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EXPERIMENTAL INVESTIGATION OF ENVIRONMENT FRIENDLY COOLING METHODS FOR DIFFERENT MACHINING CONDITIONS

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ABSTRACT

This study deals with the experimental investigation of temperature and heat generation during machining process and cooling methods. Elevated temperatures generated in machining operations significantly influence the process efficiency and the surface quality of the machine part. Heat transfer between the chip, the tool, and the environment during the metal machining process has an impact on temperatures, wear mechanisms and hence on tool-life and on the accuracy of the machined component. This study deals with experimental study of different cooling methods for different machining conditions. In this presented work cooling has been determined by calculating the heat transfer coefficient. Experiments on work piece cooling conducted on a lathe provided reference temperature data for a model of a cylindrical work piece, which was solved for temperature using a Control-Volume Finite Difference method. Heat transfer coefficients were obtained for various convective boundary conditions existing on a work piece when cooling in VTJA air and in coolant. Cooling characteristics calculated using these heat transfer coefficients showed good agreement with the experiment. Presented approach can be used to obtain the convective heat transfer coefficients for studies on modelling thermal behavior of a work piece in other conditions.

Keywords: Heat transfer coefficient, dry machining, wet machining, Vortex Tube Jet Assisted machining.

I. INTRODUCTION

There has been a growing interest in modelling of metal cutting process in recent years.so it has been also accompanied by the interest in modelling of thermal behaviour of the work piece. Thermal expansion affects the machining accuracy, hence the latter interest can be attributed to the demand for higher accuracy. Machining error caused by the thermal expansion of the work piece are expressed by the convective heat transfer coefficients. According to the L. Kops M. Arenson little has been reported on the rotating cylinder in a quiescent or in turbulent air (e.g. Mills, 1999). Similarly, there are many works on the subject of cooling by jets (e.g. Pelletier, 1984, Goldstein and Franchett, 1988, Journeaux, 1990). However, the literature search did not reveal any convection data for water cooling in conditions corresponding to turning [1]. Different approaches were carried out to predict quantitatively the temperature level and heat flux at the interface with cutting speed, feed rate, rake angle, tool geometry, tool material and work piece materials [2]. D. Ulutan explained the three-dimensional temperature fields on the chip, tool and work piece during machining, which is one of the most important characteristic of machining processes; since the fields can affect other properties such as residual stresses and tool wear, and thus tool life and fatigue life of finished parts. The finite difference method based model proposed in this paper offers very rapid and reasonably accurate solutions. Finite difference-based simulation results are validated with infrared thermal measurements which are determined from the machining of different materials under various cutting conditions [3].

II. MODELLING OF HEAT GENERATION

Heat balance for the machining process can be written from First law of thermodynamics helps to calculate the heat balance. It is the summation of rate difference that thermal and mechanical energy enters and exits the control volume, and rate of heat generation is equal to the rate of energy stored within the control volume [4].

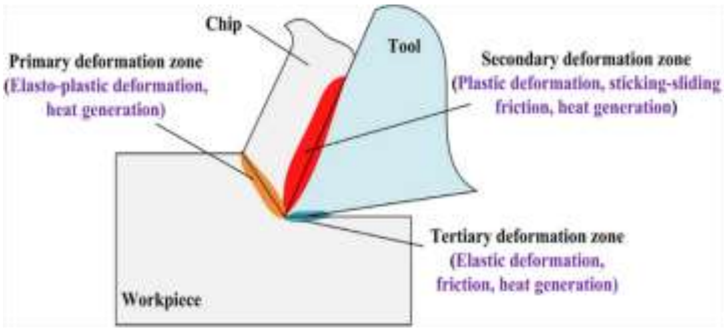


Figure 1 Sources of heat generation in the orthogonal cutting process

$$E_{in} - E_{\,out} - E_{\,generated} = E_{stored}$$

2.1 Heat balance for the work piece

According to the above energy balance equation if we define Q_x $Q_y and$ Q_z as the conduction of heat entering the control volume from x, y and z directions respectively. Let control volume has dimensions d_x d_y and d_z then rate of heat conduction is given by [5] [6] [7]

$$Q_x = -kA\frac{\partial T}{\partial x} = -k\,dy\,dz\,\frac{\partial T}{\partial x}$$

$$Q_y = -kA\frac{\partial T}{\partial y} = -k\,dx\,dz\,\frac{\partial T}{\partial y}$$

$$Q_z = -kA\frac{\partial T}{\partial z} = -k\,dy\,dy\,\frac{\partial T}{\partial z}$$

By using by Taylor series expansion, ignoring the higher orders.

$$Q_{x+dx} = Q_x + \left(\frac{\partial Q_x}{\partial x}\right)dx$$

$$Q_{y+dy} = Q_y + \left(\frac{\partial Q_y}{\partial y}\right)dy$$

$$Q_{z+dz} = Q_z + \left(\frac{\partial Q_z}{\partial z}\right)dz$$

Above equations do not involve only heat convection terms as the air is flowing around there is heat loss by convection from the system i.e. tool chips and work piece. Therefore convection rate directed from the control volume to the surrounding air is given as follows.

$$Q_{z.convection} = hA(T - T_{amb})$$

Heat generation in the control volume is equal to the volumetric heat generation rate times the volume of control volume.

$$E_{generated} = Q\,dx\,dy\,dz$$

$$E_{stored} = \rho C_p \frac{\partial T}{\partial t} dx\,dy\,dz$$

So from all of the equations heat balance equation for work piece can be written as

$$E_{in} - E_{\,out} + E_{\,generated} = E_{stored}$$

$$Q_x + Q_y + Q_z - Q_{x+dx} - Q_{y+dy} - Q_{z+dz} - Q_{z.convection} + Q\,dx\,dy\,dz = \rho C_p \frac{\partial T}{\partial t} dx\,dy\,dz$$

If both the sides are divided by$k\,dx\,dy\,dz$, assuming that heat conduction and convection coefficients are constant with time as well as space, then simplified equation for heat balance of work piece can be written as follows [8].

$$\left(\frac{\partial^2 T}{\partial x^2}\right) + \left(\frac{\partial^2 T}{\partial y^2}\right) + \left(\frac{\partial^2 T}{\partial z^2}\right) + \frac{Q}{k} - \frac{hA(T - T_{amb})}{kdz} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

Where $\alpha = \frac{k}{\rho C_p}$

Similarly equations can also be written for tool and chips as follows [9].

For chips

$$\left(\frac{\partial^2 T}{\partial x^2}\right)+\left(\frac{\partial^2 T}{\partial y^2}\right)+\left(\frac{\partial^2 T}{\partial z^2}\right)+\frac{Q}{k}-\frac{hA(T-T_{amb})}{kdz}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

For tool

$$\frac{\partial^2 T_t}{\partial r^2}+\frac{1}{r}\frac{\partial T_t}{\partial r}+\frac{1}{r^2}\frac{\partial^2 T_t}{\partial \psi^2}+\frac{Q_t}{k_t}-\frac{hA(T-T_{amb})}{kdz}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

2.2 Analytical modelling for experimentation

For the experimentation following assumptions and modelling equations are used to find out the convective heat transfer coefficients. Here three machining conditions are used i.e. dry machining, wet machining and vortex tube jet assisted machining.

$$E_{in} - E_{out} - E_{generated} = E_{stored}$$

Let us assume that $E_{generated} = 0$

$$Q_{conduction} - Q_{convection} = \rho C_p \frac{\partial T}{\partial t}$$

$$kA\frac{\partial T}{\partial x} - hA(T-T_{amb}) = \rho C_p \frac{\partial T}{\partial t}$$

Dividing by *k and* considering unit area

$$\frac{\partial T}{\partial x}-\frac{h(T-T_{amb})}{k}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

In this experimental investigation our aim is to find out the cooling rate i.e. convective heat transfer coefficients.

III. EXPERIMENTAL INVESTIGATION

Following diagram shows experimental setup for the project purpose.

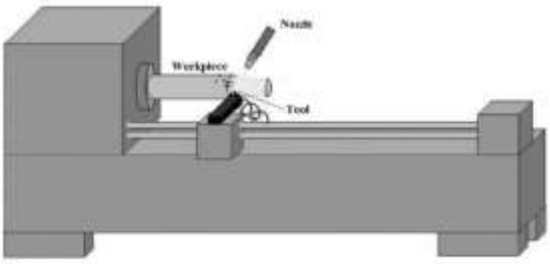


Fig. 2 Experimental setup

All geared TRUMAC lathe machine is used for conducting the experiments. Following materials were used for the investigations. Aluminium 60882 and AISI 1018 are mostly used for the industrial manufacturing purposes [10]. Following tables shows the chemical composition of the specimens used for the machining.

Table 1 Chemical composition of Al6082

CHEMICAL ANALYSIS									
Al 6082 (∅ =24mm)	Al	Mn	Zn	Fe	Mg	Sn	Si	Cu	Ti
(%)	Bal	0.73	0.01	0.19	0.4	0.01	1.24	0.1	0

Table 2 Chemical composition of Al6082

AISI 1018 (∅ =24mm)	C	Mn	Si	S	P
(%)	0.18	0.89	0.33	0.031	0

Coated Carbide insert is used as a tool. All the faces of inserts are used for different machining conditions.According to the requirement three sets of machine RPM were fixed 400 rpm, 600 rpm and 900 rpm. Depth of cut of 0.5 mm and 1 mm are used. Feed is maintained automatic for turning purpose. Dry, wet and VTJA condition of turning are used. In dry machining no coolant is used while in case of wet machining synthetic coolant is used. In VTJA compressed air coming from vortex tube is used as a coolant. Different specimens are used for different machining conditions. Following images shows the different machining conditions.

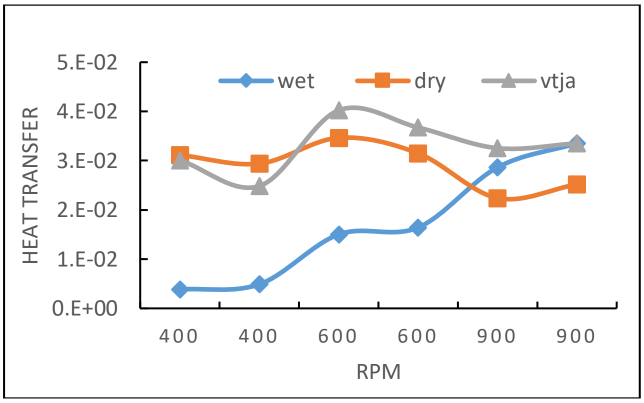
Photo 1,2,3 Dry, wet and VTJA machining

With the help of Infrared Thermometer temperature of tool as well as work piece are measured simultaneously during turning process. These temperature are measured according to the equal marking on the 10 cm long specimen and at 9-10 points' temperature of tool and work piece are recorded.

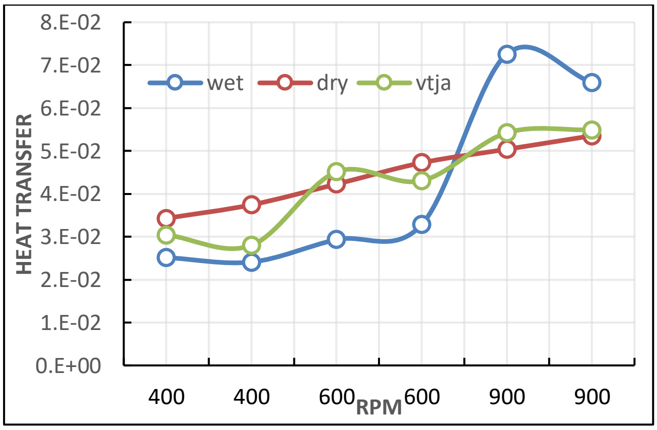
IV. RESULTS AND DISCUSSIONS

Following are the different results plotted for cooling of the work piece at 0.5 mm and 1 mm depth of cut. Readings are recorded for two sets of RPM.

3.1 Graph of cooling AL 6082 at 0.5mm & 1mm Depth of cut



Graph 1. Rpm Vs. Heat Transfer



Graph 2. Rpm vs. Heat transfer

From graph 1 it is clear that at 600 rpm and 0.5 mm depth of cut heat transfer is maximum and goes on decreasing and also increases in case of VTJA machining condition. While wet machining heat transfer is less at 900 rpm. Graph 2 shows that heat transfer during dry and wet machining is almost equal for 1 mm depth of cut. But maximum heat transfer occurs at 900 rpm for wet machining.

3.2 Graph of cooling AISI 1018 At 0.5mm & 1mm Depth of cut

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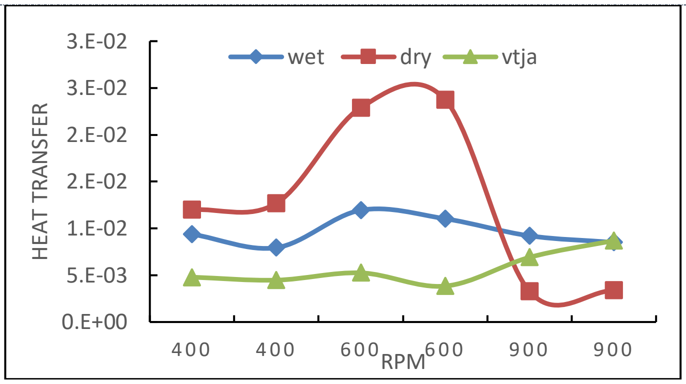
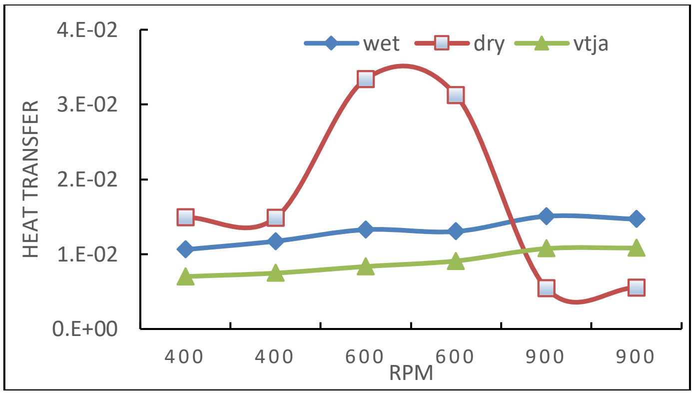


Graph 3 Heat transfer Vs RPM

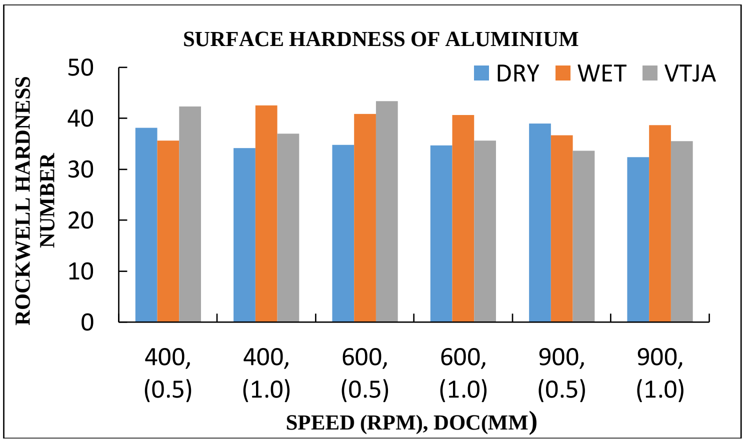


Graph 4 Heat transfer Vs RPM

Form Graph 3 and 4 it can be concluded that heat transfer in case of wet and VTJA machining condition is almost similar for the 400, 600 and 900 rpm. Dry machining shows maximum heat transfer for 600 rpm and then goes on decreasing.

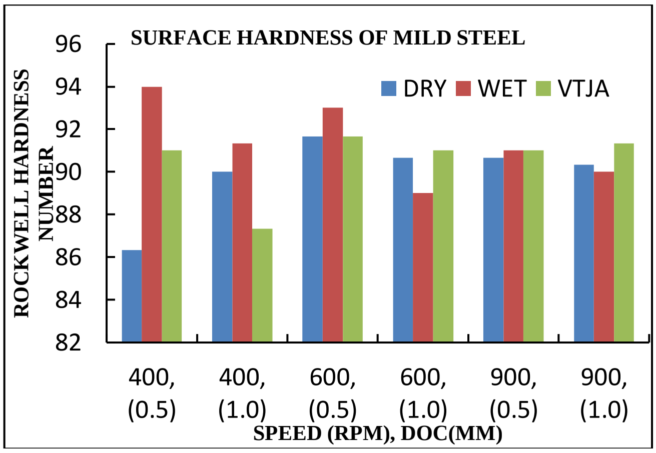
3.3Comparison of hardness for different machining conditions

1) Hardness of AL 6082



Graph 5 Hardness during different machining for Al

2. *Hardness of AL 6082*



Graph 6 Hardness during different machining for AISI 1018

From graph 5 and 6 it can be stated that excepting few readings surface hardness during VTJA machining is more accordance with other wet and dry machining. These readings of hardness were recorded with help of Rockwell hardness testing machine.

V. CONCLUSIONS

From the above experimental investigation it can be concluded that cooling of the work pieces of Aluminium found to be better during VTJA machining process. While for the mild steel dry and wet machining is best for cooling but provided with better compressed air VTJA can be also best effectively used for higher speeds.
Investigating the hardness of the aluminium and mild steel work pieces it is clear that all three i.e. Dry, Wet as well as VTJA machining shows almost similar results. But in case of more speed VTJA could be useful.

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