. Terdapat satu kajian korelasi di antara tekanan udara dan suhu udara vorteks dalam eksperimen pertama, manakala perbandingan kehausan rusuk dan kekasaran permukaan antara penyejukan udara vorteks dan penyejukan konvensional dalam eksperimen kedua. Suhu udara vorteks telah diukur oleh Hanna K-type thermocouple. Dalam eskperimen kedua, proses pemesinan dilakukan dalam parameter yang dioptimumkan serta tetap, 425rpm kecepatan pemotongan, 0.05mm/rev kecepatan dan 0.5mm kedalaman pemotongan. Mesin Larik adalah digunakan untuk proses pemesinan, manakala Stereo Microscope dan Mitutoyo profilometer digunakan mengukur kehausan rusuk serta kekasaran permukaan masing-masing. Coefficient of determinant, $R^2$ dalam eksperimen pertama berhampiran dengan 1, bermakna satu hubungan yang kuat antara tekanan udara dan suhu udara vorteks. Berdasarkan analisis ANOVA, eksperimen kedua menunjukkan kedua-dua bendalir pemotong menjejaskan kehausan rusuk dan kekasaran permukaan dengan signifikasi. Penyejukan secara konvensional membekalkan kehausan rusuk sebanyak 2.4 kali lebih kecil daripada penyejukan udara vorteks. Ini kerana kekonduksian haba dan perolakan haba pekali udara adalah rendah daripada cecair. Namun, penyejukan udara vorteks mempunyai kekasaran permukaan dengan 60% lebih rendah daripada penyejukan konvensional kerana lazim kemunculan “built up edge” semasa menggunakan penyejukan konvensional.

# ABSTRACT

In turning process, cutting fluid is used to reduce cutting temperature at tool-chip interface. A green machining is always preferable, so vortex air cutting is introduced. Vortex air helps to reduce cutting temperature at the tool-chip interface, without using cutting fluid that caused health hazard, pollution and a high cost have to spend on purchasing and treatment. Cold air is produced by compressed air without using any refrigerant and it is used to spot onto tool-workpiece interface. First experiment studied correlation between air pressure and vortex air temperature, while second experiment compared the flank wear and surface roughness between both vortex air cooling and conventional cooling. Vortex air temperature was measured by Hanna K-type thermocouple. For the second experiment, optimized machining parameters were used which are high cutting speed of 425rpm, low feed rate of 0.05mm/rev and 0.5mm depth of cut. A lathe machine, a Stereo Microscope and a Mitutoyo profilometer were used for machining, measuring flank wear as well as surface roughness respectively. The coefficient of determinant, $R^2$ of first experiment is closed to 1 which means a strong correlation between air pressure and vortex air temperature. Based on ANOVA analysis, the second experiment indicated that both coolant type significantly influenced flank wear and surface roughness. For flank wear performance, conventional cooling was 2.4 times smaller than that of vortex air cooling. The main reason is the air is a poorer heat conductivity and lower specific heat convection. However, vortex air cooling made an improvement of 60% on surface roughness when compared to that of conventional cooling. This is because built up edge was prevalent for conventional cooling.

*Keywords: Vortex Air Cooling, Flank Wear, Surface Roughness*

# DEDICATION

To my beloved family

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| $F_R$ | Resultant Force |
| $H_0$ | Null hypothesis |
| $H_1$ | Alternative hypothesis |
| mm | millimeter |
| MQL | Minimum quantity lubrication |
| $R^2$ | Coefficient of Determination |
| Ra | Surface roughness |
| rpm | Revolution per minute |
| $VB_B$ | Flank Wear-Land Width |
| $VB_{max}$ | Maximum Flank Wear |
| α | Alpha |
| β | Beta |
| μm | Micrometer |

# CHAPTER 1

# INTRODUCTION

This chapter briefly explained the background of cutting fluid in machining, problem statement, objectives of research, scope of research and its hypothesis.

## 1.1 Background of Cutting Fluid

Friction is generated at the tool-chip interface during machining process and it produced high temperature on the cutting tool. Wear is accelerated at elevated temperature, subsequently cutting tool life is decreased. Besides, the surface roughness is increased, whilst dimensional sensitiveness of workpiece is decreased due to generated friction (Cakir et al., 2007)(Boswell and Chandratilleke, 2009). Cakir et al.(2007) pointed out that there are some approaches to protect cutting tools from heat generation. For example, the cutting tool can be coated with heat resistance alloys such as titanium alloy. From economical perspective, conventional coolant is one of the more economical approach to reduce the heat generation and increase material removal rates. Basically, coolant is used to cool cutting tool and workpiece as well as lubricates them. Besides, it flushes the chips away from the cutting zone. The cooling effect plays the most important role to decrease temperature on the cutting zone so that longer tool life, high dimensional accuracy and good surface quality of machined workpiece are achieved. Water based coolant is more suitable for turning process due to high cutting speed. A high pressure cutting fluids with additive is utilized in steel machining. However, this method causes some problems, such as mixture of sulphur (cutting fluid) and oils (additive) left stain over the workpiece's surface. The used cutting fluid usually consists of fine chip, tramp oil and contaminants (Chowdhury et al., 2014).

Although, conventional coolant has a lot of benefits, it is unfriendly to environment and produces biological hazards to operators. An alternative is approached to solve this problem during machining process, which is dry machining. Dry machining is the machining process without using any coolant which can address concerns regarding to environmental legislation (Cakir et al., 2007 and Duspara et al., 2013). Sharma et al. (2009) stated that there are some techniques that can be used to replace the conventional cutting fluid during dry machining. For example, minimum quantity lubrication (MQL), compressed air cooling, cryogenic cooling and high pressure coolant. They have a potential to reduce the friction and heat at cutting zone as well increase material removal rate. According to Duspara et al. (2013), a stream of cold air from vortex tube spots onto interface between tool tip and workpiece can reduce the tool wear and machining cost.

## 1.2 Problem Statement

Boswell and Chandratilleke (2009) indicated that air cooling method is seldom being considered in manufacturing industry because of the effectiveness of conventional cutting fluid during machining process. However, usage conventional cutting fluid is harmful the environment and create the health hazards to human being. In addition to that cost for conventional cutting fluid is quite high. Dangar and Mukherjee (2014) stated that dry machining should be given a lot of awareness for sake of environment and workers' health. Mac (2012) said that those that were exposed cutting fluids for a long period of time have higher probability to suffer from a lot of diseases. He gave an example of illness suffered by workers in Birmingham in year 2004. Around 70 workers at a car engine factory were diagnosed with serious lung illness. In addition, the Health and Safety Executive (HSE) had screened over 1000 workers of Powerstrain in Longbridge Plant, Birmingham. It was found that 73 people were definitely had suffered occupational asthma or extrinsic allergic alveolitis and worried about the outbreak of occupational lung disease among workers. Accordingly, HSE advised Powerstrain to take a serious improvement on the cleaning and monitoring regimes for the metalworking machines and cutting fluids. HSE discovered that microbes in cutting fluids resulted in diseases and need to be controlled.

Apart from the negative environmental and health impacts, the cost of conventional cutting fluid is quite high which is around 7-17% of total machining cost. Selek et al. (2011) said the cutting become polluted during machining process. Actually, only 15% of cutting fluid is used to dissipate heat, another 1% sticks onto part which may influence the quality of part and the rest cutting fluid is returned back to oil tank, and remained in cooling oil to avoid a contact with air. This step resulted in the thriving condition for bacteria to breed in the cooling oil. So, another economic burden associated to usage of cutting fluid was to establish regular cleaning of cooling tank and treatment. Moreover, cutting fluids have to change regularly due to their low efficiency after being used for a certain time.

## 1.3 Objectives of Research

Objectives of this research are:

- To study the correlation between inlet air pressure and the vortex outlet air temperature.

- To compare the effectiveness of vortex air cooling to that of conventional cutting fluid with respect to flank wear and surface roughness.

## 1.4 Scope of Research

There are two experiments executed for this project. The first experiment was done to determine the minimum temperature that can be achieved using available compressed air using vortex tube. The second experiment focused on the effectiveness of vortex air cooling on the flank wear and surface roughness of workpiec. Other input variables which are cutting speed, feed rate and depth of cut were set at constant values. The cutting tool was tungsten carbides, the workpiece was mild steel.

## 1.5 Hypothesis

The hypothesis testing is to investigate the effect of conventional coolant and vortex air cooling to tool flank wear and surface roughness. Null hypothesis, $H_0$ and alternative hypothesis, $H_1$ specify the relationship between conventional coolant ad vortex air cooling.

$H_0$ : flank wear (vortex air cooling) = flank wear (conventional cooling)
$H_1$ : flank wear (vortex air cooling) ≠ flank wear (conventional cooling)

$H_0$ : surface roughness (vortex air cooling) = surface roughness (conventional cooling)
$H_1$ : surface roughness (vortex air cooling) ≠ surface roughness (conventional cooling)

# CHAPTER 2

## LITERATURE REVIEW

This chapter described machining process, especially turning operation. Next, dry machining is introduced in term of vortex air. Then, some information was collected from journals with similar scope as that of this study. Lastly, the strategy of inferential statistic and statistical test were briefly explained.

### 2.1 Machining

According to Kaushish (2010), machining is a process that involves removes material and transforms the machined product into desired size and shape. Machining includes a huge number of cutting operations. The basic machining includes milling, drilling, boring grinding, turning and etc.