



AN INVESTIGATION OF TEMPERATURE DISTRIBUTION OF A CVD COATED TURNING TOOL

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Abstract-

The manufacturing industries experience a technological advances and development which requires high speed machining at less time. The high speed machining of the hard to machine materials put the limitation to the cutting speed and generates a lot of heat during machining which causes the tool to fail due to plastic deformation, change in mechanical properties or fracture failure of the tool. Temperature at the cutting point of the tool is a crucial parameter in the control of the machining process. Due to advancement in the machining processes, a special attention has been given on the life of a tool. To achieve this, the best way is to apply the coating to the tool. In this paper, Chemical vapor deposition (CVD) coated tool is used for experimentation and the interface temperature is measured using tool work thermocouple. The nature of temperature distribution is explained using finite element analysis.

Keywords—Tool work thermocouple, Chemical vapor deposition (CVD) coating, Finite element analysis

INTRODUCTION

The mechanical work required for machining is highly converted into the heat which causes number of technical and mechanical problems of machining. The importance of knowledge on the temperature gradient and its distribution within the cutting zone resulting from changes in the cutting conditions is well recognized due to severe effects on the tool and work piece materials properties and a considerable influence on the tool wear [1] [3].

In general, three regions of intensive heat generation are distinguished, namely the primary shear zone, the tool-chip interface or the secondary deformation zone and the tool work piece interface. Heat is removed from the primary, secondary and tertiary zones by the chip, the tool and the work piece. Figure 1 schematically shows this dissipation of heat. The temperature rise in the cutting tool is mainly due to the secondary heat source, but the primary heat source also contributes towards the temperature rise of the cutting tool and indirectly affects the temperature distribution on the tool rake face [11] [14].

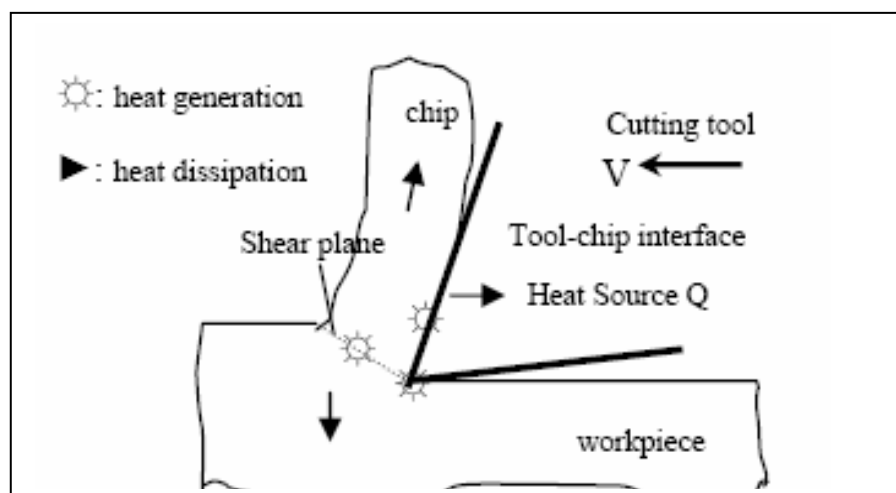


Fig. 1 Zones of Heat Generation during the Metal Cutting Process

EXPERIMENTATION

Experimental Setup

In this experiment, the temperature was measured on the HMT heavy duty lathe LTM-20 without using any coolant. A commercially available CVD coated turning insert CNMG 120408 PR 4225 were used to compare the temperature obtained at uncoated tool inserts. The machining was performed using work piece EN8 alloy steel (250 mm long and 45 mm diameter).

Tool-Work thermocouple

The Tool-Work thermocouple was used to measure the temperature at the cutting point of the tool. The tool-work thermocouple works on the principle of seebeck effect which states that if there is a temperature difference between any two junctions then there will be a development of emf in between the two junctions [18] [19]. The principle of this method is shown in figure 2.

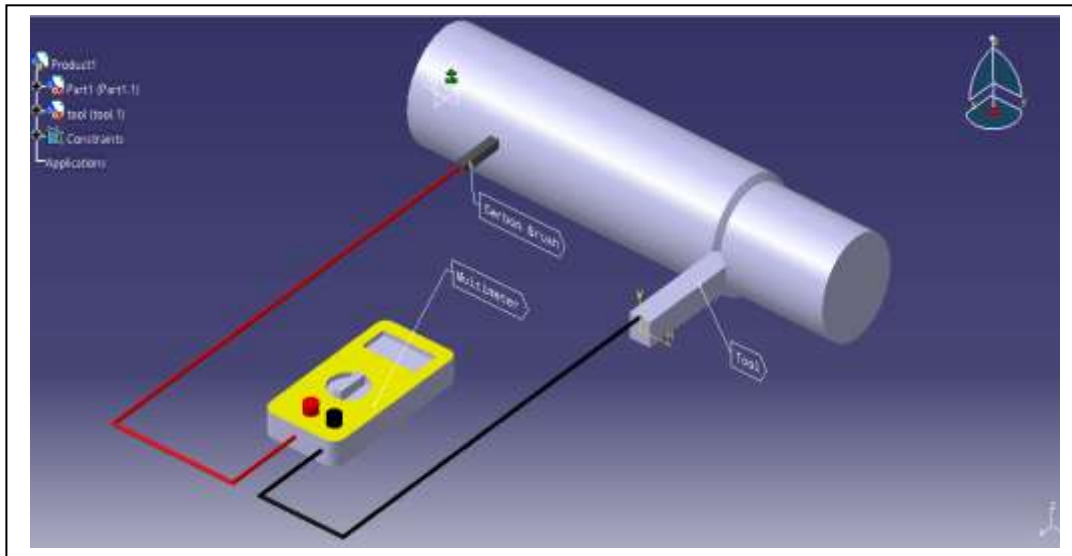


Fig. 2 Tool Work Thermocouple Setup

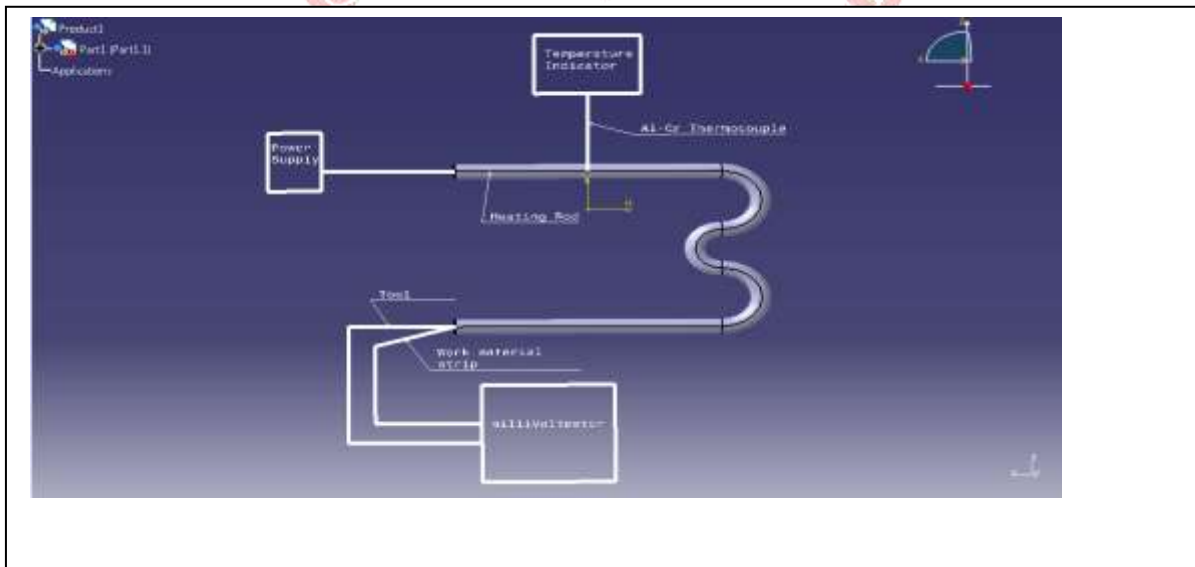


Fig. 3 Calibration setup

In this experiment, turning insert and work piece were insulated from the lathe machine by using mica as an insulating material. Cold end of the inserts and work piece were connected to the millivolt meter and carbon brush is used to connect the millivolt meter to the work piece as the work piece in turning is rotating. In this work, calibration of the tool work thermocouple was carried out by using a heating coil. This set-up is similar to one used by Abhijeet Amritkar [13], in which workpiece was directly calibrated with the tool. Figure 3 shows the calibration set-up for tool-work thermocouple. In this set-up, Junction of tool and workpiece was connected to the milliVoltmeter and also K-type Alumel-Chromel thermocouple was connected to the heating rod. The temperature indicator was used to display the temperature of heating rod sensed by the Al-Cr thermocouple.

EXPERIMENTAL RESULT

The primary focus of this experiment is to analyse the temperature generated during machining at uncoated and CVD coated tungsten carbide (WC) cutting tool. The machining tests were conducted by varying cutting speeds, feed rate and the constant depth of cut of 1 mm. The cutting speed used was 35.32, 59.34, 100.32 and 169.56 m/min. The feed rate was taken as 0.83, 1.04, 1.25 and 1.65 mm/rev. For the analysis purpose, the cutting speed of 59.34 mm/min and 169.56 mm/min are used among the four cutting speed used. Using these cutting conditions the value of mV is measured on HMT heavy duty lathe which was further used to calibrate the temperature obtained during machining of EN8 alloy steel. The calibration curve obtained for uncoated and CVD coated Tungsten carbide insert is shown in Figure 4 and Figure 5 respectively.

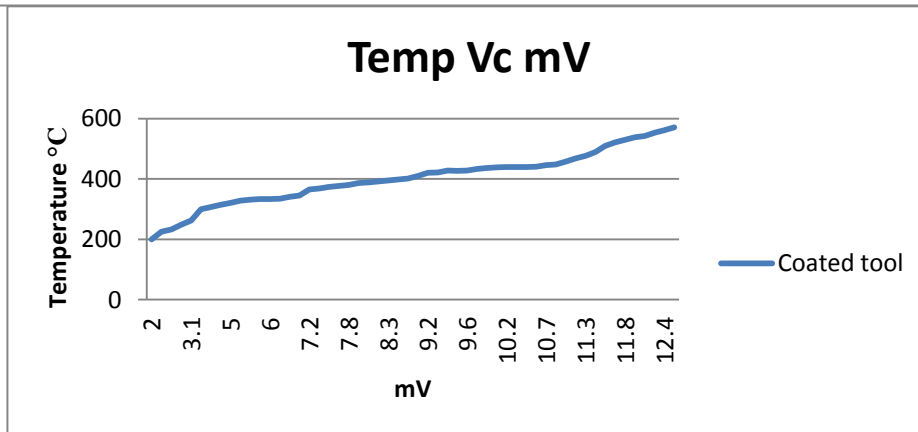
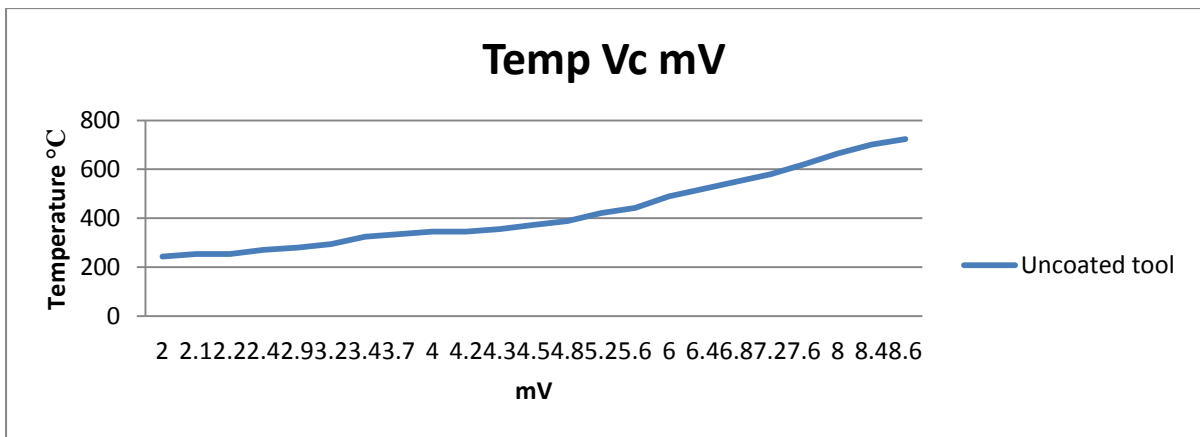


Fig. 4 Calibration curve of uncoated WC tool

Fig. 5 Calibration curve of CVD coated WC tool

Effects of feed rate at cutting speed

Chip-tool interface temperature is closely connected to feed rate. Figure 6 and 7 shows the effect of feed rate on the cutting temperatures (chip-tool interface temperature) of the uncoated and coated tool at constant depth of cut 1 mm for cutting speed of 59.34 m/min and 169.56 m/min respectively. With increase of feed rate, friction increases, this induces an increase in temperature in the cutting zone.

In this respect, the temperature measurement by tool-work thermocouple indicates that for a speed of 59.34 m/min and depth of cut 1 mm, the maximum temperature for the uncoated tool is 388 °C and that for coated tool is 369 °C. Hence the coated tool experiences a 19 °C less temperature than the uncoated tool.

Similarly, the maximum temperature recorded for Uncoated and CVD coated Tungsten carbide tool at cutting speed of 169.56 m/min are 612 °C and 530 °C. This shows that coated tool experience 82 °C less temperature than uncoated tool.

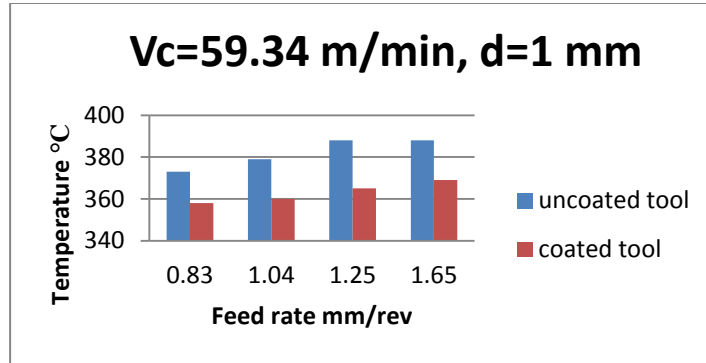


Fig. 6 Effect of feed rate on cutting temperature at Vc =59.34 m/min

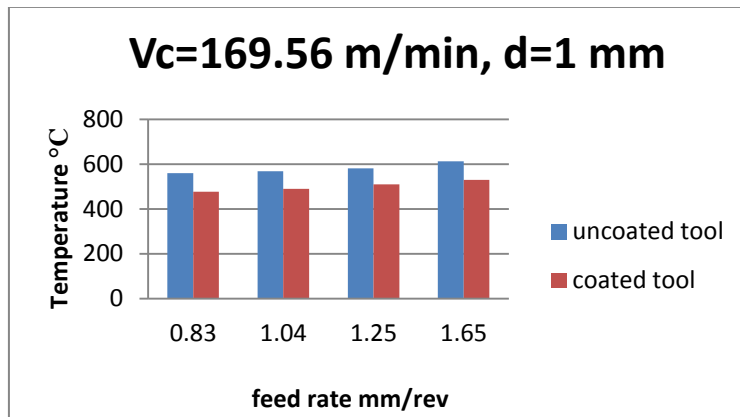


Fig. 7 Effect of feed rate on cutting temperature at Vc =169.56 m/min

Finite element Analysis

Finite element analysis, as a method of simulation of the cutting phenomenon during machining process allows obtaining information relevant for further computational analysis of cutting temperature. Figure 8 shows the CAD model of turning tool insert. The CAD model of cutting tool insert is imported into the FEA package ANSYS 14 workbench for further analysis. Figure 9 shows the meshed model of cutting tool insert obtained by ANSYS 14.

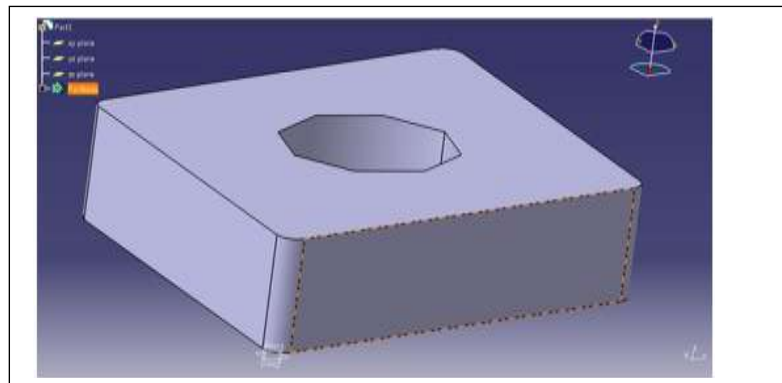


Fig. 8 CAD model of turning tool insert

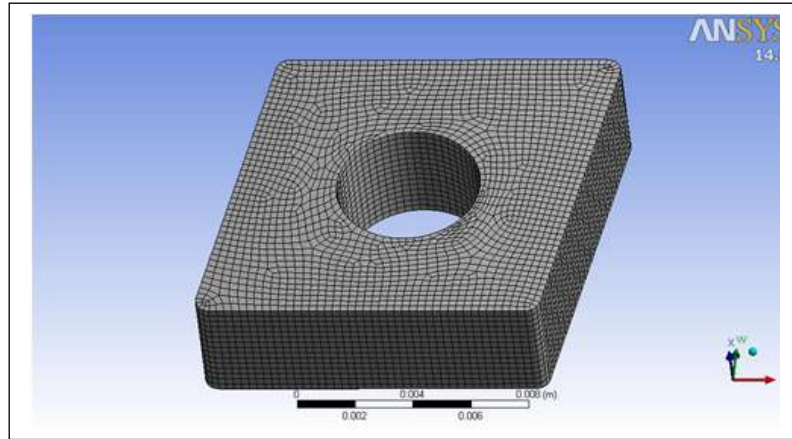


Fig. 9 Meshed model of cutting tool insert

The numerical solution of the temperature in the cutting zone is carried out for the cutting velocity 169.56 m/min. The thermal properties of the coated and uncoated tool inserts are listed in table I. Figure 10 and 11 shows the temperature profiles of the uncoated and coated tool inserts respectively. The maximum temperature is obtained for the both the inserts are at the cutting point. The initial temperature for the uncoated tool obtained during machining is 555 °C but after the 15 sec of machining, the minimum temperature found in simulated result is 586.93 °C and maximum temperature obtained is 723 °C. On the other hand the initial temperature for the coated tool is 458 °C and minimum and maximum temperature according to simulated results are 462.17 °C and 571 °C respectively.

TABLE I Thermal Properties of Tool and Workpiece

Description	Uncoated WC tool	CVD coated WC tool	EN 8 Alloy steel
Density (g/cm ³)	15.63	4.65	7.845
Thermal Conductivity, K (W/mK)	84.02	30	51.9
Specific Heat (J/KgK)	150	645	800

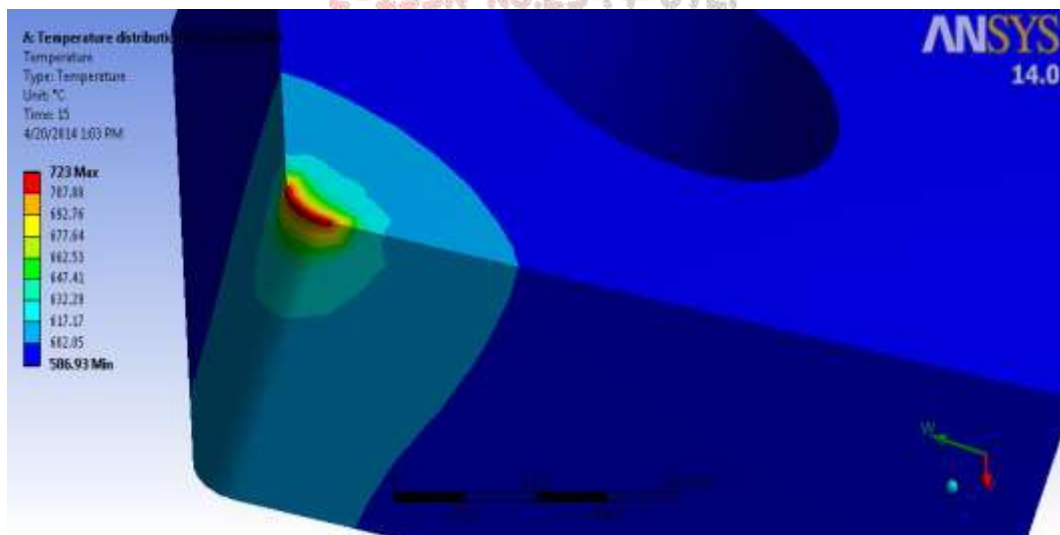


Fig. 10 Temperature profile of uncoated tool insert at Vc =169.56 m/min

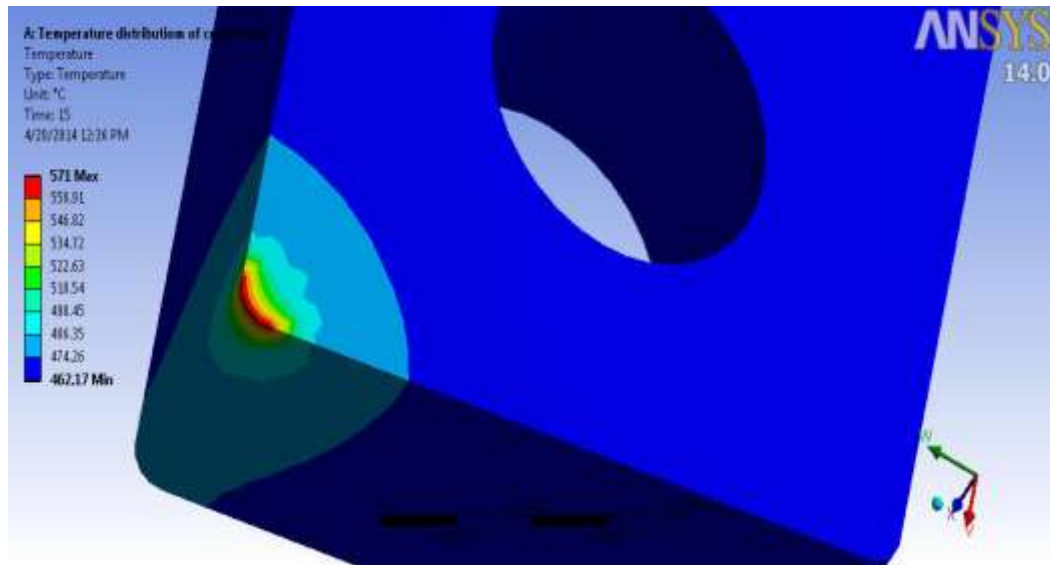


Fig. 11 Temperature profile of CVD coated tool insert at $V_c = 169.56$ m/min

CONCLUSIONS

The study carried out to analyze the thermal distribution at the cutting point of the tool inserts. For this purpose uncoated and CVD coated tool inserts are used. The conclusions drawn from the present study are:

- The execution of the work showed that for a uniform heat source and uniform heat flux was varying with time, considering a constant contact surface on the chip-tool, the temperature on the tool may be slightly influenced by the coatings when the thermal properties of the coating are very different from those of the substrate. Due to the advancement in machining processes, generation of high temperature at the tool rake face takes place. This generation of heat can be resisted by using a coated tool.
- From the experimental data, it is found that as compared to uncoated tool the coating of the tool increases the life of a tool for the same cutting velocity or for the same tool life, coated tool can be used at higher cutting speed as compared to uncoated tool.
- The Tool-Work thermocouple is the best way to obtain the temperature at the tool rake face as it is easy to install and inexpensive as compared to other methods. With the increase in a cutting speed or a feed rate, the temperature at the tool rake face also increases as found in the machining tests. Reduction in the temperature of the tool improves the tool strength and also improves the surface roughness of work piece.
- FEA results show that the maximum temperature, at the tool–chip contact is increasing with cutting speed but not linearly and this could be attributed to the trend of the heat fraction flowing into the tool. After solving the solution obtained showed that the temperature at the tip(tool-work piece contact area) was maximum and it goes on decreasing towards the surface and it was also observed that the temperature generated for coated tool is little less in comparison to uncoated cemented carbide insert this shows that the tool life can be increased by placing a layer of coating as the coating material has anti-friction and low thermal conductivity which does not allow heat to penetrate as a result heat is carried away by the chip.

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