Experimental Study on impact of temperature variations in CNC Milling, during dry machining and wet machining for Al and CI material

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Abstract - The study of heat has become prominent in metal cutting as it has very critical influence on machining processes. Any machining process involves three basic elements viz., chip, tool and workpiece. Heat developed among these three elements is vital and may cause considerable effect in the machining performance. The heat is generated due to several factors among which friction between the tool and the chip is one of the reasons. The effect of heat generation can be viewed in two forms, one from the workpiece and another form the cutting tool. In this paper a review has been done on the various sources of heat generation and its considerable effects on the life of cutting tool and the quality of the machined part. A study has also been conducted on the temperature distribution on the different regions. Generation of heat can be controlled by various machining parameters and cutting tool geometry, this paper also focuses on various factors that influences on the temperature generation. Although any amount of heat can be generated during machining, the determination of cutting temperature is also one of the important factors. A review is also done on various measurement techniques of cutting temperature. For the betterment of the machining, the perspective of heat generation in metal cutting is a prominent factor.

Index Terms - CNC milling, cutting temperature, dry machining, depth of cut, heat generation, spindle speed, wet machining

1 INTRODUCTION

As a large amount of plastic strain is involved in metal cutting, almost 99% of heat is transferred to chip, cutting tool and the work piece, while more than 1% of work is stored as an elastic energy. The three sources of heat generation include Shear-plane (AB), where the actual plastic deformation occurs, second is the Tool-chip interface (BC), due to the friction between tool and chip and the final source is where Tool-work piece interface (BD), which occurs at flank surface. As a large amount of plastic strain is involved in metal cutting, almost 99% of heat is transferred to chip, cutting tool and the workpiece, while more than 1% of work is stored as an elastic energy. The three sources of heat generation include Shear-plane (AB), where the actual plastic deformation occurs, second is the Tool-chip interface (BC), due to the friction between tool and chip and the final source is where Tool-work piece interface (BD), which occurs at flank surface.

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Due to the thermal distortion and thermal expansion during cutting, there may chance of dimensional inaccuracy of the job Because of the oxidation, there is a chance of surface damage. In some cases, micro cracks at the surface, corrosion and burning of job can also be seen. The reduction in the life of tool and the poor quality of the job is the cause for temperature generation

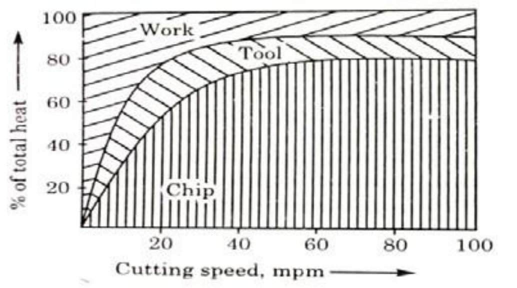


Fig.1 Cutting Speed Vs Percentage of total heat

From this study it can be concluded that heat distribution in the chip, workpiece and tool are in the ratio 80:10:10.

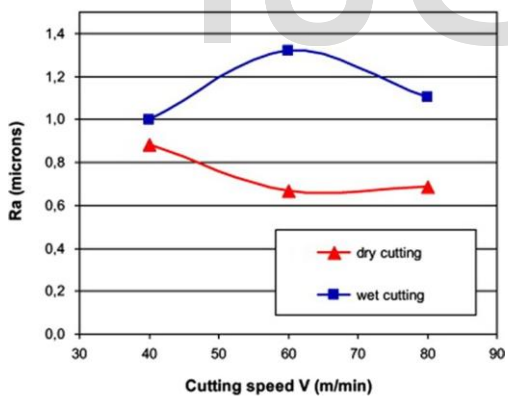


Fig.2 Cutting Speed Vs Ra

The surface roughness comparison in dry and wet cutting at different cutting speed, with a feed rate of 0.1 mm/rev, depth of cut 0.5 mm. Both the material mechanical properties and machined surface integrity are directly related to the material microstructure attributes. The cutting methods which based on jet principle are preferred for hard to cut materials. Microfeatures of surfaces show variations depending on cutting methods.

2 LITERATURE SURVEY

A thermomechanical modelling has been established including heat balance equations of the tool–workpiece interface which take into account the heat generated by friction and the heat transfer by conduction due to the thermal contact resistance. The interface heat balance equations involve two coefficients: heat generation coefficient (HGC) of the frictional heat and heat transfer coefficient (HTC) of the heat conduction [1] (inverse of the thermal contact resistance coefficient). While machining, large amount of heat is generated from the cutting point at three distinct points of sources as shown in the figure 1. In cutting, almost all the energy dissipated in plastic deformation is converted into heat which causes raise in the temperature in the cutting zone. To some extent, it can enhance the tool wear and then decrease the tool life [2].

Few other papers refer the general theory for analysis in the frequency domain and for any speed variation strategy. Results are compared with those obtained by semidiscretization and time integration, as well as with those obtained by experiments [3]. The machining cutting parameters (cutting speed, feed rate and depth of cut) optimized to evaluate high material removal rate and minimum surface roughness shown in figure.2. Response surface method interpreted the experiment data with the help of Design of experiment. Analysis of variance (ANOVA) shows the different parameters which provide the significant impact on the values of surface roughness and material removal rate [4]. The cutting forces are more sensitive to the variations of the feed. In fact, the feed determines the chip thickness, which is the major factor governing the cutting forces. Different drilling tests were performed using a High-

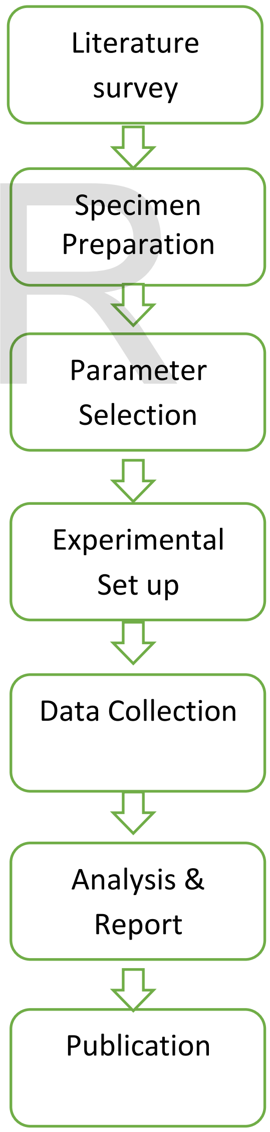
Speed Steel drill with a 10 mm diameter and a point angle of 118° in order to determine the effect of feed and alloys on cutting forces [5].

Particular attention is given to modeling of the tool-chip, chip-work piece and tool-work piece interfaces. Since the direct temperature measurement at the chip-tool interface are very complex, this work proposes the estimation of the temperature and the heat flux at the chip-tool interface using the inverse heat conduction problem technique. The shear energy created in the primary zone, the friction energy produced at the rake facechip contact zone and the heat balance between the moving chip and the stationary tool are considered. The temperature distribution is solved using finite difference method [6]. The heat fluxes generated by cutting processes lead to thermal deformations in the tools. Particularly, in precision machining it is essential to know the amount of the process heat and its distribution of heat fluxes into tool, workpiece and chips. This paper presents an extended methodology for the calculation of these heat fluxes in machining operations. Additionally, by comparison of experimental results with finite element simulations, the thermally caused tool center point (TCP) displacements in turn-milling operations are discussed [7]. Chip-tool interface temperature is closely connected to cutting speed. With increase of cutting speed, friction increases, this induces an increase in temperature in the cutting zone. With the increase in feed rate, section of chip increases and consequently friction increases this involves the increase in temperatures [8].

To investigate the influence of material microstructure changes on residual stresses [9]. As main results, it was firstly demonstrated by surface topography analysis as both the white and dark layer are the result of microstructural alterations mainly due to rapid heating and quenching [10]. Furthermore, it was found as both the presence of white and dark layers influence the residual stress profile [9]. Microstructure of cut surfaces is affected from the kind of cutting process. Microstructural changes during cutting of the materials are observed with all of the cutting process other than Abrasive water jet. Abrasive water jet method can be effectively used in industrial applications where no microstructural changes and hardness reduction is essential [10].

3 METHODOLOGY

The following process flow shows the various stages carried out as methodology.



4 EXPERIMENTAL SET UP

The experiment carried over with a 3 axes CNC milling machine (Haash make) and the 2 work pieces made of Cast iron and Aluminium. The cutting tool is a HSS end mill cutter 25 mm diameter. The size of the both work pieces are 100mm x 75mm x 25 mm thick. The material removal is an up milling process.

Fig.3 Experimental observation during Dry Machining

Fig.4 Experimental observation during Wet Machining

5 OBSERVATION

The tool temperature was measured during the procedure with the help of a laser pyrometer with a range of measurements from -30 to 1200 ℃. The laser beams were focused on the back edge of the cutting insert, meaning that the temperature measured was the 20% of the temperature in the cutting edge. The depth of cut was set up to 1 mm and there was taken the average of 3 measurements for each combination of the cutting variables. Figure.3 shows Temperature variations observed during CNC Milling for Cast Iron material at constant depth of cut 1mm.

Table 1. Temperature variations observed during CNC Milling for Cast Iron material at constant depth of cut 1mm.

Depth of cut (mm)	Spindle speed (rpm)	Temp. dry machining (°C)	Temp. wet machining (°C)
1 mm	500	28	27
	1000	27	25
	1400	27	24

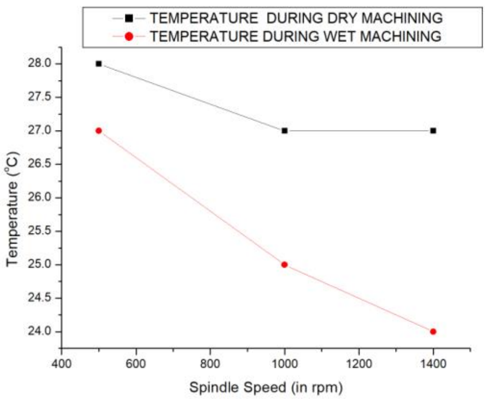


Figure.5 shows Temperature variations observed during CNC Milling for Cast Iron material at constant depth of cut 1mm.

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Table 2. Temperature variations observed during CNC Milling for Aluminium material at constant depth of cut 1mm.

Depth of cut (mm)	Spindle speed (rpm)	Temp. dry machining (°C)	Temp. wet machining (°C)
1 mm	500	31	26.5
	1000	30	27.6
	1400	27.7	27.2

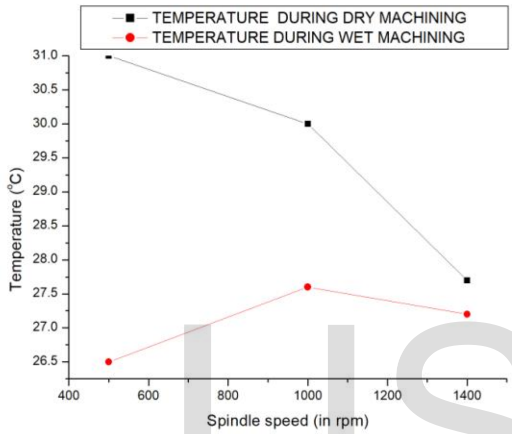

Fig 6. Temperature variations observed during CNC Milling for Aluminium material at constant depth of cut 1mm.

Table 3. Temperature variations observed during CNC Milling for Cast Iron material at constant spindle speed.

Spindle speed (rpm)	Depth of cut (mm)	Temp. dry machining (°C)	Temp. wet machining (°C)
500	1.0	26	24
	1.5	27	25
	2.0	28	26

The following Figure.7 shows Temperature variations observed during CNC Milling for Cast Iron material at constant spindle speed.

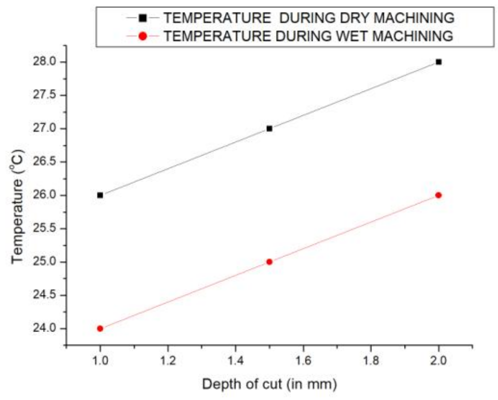

Fig 7. Temperature variations observed during CNC Milling for Cast Iron material at constant spindle speed.

Table 4. Temperature variations observed during CNC Milling for Aluminium material at constant spindle speed.

Spindle speed (rpm)	Depth of cut (mm)	Temp. dry machining (°C)	Temp. wet machining (°C)
500	1.0	29	28
	1.5	28	27
	2.0	34	30

The following Figure.8 shows Temperature variations observed during CNC Milling for Aluminium material at constant spindle speed.

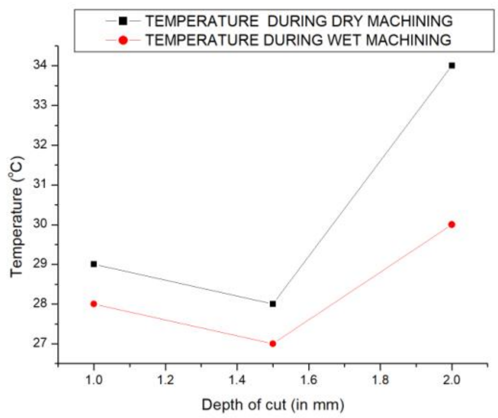

Fig. 8 Temperature variations observed during CNC Milling for Aluminium material at constant spindle speed.

6 RESULTS AND DISCUSSION

As it was expected, the tool temperature was higher in dry cutting than in wet one and also was increased with the increase of the cutting speed. Cutting speed has a major influence on temperature. As the speed increases, there is a little time for the heat to be dissipated and hence temperature rises. From the rest amount of heat, the most of it is carried away by the tool. According to the cutting parameters, high speed and big cutting depth implies high temperature in the process. Feed rate actually does not affect in so high level the alteration of the temperature. In comparison with the results of the surface roughness, the combination of the cutting parameters in such a way, to achieve the better surface quality, incurs greater thermal impact to the tool and to the workpiece. Furthermore, for an overview of view for the temperatures effect, when the used tool was examined after the end of the experiments, it was found that there has not been framed any crater in its cutting edge, however there were areas of diffusion where the coating had come in contact with the workpiece during the process under high temperatures.

7 CONCLUSION

This paper summarizes the effect of the cutting parameters on the tool surface temperature, after milling process of cast iron, aluminium and steel. With dry machining can be achieved the appropriate surface quality, choosing the accurate cutting conditions, which needs to be higher cutting speed and less feed rate speed. However, this selection has as result the high increase of the temperature, which acts on the cutting tool and affects its life by increasing the wear factor. In order to have best results, it is required the development of new materials and new coatings for the cutting tools. Combining these, it can be achieved that method, which is ecologically desirable; it is closer to the clean machining methods and it will become assuming in the future.

8 ACKNOWLEDGEMENT

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REFERENCES

[1] Badis Haddag etal, Analysis of the heat transfer at the tool–work piece interface in machining: determination of heat generation and heat transfer coefficients, January 2015, DOI: 10.1007/s00231-015-1499-1
[2] M. PradeepKumar, A Review on Heat Generation in Metal Cutting, International Journal of Engineering and Management Research Volume-5, Issue-4, August-2015.
[3] M. Zatarain, Stability of milling processes with continuous spindle speed variation: Analysis in the frequency and time domains, and experimental correlation.
[4] Puneet Kumar, Optimization of process parameters for machining of mild steel EN18 by response surface methodology,
[5] V. Songmene, Machining and Machinability of Aluminum Alloys
[6] Uzorh Augustine.C Thermal Aspect of Machining: Evaluation of Tool and Chip Temperature during Machining Process Using Numerical Method.
[7] Matthias Putz, Modeling of heat fluxes during machining and their effects on thermal deformation of the cutting tool.
[8] Akhil C S, Measurement of Cutting Temperature during Machining.
[9] Domenico Umbrello, Influence of material microstructure changes on surface integrity in hard machining of AISI 52100 steel.
[10] Adnan Akkurt, The effect of cutting process on surface microstructure and hardness of pure and Al 6061 aluminum alloy.