Performance Comparison Between Dry and Nitrogen Gas Cooling when Turning Hardened Tool Steel with Coated Carbide

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Overview

• Hardened steels are widely used when producing tools and dies, automotive parts, as well as various mechanical and tribological components. This is due to their high strength and wear resistance properties. Their hardness result in low machinability where grinding is applied in finish machining operation.

• Conventional cutting fluid plays an important factor in improving machinability. Meanwhile, it is one of the most serious pollution sources in metal cutting industry such as their degradation and ultimate disposal [1]
Introduction

• Recent decades, dry cutting is becoming more and more popular due to several benefits such as increase material removal rate, reduce production costs, and enhance of material properties. Noordin et al. [2] reported significant results when dry turning hardened stainless steel (43 – 45 HRC) using coated carbide tool. During dry cutting the high temperature was generated at cutting zone due to the friction between tool and workpiece and between tool and chip which shorter tool life and negatively effect on surface quality [3]. Applying cutting fluid is important during machining process to reduce the temperature by deliver lubricant in between the cutting tool and workpiece which provide longer tool life and better surface quality, but otherwise, it’s costly and hazard to the operator [4]
Therefore, the new green cutting technique, which is ecological, economical and superior cooling and lubricating parameters, has become focus in metal machining. Although there is no appropriate substitution for cutting fluid due to its special performance of cooling, lubricating and chip-removing, increasing new cutting media, such as low temperature air jet, nitrogen gas, water vapor, cryogenic pneumatic mist and minimum quantity lubrication (MQL) [5]

Zhang at al.[7] investigated the effects of gases (nitrogen, oxygen, argon, carbon dioxide, and water vapor) as coolant and lubricant on machined surface, the micrograph and roughness value when turning of Cr18Ni9Ti stainless steel and C45 steel. It was reported compared with other gases, water vapor and nitrogen gas may give a better restrain action to nubs adhibiting on the machined surface, but nitrogen gas has hardly help to lower roughness value. Other gases, only at a certain extent, can restrain nubs adhibiting and lower roughness value
Methodology

Experiments were carried out on a CNC lathe machine. A cylindrical workpiece (diameters 115mm and length is 200 mm) stainless tool steel (STAVAX ESR) with hardness 48 HRC and chemical compesions (C 0.38%, Si .9 %, Mn 0.5%, V 0.3%, and Fe Balance). The cutting tools were PVD-TiAlN coated carbide inserts (KC5010) with ISO tool designations CNMG 120408FW, manufactured by Kennametal were used for the machining trials. The insert was mounted on tool holder which giving the tool end and back rake angles of 5°, end and side relief angles of 5°, end cutting edge angle of 5°, side cutting edge angle of -5° and entering angle 95°. Table 1 Cutting parameters for the experiments

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<th>Cutting speed (Vc) m/min</th>
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<td>Feed (f) mm/rev</td>
<td>0.16</td>
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<td>0.24</td>
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<td>Depth of cut (d) mm</td>
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Objective

In the present work, comparison of nitrogen gas as coolant with dry cutting was performed. The gas tube was standard type with suitable pressure regulators for nitrogen gas. The plastic pipe with an outer diameter of 12mm and inner diameter of 10mm with 2m length was used to connect regulator and the diameter of nozzle was 2mm. It was supplied by the nozzle with diameter 3mm and the distance between the nozzle and the cutting zone at 4-6mm. This nitrogen gas temperature were $20\pm2$ °C and the supply pressure pipe was 5 bar. For measuring the centerline average (CLA) surface roughness values (Ra), Mitutoyo, type: SJ-301 was used. The surface roughness length in each case was kept as 0.8 mm. The tool wear was measured under an optical microscope (Zeiss, type Stemi 2000-C). It was measured according to the international standard normative ISO 3685:1993 “tool-life testing with single-point turning tools, subjected to the maximum flank wear width (VBmax) and within the nose radius of the tool (zone C). The tool life criteria were set as: maximum flank wear width of 0.12 mm or tool is severely broken (catastrophic failure occurred).
Results

A significant difference in variation of surface roughness under dry and nitrogen conditions was observed. The surface roughness values were ranging from 0.225 to 0.50μm. It is obviously seen the surface roughness value in nitrogen gas coolant condition decreases as the cutting speed increases and on contrast in dry condition. At low speed and feed both the applications of dry and nitrogen gas conditions gave almost the same surface roughness. The optimal parameters for nitrogen gas condition to get a better surface finish were high speed (170 m/min) with high feed rate (0.24 mm/rev), and the obtained surface roughness was 0.225 μm. The reason for better surface finish in gas applications in high feed would be high penetration between chips and tool surfaces [8]
It can be clearly seen that the tool life decreases with increasing cutting speeds and feeds for both conditions. At high and low cutting parameters the nitrogen coolant condition gave 50% and 11.5% improvement in tool life over dry respectively. Nitrogen gas atmosphere retards oxidation due to heat build up during cutting. This reduces the cutting temperature and improves the tool life [10].
• In machining, typical forms of tool wear are found as crater wear and flank wear. Figures 3,4 show flank wear and crater wear at three different cutting parameters. Comparison was based on machining at end tool life. Flank wear and crater wear are the dominant failure modes at all cutting conditions. Several studies reported that the heat sources during dry cutting produces a high temperature between the tool and the chip and the tool and the workpiece which lead the tool to reach its criteria fast or catastrophic failure occurred [2].
<table>
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<th>V = 100 m/min, F = 0.16 mm/rev</th>
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• Increasing speed and feed lead to increase the wear which is due to the temperature generated in the cutting zone. The use of a nitrogen gas coolant would be expected to assist in the reduction of flank tool wear, due to reducing oxidation wear under sliding conditions at the extremities of the high speed and feed.

• the flank wear and crater wear in dry cutting are gather than nitrogen gas coolant. The reduction in flank wear suggests that the nitrogen environment enhances the tool/chip interface’s ability to extend tool life, and reduces the propensity for wear between coated carbide tooling and workpiece material in the flank face region.
Conclusion

- This study on turning of hardened stainless tool steel is performed under various dry cutting and nitrogen gas coolant conditions. Based on the results of study investigation, the following conclusions can be summarized:
- Nitrogen gas coolant has obvious advantages in better surface finish and increasing tool life when turning of hardened tool steel.
- At high conditions, Compared with dry cutting, the surface roughness under nitrogen gas coolant is reduced by 59%.
- At low levels of speed and feed rate nitrogen coolant condition gave 11.5% improvement in tool life over dry.
- Nitrogen gas reduction of oxidation abrasion on the tool.
- Flank wear and crater wear are the dominant failure modes when hard turning of tool stainless steel.
References


