THE INFLUENCE OF CUTTING FLUIDS ON THE WEAR CHARACTERISTICS AND LIFE OF CARBIDE CUTTING TOOLS

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Abstract In all machining operations, tool wear is a natural phenomenon and it eventually leads to tool failure. Tool failure is considered to have occurred when there is a poor surface finish on the workpiece. The application of coolant during any machining operation is believed to reduce tool wear since the cutting fluid produces a lubricating as well as a cooling effect. A study is therefore carried out to substantiate or refute the belief that when coolant is applied, tool wear is actually reduced, thereby enhancing the tool life. This is especially important in industry in which cost of tool material may have a significant contribution to the total production cost. Experiment were conducted in which a medium carbon steel were machined by turning using two different types of uncoated tungsten carbide tools. The coolant used was a water-based (1:20 soluble oil) one. All these experiments were performed on a 11 kW NH22 HMT (India) lathe under machining conditions commonly used in workshops and industry. The experimental results in this paper show that, contrary to common belief, the application of coolant is not necessarily beneficial to tool life. In fact, it was discovered that one effect of the coolant is to slightly increase the crater wear and more importantly, to shift the position of the crater wear nearer the tool tip. The worn crater also becomes deeper and narrower as a result of the coolant. This causes the tool cutting point to become weaker. The flank wear is even more significantly affected by the application of coolant, especially at high cutting speeds. This large increase in flank wear due to the application of coolant can drastically decrease tool life.

Keywords: Turning, Cutting fluid, Tool wear, Tool life

INTRODUCTION

In a conventional machining operation, the tool removes material from the workpiece through direct contact. In general, wear due to adhesion, diffusion and oxidation are known to occur, but especially abrasion and attrition between the tool and the workpiece, as well as between the tool and the chip formed, for the case of machining of steel using carbide tools [*Kannatey-Asibu*]. Tool wear thus occurs on these two surfaces and are called crater wear and flank wear respectively.

The application of coolant during a machining operation is believed to reduce tool wear [*Shaw, 1984*]. The cutting acts as a lubricant as well as a coolant during the operation. It reduces the surface friction and temperatures on the tool-work and chip-tool interfaces. The coolant, when applied during a machining operation, can have a significant effect on the cutting temperatures and tool wear.

Chip formation is also affected when coolant is applied during a machining operation [*Shaw, 1984*]. The chip curl changes with the temperature gradient along the thickness of the chip. The direction from which the cutting fluid is applied is therefore an chip curl. Chip curl affects the size of the crater wear and edge. The application of coolant increases or reduces the chip curl, and also shifts the location of maximum crater depth. The combined effects of the size and location of maximum depth of the crater are essential in the investigation of the effect of coolant on tool wear.

The purpose of this research is to investigate the effect on tool wear of applying coolant from one specific direction during a machining operation, compared with machining without coolant. In any machining process, heat is generated as a result of work done. The main source of heat are the work done : (a) in the plastic deformation of the layer being cut and (b) in overcoming friction on the chip-tool and work-tool interfaces. According *to Arshinov and Aleksev,* Ya Usachev observed that a large percentage of the heat is removed by the chip; the higher the cutting speed, the higher this percentage is. Removal of heat from the tool is vital because at high temperatures, the tool experiences a reduction in hardness and wear resistance.

Cutting fluids not only reduce heat evolution (by facilitating chip formation and reducing friction), but also absorbed and carry away part of the generated heat, thereby lowering the cutting temperature. Liquids delivered in an atomized state as an aerosol (mist lubrication) removes heat more effectively as compared with an ample flow of ordinary coolant.

During the cutting process, the chip and tool rake faces are in very close contact and the gap in between is only accessible to fluid particles of micron size [*Boothroyd, 1981*]. Thus the large fluid particles cannot penetrate this very narrow space.

However, when atomized (aerosol) coolant is directed at the tool cutting edge at very high pressure, significant temperature reduction can be expected. In addition to being able to reach inside the gap, these fluid particles remove heat more effectively by means of vaporization.

The application coolant can also causes a change in the distribution and location of the peak temperature region in the tool. This changes is directly linked to the effect of coolant on chip curl and tool wear.

EXPERIMENTAL PROCEDURE

Experiment were done on a 11kW NH22 HMT (India) lathe. The cutting inserts used were uncoated tungsten carbide inserts (SNMG 120408-26, P30 grade) clamped on a right hand style tool holder designated by ISO as PSBNR 2525M12. The workpiece material used was AISI 1060 steel. The coolant used was a water soluble lubricating oil.

The static cutting force was measured using a 3-compont Kistler piezoelectric dynamometer (model: 9257B and a Kistler charge amplifier (model: 5007).

The flank wear was measured using a Olympus inverted metallurgical microscope (model: MG, Japan). At the end of machining and attaining sufficient wear the pattern and extent of wear of the tool was examined under Scanning Electron Microscope (model: JSM 5800, JEOL, Japan). The surface roughness and dimensional deviation on diameter in axial direction of the machined jobs were measured respectively by s talysurf (model: Surtronic 3P, Rank Taylor Hobson Limited) and by a sensitive dial gauge which was firmly fitted on the saddle and traveled slowly parallel to the job axis.

RESULTS AND DISCUSSIONS

The usual pattern and the parameters of wear that develop in cutting tools are schematically shown in Fig.1. Fig. 2 shows the growth in average flank wear, V_B, on the main cutting edge while machining AISI 1060 steel using two carbide inserts of different integrated chip breaker geometry under dry and wet machining (conventional cooling with 1:20 soluble oil). The gradual growth of V_B, the predominant parameter to ascertain expiry of tool life, observed under all the environments and for both the carbide inserts indicates steady machining without any premature tool failure by chipping, fracturing etc. establishing proper choice of domain of process parameters.

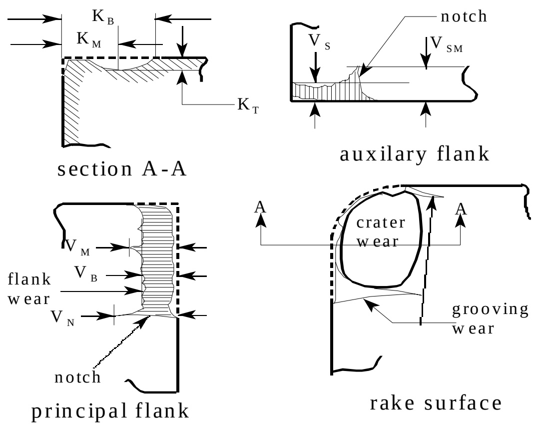


Fig. 1 Geometry of wear of turning tools

Fig.2 further reveals insignificant effect of conventionally applied cutting fluid on growth of tool wear as compared to dry machining for both the inserts undertaken. This may be attributed to ineffective coolant and lubrication action of conventional cutting fluids as supported by previous researchers [*Shaw et al, 1951, Cassin and Boothroyd, 1965, kitagawa et al., 1997*].

Another important tool wear criteria is average auxiliary flank wear, V_S which governs the surface finish on the job as well as dimensional accuracy. Irregular and higher auxiliary flank wear leads to poor surface finish and dimensional inaccuracy [*Dhar et al, 2000*]. The growth of, V_S has been depicted in Fig.3 for all the trials undertaken. The nature of growth of V_S matches with that of V_B expectedly. The application of liquid nitrogen jet along the auxiliary cutting edge has reduced V_S. Figure 5 clearly shows the amount of auxiliary flank wear after machining for 30 minutes with SNMG and SNMM and depicts beneficial role of cryogenic cooling, which is expected to provide better surface finish and dimensional accuracy.

Both under dry and wet machining, severe groove wear and notch wear at the main cutting edge and auxiliary cutting edge were seen in the SNMG and SNMM inserts. The notch wear on main cutting edge develops mainly because of oxidation and chemical wear where the thermo-mechanical stress gradient is also very high. The notch wear on the auxiliary cutting

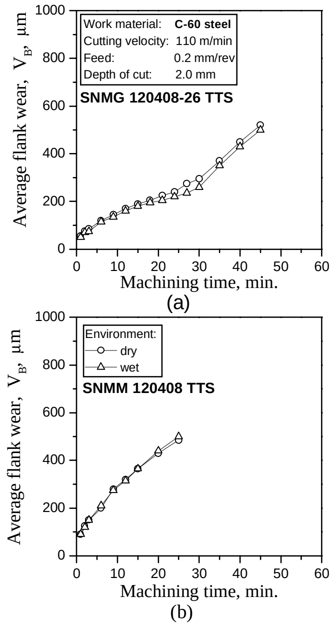


Fig .2 Growth of average flank wear, V_B

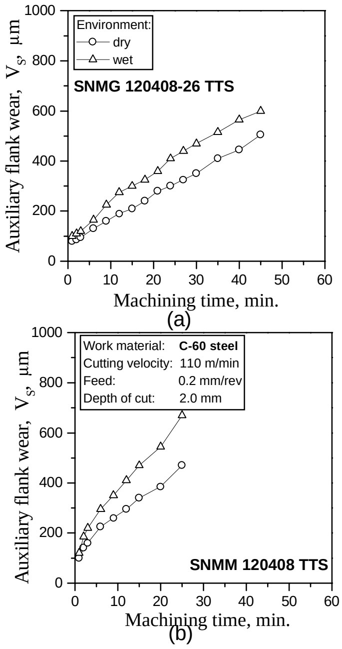


Fig .3 Growth of auxiliary flank wear, V_S

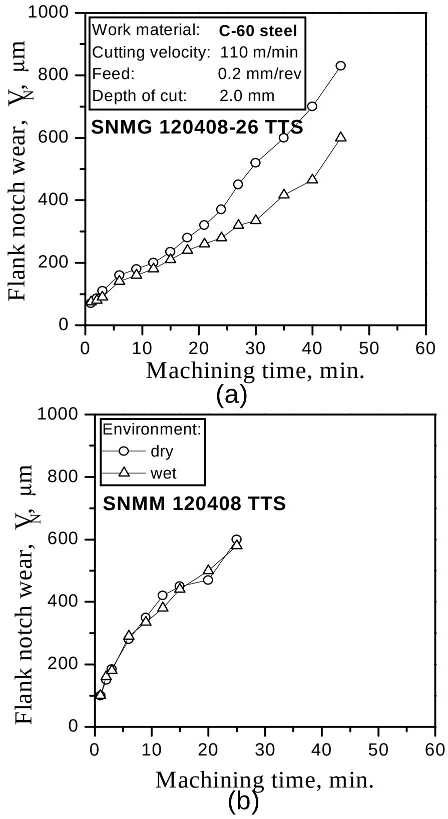
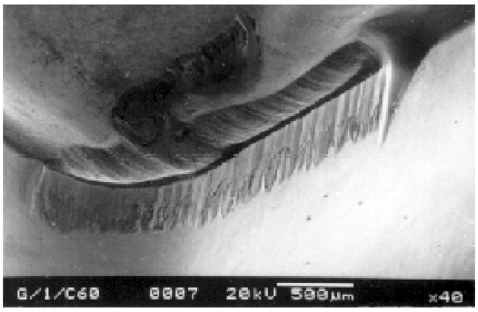


Fig . 4 Growth of flank notch wear, V_N

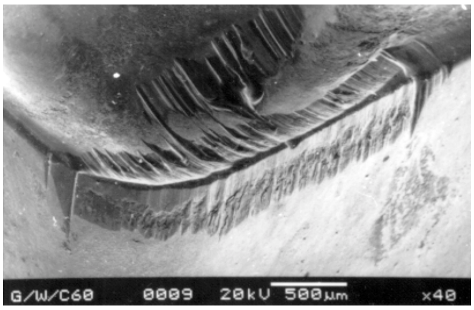
edge develops mainly because of its interaction with the uncut ridges of the work surface and mechanism of this wear is abrasive.

The SEM views of the worn out (a) SNMG and (b) SNMM inserts after being used for about 45 minutes and 25 minutes of machining under dry and wet condition are shown in Fig.5 and Fig.6 respectively. Under all the environments and in both the inserts, abrasive scratch marks appeared in the flanks. The examination of the craters revealed deep scratches left by the back side of the chip on the rake surface of the tool. There has also been some indications of adhesive wear especially in the SNMM insert, which produced longer continuous chips as compared to SNMG which produced mainly broken chips. Some plastic deformation and micro-chipping were found to occur under dry and wet machining.

Fig. 7 shows the variation in surface roughness with machining time for both the inserts under all the three environments. As cryogenic cooling by liquid nitrogen reduced average auxiliary flank wear and notch wear on auxiliary cutting edge, surface roughness also grew very slowly under cryogenic cooling. Conventionally applied cutting fluid did not reduce tool wear compared to dry machining. But the surface roughness deteriorated drastically under wet machining compared to dry, which may possible be attributed electrochemical interaction between insert and work piece [*Ellis and Barrow, 1969*].

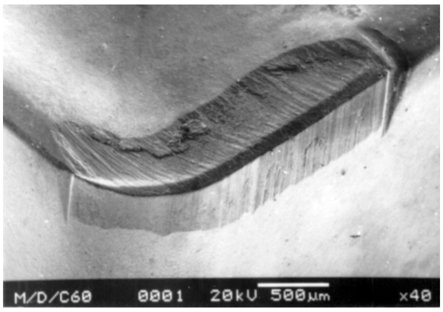


Dry machining, 45 min

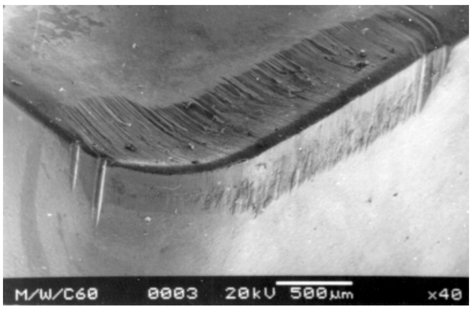


Wet machining, 45 min

Fig .5 SEM views of the worn out SNMM insert



Dry machining, 25 min



Wet machining, 25 min

Fig .6 SEM views of the worn out SNMM insert

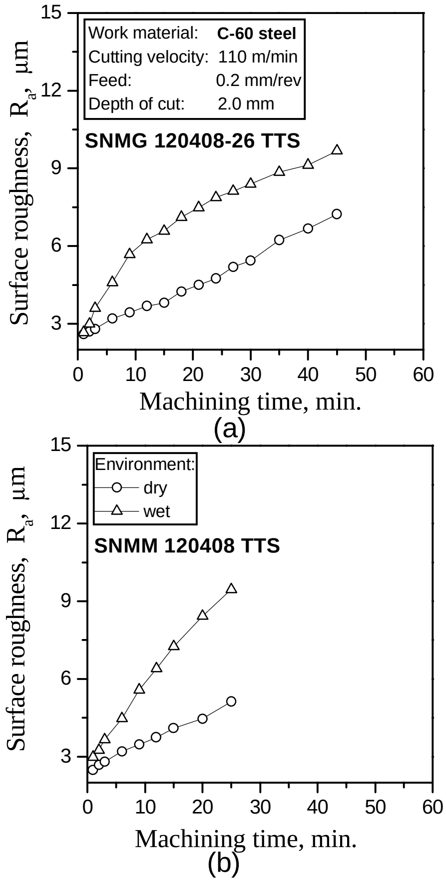


Fig. 7 Surface roughness, R_a developed during machining

CONCLUSIONS

The experimentally observed role of cutting fluid in machining AISI 1060 steel by two carbide inserts may be summerized as follows:

1. Dry machining of steel caused maximum tool wear and surface roughness and wet machining did not show appreciable improvement.

2. The cutting fluid was found to have a negative effect on flank wear, albeit its cooling action.

3. In spite of their cooling action the cutting fluid was found to accelerate the groove wear on the trailing edge, particularly at low feeds. This effect was found to be related primarily to the relative corrosiveness of the fluids.

4. Under finishing conditions, tool life can decrease with the cutting fluid due to the accelerated groove wear on the trailing edge.

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