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Research Paper

PERFORMANCE EVALUATION OF CVD COATED TOOL BY MEASURING TEMPERATURE USING TOOL-WORK THERMOCOUPLE

Sushil D Ghodam[1]*

Corresponding Author: **Sushil D Ghodam ✉ sushghodam@yahoo.co.in*

A continuous advancement and development in manufacturing industry demands the high speed machining at less time which improves the efficiency of the machining. The hard to machine material put the limitation to the cutting speed and generates a lot of hear during machining. Due to machining of these hard materials,tool experiences a high temperature at the cutting point which causes the tool to fail due to plastic deformation, change in mechanical properties or fracture failure of the tool. To avoid this generation of temperature, coating of TiN/TiC/Al_2O_3 has been used. In this paper, CVD coated tool is used for experimentation and the interface temperature is measured using tool work thermocouple. The nature of temperature with respect to different cutting speed and feed rate is explained.

Keywords: Tool-work thermocouple, CVD coating, Temperature measurement

INTRODUCTION

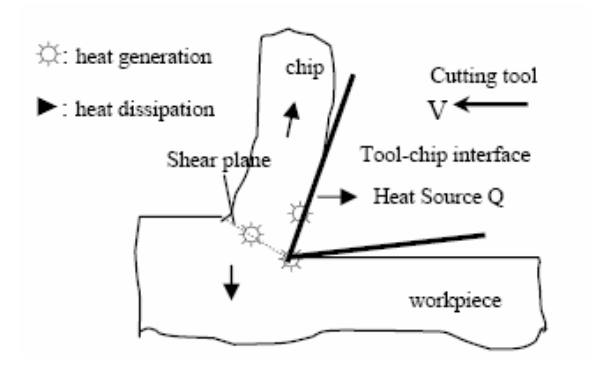
The mechanical work required for machining is highly converted into the heat which causes number of technical and mechanical problems of machining. The importance of knowledge on the temperature gradientand its distribution within the cutting zone resulting from changes in the cutting conditions is well recognized due to severe effects on the tool and work piece materials properties and a considerable influence on the tool wear (X L Liu *et al*., 2002); (W Grzesik and P Nieslony, 2000). In general, three regions of intensive heat generation are distinguished, namely the primary shear zone, the tool-chipinterface or the secondary deformation zone and the tool-work piece interface.

Heat is removed from the primary, secondary and tertiaryzones 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

[1] M.Tech. Student, Production Engineering, Government College of Engineering, Amravati, (M.S.) India.

on the tool rake face (N A Abukhshim *et al*., 2005; L B Abhang and M Hameedullah, 2012).

Figure 1: Zones of Heat Generation During the Metal Cutting Process



During the process, part of the heat generated at the shear plane flows by convection into the chip and then through the interface zone into the cutting tool. Therefore, the heat generated at the shear zone affects the temperature distributions of both the tool and the chip sides of the tool- chip interface, and the temperature rise on the tool rake face is due to the combined effect of the heat generated in the primary and secondary zones (L B Abhang and M Hameedullah, 2012).

Heat flow in a tool is known in thermodynamics as heat conduction. Its behavior is obviously expressed by using Fourier's law of conduction which is given by:

$$q = K\,(dT/dx)$$

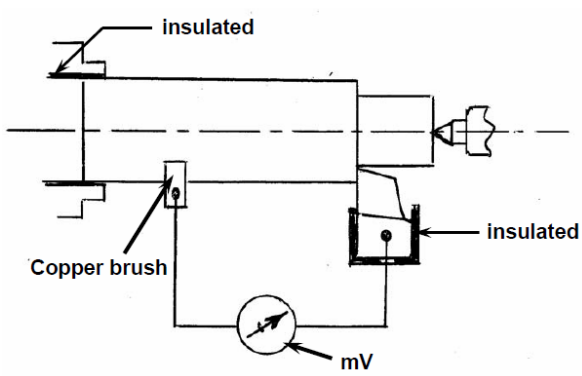
Where q is heat flux (W/m^2), K is thermal conductivity (W/mK), dT is difference in temperature and dx is the linear distance perpendicular to which the flow of temperature takes place (W Grzesik *et al*., 2004).

EXPERIMENTAL PROCEDURE

The cutting experiments were conducted onHMT heavy duty lathe LTM-20. A commercially available CVD coated turning insert CNMG 120408 PR 4225 and uncoated tungsten carbide insert CNMG 120404 grade K313 were used to compare the temperature obtained during machining. The machining was performed using work piece EN8 alloy steel (250 mm long and 45 mm diameter).

Among the various temperature measuring techniques, tool-work thermocouple was used to measure the interface temperature. Figure 2 schematically shows the principle of tool-work thermocouple technique. The tool-work thermocouple works on the principle of see beck effect which states that if there is temperature difference between two junctions of dissimilar metals then an emf is produce between those metals. In this case tool and work compromise two dissimilar metal and cold end of tool and work piece acts as one junction whereas hot junction is cutting zone. The emf is produced only when the circuit is complete i.e. tool and work piece are in contact. The tool and work piece were insulated from the lathe machine using mica as an insulating material.

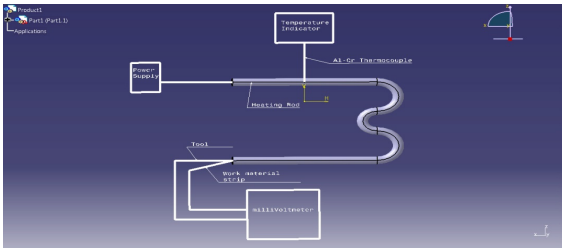
Figure 2: Tool-work Thermocouple Setup



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 Amritkaret *et al*., 2012), 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 work piece was connected to the milli Voltmeter 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.

Figure 3: Calibration Set-up of a Tool-work Thermocouple



EXPERIMENTAL RESULTS

The primary objective of this test was to evaluate and compare the performance of a CVD coated Tungsten carbide insert with uncoated Tungsten Carbide turning insert. For this purpose cutting tests were conducted at cutting speeds (m/min) 35.32, 59.34, 100.32 and 169.56 m/min and the depth of cut was kept constant (1 mm) whereas the feed rate (mm/rev) was varied as 0.83, 1.04, 1.25 and 1.65 mm/rev. Using this 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.

Figure 4: Calibration Curve for Uncoated WC Tool

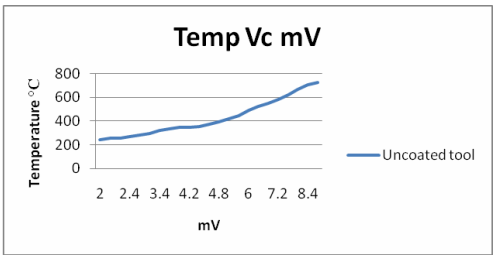
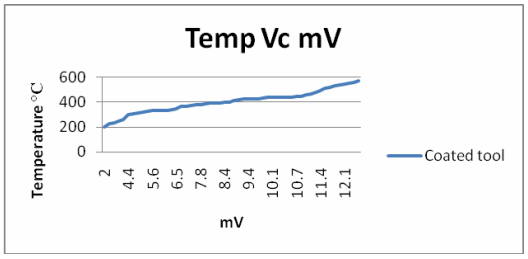
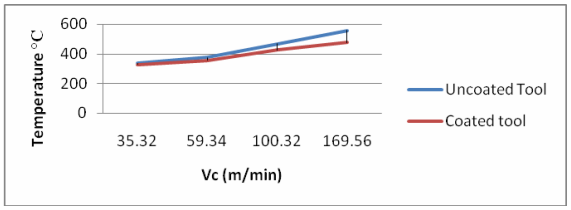


Figure 5: Calibration Curve for CVD Coated WC Tool



The nature of temperature obtained at cutting point of insert is represented with respect to different cutting speeds at various feed rate. Figure 6 represents the temperature vs. cutting speed curve at feed rate 0.83 (mm/rev). For Vc= 35.32 m/min, the temperature difference between uncoated and coated tool was less but when cutting speed increases from 35.32 m/min to 169.56 m/min, the uncoated tool experiences a higher amount of temperature as compared to coated tool. For Vc = 35.32 m/min, coated tool experience 8°C less temperature than the uncoated tool whereas at Vc = 169.56 m/min this difference in temperature increases upto 80°C.

Figure 6: Influence of Cutting Speed on Tool Temperature at f=0.83 mm/rev



The similar results were obtained for feed rate 1.04, 1.25 and 1.65 mm/rev. which are shown by Figures 7, 8 and 9 respectively.

Figure 7: Influence of Cutting Speed on Tool Temperature at f=1.04 mm/rev

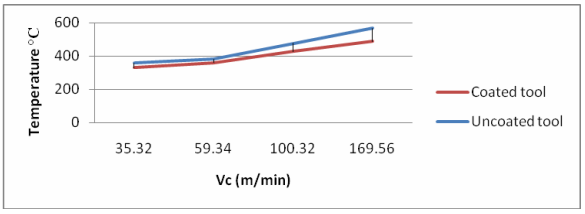


Figure 8: Influence of Cutting Speed on Tool Temperature at f=1.25 mm/rev

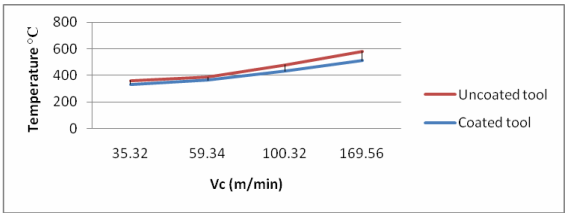
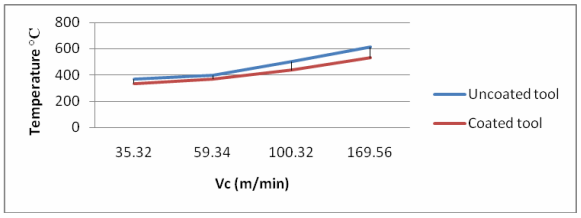


Figure 9: Influence of Cutting Speed on Tool Temperature at f=1.65 mm/rev



It was observed at f=1.65 mm/rev, Vc =35.32 m/min, the temperature difference between coated and uncoated tool was higher i.e. 32°C as compared to the readings obtained at f=0.83 mm/rev, Vc= 35.32 m/min i.e. 8 °C. At f=1.65 mm/rev,Vc=169.56 m/min the temperature difference for between coated and uncoated tool was higher i.e. 82°C as compared to the readings obtained at f=0.83 mm/rev, Vc= 169.56 m/min i.e. 80°C but this difference is very less. Hence at higher cutting speed the coated tool found to be efficient due to its heat resistive ability.

The heat generation per unit area with respect to cutting speed by varying feed rate from 0.83 mm/rev to 169.56 mm/rev is shown in Figure 10 and 11 respectively.

Figure 10: Heat Flux vs. Cutting Speed at f= 0.83 mm/rev

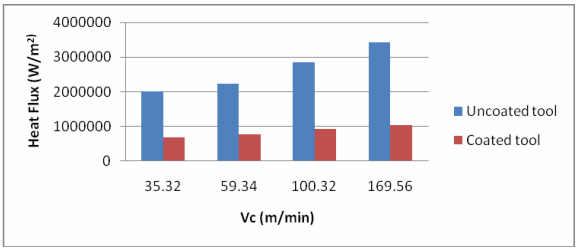
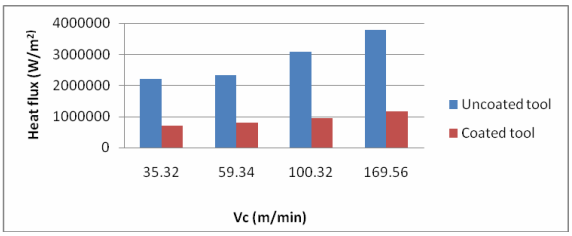


Figure 11: Heat Flux vs. Cutting Speed at f= 1.65 mm/rev



The heat generated for uncoated tool per unit area is much higher than that of coated tool for different cutting speeds. The increase in heat flux for uncoated tool is rapid as compared to the coated tool.

CONCLUSION

This study evaluates the machining performance of commercially available Coated and uncoated cutting tool inserts in turning EN8 alloy steel. Uncoated and coated tools were examined by measuring the temperature at the cutting point of tool inserts. Tool-work thermocouple method was found to be efficient method to measure the temperature of the tool inserts. The coating material of a cutting tool is having a less thermal conductivity due to which coated tool resist the penetration of temperature into the cutting tool whereas it was found that uncoated tool experiences a large heat as compared to coated tool. Hence the coated tool can be used for high cutting speed machining for the same tool life. Due to the resistive ability of coated tool, the life of a tool can be improved.

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