UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EFFECT OF CHILLED AIR COOLANT ON SURFACE ROUGHNESS AND TOOL WEAR WHEN MACHINING 2205 DUPLEX STAINLESS STEEL

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

by

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I hereby, declared this report entitled "Effect of Chilled Air Coolant on Surface Roughness and Tool Wear When Machining 2205 Duplex Stainless Steel" is the results of my own research except as cited in references.

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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:

………………………………

(Dr. Liew Pay Jun)

ABSTRAK

Cecair pemotong adalah penting untuk meningkatkan kemudahan sesuatu alatan kerja untuk dimesin. Walau bagaimanapun, cecair pemotong konvensional adalah tidak ekonomik dan berbahaya kepada alam sekitar dan kesihatan. Oleh itu, kaedah penyejuk bukan konvensional dikaji untuk mengatasi masalah ini. Dalam kajian ini, kesan penyejuk udara sejuk pada kekasaran permukaan dan kehausan alat apabila pemesinan 2205 dupleks keluli tahan karat disiasat. Udara termampat disejukkan dengan menggunakan tiub vorteks. Udara sejuk dan udara panas yang dihasilkan melalui tiub vorteks daripada sumber udara termampat. Kajian ini juga melibatkan perbandingan antara prestasi pemesinan antara penyejuk banjir konvensional dan penyejuk udara sejuk. Ujian telah dijalankan pada mesin perubahan konvensional dengan TiAlN bersalut alat karbida dan parameter yang berterusan terpilih adalah kadar suapan, kedalaman pemotongan, dan kelajuan pemotongan. Kekasaran permukaan dan kehausan alat diukur bagi setiap kali eksperimen dijalankan. Jangka hayat mata alat dan kemasan permukaan bahan kerja telah dianalisis dalam setiap keadaan pemotongan. Keputusan eksperimen menunjukkan bahawa penyejuk udara sejuk memberikan kemasan permukaan yang lebih baik daripada penyejuk banjir konvensional. Walau bagaimanapun, jangka hayat alat adalah lebih baik apabila menggunakan penyejuk banjir konvensional berbanding penyejuk udara sejuk. Bagi kedua-dua kaedah penyejuk, hasilnya menunjukkan penurunan corak untuk kekasaran permukaan dan kehausan mata alat apabila suhu pendingin udara sejuk menurun.

ABSTRACT

Cutting fluid is important to enhance machinability. However, conventional cutting fluid is uneconomical and hazardous to environment and health. Thus, non conventional coolant method is studied in order to overcome these problems. In this study, the effect of chilled air coolant on surface roughness and tool wear when machining 2205 duplex stainless steel is investigated. The compressed air is chilled by using vortex tube. Cold air and hot air is produced by means of vortex tube from the source of compressed air. This study also investigated the comparison of machining performance between conventional flood coolant and chilled air coolant. The tests were conducted on a conventional turning machine with TiAlN coated carbide tools and the constant parameters selected were feed rate, cutting depth, and cutting speed. Surface roughness and tool wear were measured after each run and the results were analysed. The experiment results showed that chilled air coolant gave better surface finish compared to conventional flood coolant. However, tool life was better when using conventional flood coolant compared to chilled air coolant. For both coolant method, the result showed decreasing trend for surface roughness and tool wear values when the temperature of chilled air coolant decreased.

DEDICATION

To my beloved family

DEDICATION

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A. C.	Alternate Current
ANOVA	Analysis of Variance
ASTM	America Standard Testing Material
BUE	Built Up Edge
CNC	Computer Numerical Control
CVD	Chemical Vapor Deposition
D	Diameter
DSS	Duplex Stainless Steel
f	Feed
ISO	International Standard Organization
LN	Liquid Nitrogen
MQL	Minimum Quantity Lubricant
OHNS	Oil Hardened Non Shrinkable
PVD	Physical Vapor Deposition
Ra	Roughness Average
RPM	Revolution Per Minute
SEM	Scanning Electronic Microscope
TiAlN	Titanium Aluminium Nitride

TiC	Titanium Carbide
TiCN	Titanium Carbonitride
TiN	Titanium Nitride
VBmax	Maximum Flank Wear
V_c	Cutting Speed

CHAPTER 1
INTRODUCTION

This chapter covers the introduction, problem statement, objectives, and scopes of this project. The chapter overview is also included in this chapter.

1.1 Introduction

Duplex stainless steels (DSS) are chromium- nickel-molybdenum alloys that consist of balanced amount of austenite and ferrite mixture. By comparing to austenitic stainless steel alloy, the resistance to chloride stress corrosion cracking and the mechanical properties of DSS alloys are much higher. DSSs are widely being used in many industrial sectors like chemical and petrochemical, offshore, pharmaceutical industry and marine industry.

Machining is a process in which the unwanted raw material is removed by using sharp cutting tool in order to attain a desired geometry. There are several types of machining processes such as turning, drilling and milling. Turning is a process where the cutting tool is fed to a rotating workpiece to generate an external and internal surface concentric with the axis of rotation. The machine tool used for turning is called lathe. When the metal is cut, energy is dissipated in overcoming friction between the tool and workpiece and in deformation of the chip. This energy is converted to heat, this cause high temperature in the deformation zone as well as the tool and workpiece. Therefore a cutting fluid or coolant is needed to reduce the temperature (Stephenson & Agapiou, 2006).

Cutting fluid performance in the machining operation is important to enhance the effectiveness of the machining process. The main purpose of cutting fluid is for cooling and lubrication but it also helps in improving surface finish, increasing life span of the cutting tool, and increasing the dimensional accuracy of the workpiece. Other than that, cutting fluid is used to flush away the chips from the cutting zone, increase the corrosion resistance of the workpiece and machine, and prevent formation of build up edge (Johnson et al., 2014).

The general type of cutting fluid consist of water-soluble fluid, neat cutting oil and gaseous. Water soluble fluids are preferable for operations where cutting speeds are very high and pressures on the tool are relatively low. Neat cutting oils are straight mineral oils, or mineral oils with additives which are suitable when the cutting pressures between chip and cutting tool were very high. Lubrication is important to reduce the cutting pressure at the cutting zone. At high cutting speed the cutting fluids are unable to penetrate into the chip–tool interface. Gaseous lubricants are preferable when the cutting fluid penetration problem is considered but the high cost of gases made them uneconomical for production applications (Yildiz & Nalbant, 2008).

The use of cutting fluid is not only uneconomical for production application, but it also harmful to environment as well as the health of the worker. These disadvantages have made many companies seriously searching for an alternative to replace the conventional flood coolant method. Therefore the study on chilled air coolant was done to find the solution to this problem. Most of the works on low temperature machining are in the cryogenic machining. Even though this is process is promising, it is cost prohibited in most machining situations. The proposed research will utilize passive cooling method using vortex tube to chill the compressed air. Since the source of energy for this application coming from regular compressed air, the cost associate with it is much lower than that of cryogenic cooling method (Rinaldy et al., 2016).

1.2 Problem Statement

Coolant is important as it helps in increasing tool life and improves surface roughness. However conventional flood coolant is uneconomical and it brings harm to the environment and the human health. There were researches that have been done on low temperature machining study such as cryogenic coolant but to implement this type of coolant is quite expensive. Therefore, a research on chilled air liquid coolant will be done to see its effect on the surface roughness and tool wear.

1.3 Objectives

The objectives of this project are:

- To investigate the effect of chilled air coolant on surface roughness and tool wear when machining 2205 duplex stainless steel.
- To compare the machining performance between chilled air coolant and conventional flooded coolant method.

1.4 Scope

This study is carried out using a vegetable oil coolant that is widely used in machining. The process that is used is turning process, using the TiAlN coated tungsten carbide grade. The workpiece material is 2205 duplex stainless steel. The coolant methods that are used are chilled air coolant and flood coolant. The input variables which are cutting speed, feed rate and depth of cut are set as the constant parameter. The effect of chilled air coolant on the surface roughness and tool wear when machining 2205 duplex stainless steel is studied and analysed in detail.

1.5 Chapter Overview

Chapter 1 covers the introduction of this investigation. It contains the general information about the investigation, problem statement, objectives, and scope of the project.

Chapter 2 covers the literature review for this pro. It contains the literature review for turning, cutting fluid in turning, studies on cutting fluid and chilled coolant.

Chapter 3 contains the methodology of this project. It contains flow chart, literature review, execution of the experiment, data collection and data analysis.

Chapter 4 contains the result and discussion for this project. The data from the experiment is collected and analysed.

Chapter 5 covers the conclusion of this investigation. This chapter also covers the recommendation for future work and sustainability of this investigation.

CHAPTER 2
LITERATURE REVIEW

This chapter contains the literature review of the project which is related to the objectives and scope of the project. This chapter also tells about the literature review that will be used in this entire investigation.

2.1 Turning Process

Turning is one of the most basic machining operations. Turning is a very important machining process in which a single point cutting tool removes unwanted material from the surface of a rotating cylindrical work piece. The basic principle of turning operation is shown in Figure 2.1. The cutting tool is fed linearly in a direction parallel to the axis of rotation (Ozcelik et al., 2011). It can produce an internal or external surface concentrically with the axis of rotation. The workpiece is clamped on a rotating spindle using a chuck, collet, face plate, or between pointed conical centers. The cutting tool is held on a turret on a translating carriage or in the tailstock. The carriage moves along the bedways which is parallel to the part axis (Z-axis) (Stephenson et al., 2006). It can be adjusted axially on the bedways to accommodate workpieces of various lengths. The feed motion is usually parallel to the axis of the workpiece.

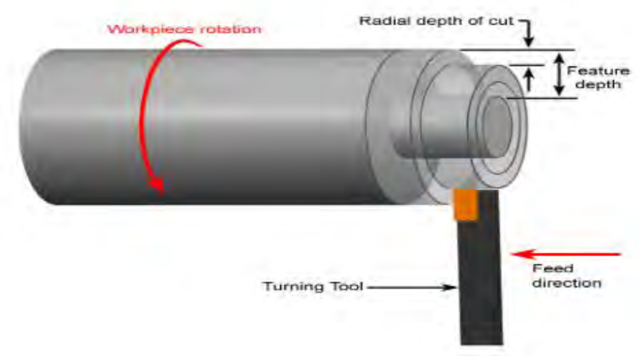

Figure 2.1: Turning operation (Tulasiramarao et al., 2013)

Turning is used to reduce the diameter of the workpiece usually to a specified dimension, and to produce a smooth finish on the workpiece. Often the work piece will be turned so that adjacent sections have different diameters (Khandey, 2009).

2.2 Machining Parameters

In turning, the main machining parameters are speed, feed and depth of cut. There are other parameters or input factors that will influenced the output parameter such as surface roughness and tool wear, however the control of those three parameters can be adjusted during the turning operation (Agrawalla, 2014).

2.2.1 Cutting Speed

Cutting speed is the rate at which the part moves past the cutting tool. It is also referred as surface speed. The spindle speed is the speed when the spindle rotates and it is measured in revolution per minute. It is the basically the product of the rotating speed times the circumference of the work piece before the cut is begun. It is only referring to the work piece and is expressed in meter per minute (m/min). Cutting speed will be different if the diameter of the workpiece is different, although the rotating speed does not change.

$$V_c = \frac{\pi DN}{1000} \quad [2.1]$$

V_c is the cutting speed in turning, D is the initial diameter of the work piece in mm, and N is the spindle speed in RPM (Agrawalla, 2014).

2.2.2 Feed Rate

Feed rate is the rate of the cutting tool moves through the material that is being cut. The feed rate units depend on the motion of the tool and workpiece. When the workpiece rotates, the units are almost distance per spindle revolution. It is usually expressed in mm per revolution, or mm/rev.

$$F_m = f.N \text{ mm.min}^{-1} \quad [2.2]$$

F_m represents the feed in mm per minute, f is the feed in mm/rev and N is the spindle speed in RPM (Khandey, 2009).

2.2.3 Depth of Cut

Depth of cut referred to the thickness of the material that is removed from the workpiece. The diameter after machining is reduced by twice of the depth of cut due to the removal of the material from both sides.

$$d_{cut} = \frac{D-d}{2} \text{ mm} \quad [2.3]$$

D and d represent initial and final diameter (in mm) of the job respectively (Agrawalla, 2014).

2.2.4 Studies on Machining Parameter

Johnson et al. (2014) studied the optimization of the cutting parameters and fluid application parameters while turning of Oil Hardened Non shrinkable steel (OHNS) with minimal cutting fluid application using Taguchi technique. Three different