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Green Machining and Forming by the use of Surface coated tools

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Abstract

In metal cutting industries cutting fluids are widely used to obtain longer tool life and better surface finish of the component. In metal forming industries oil based lubricants are used to control friction, reduce die wear and thereby increase the surface quality of the component. The cutting fluids and lubricants used in metal cutting and forming industries represent 16 -20 % of the manufacturing costs and have several negative health and environmental impact. Green or dry machining is desirable for a clean, safe and cost effective process with high quality products. In this paper, the performance evaluation of poly crystalline cubic boron nitride cutting tool towards the goal of dry machining is presented.

Keywords: Dry machining; Surface coated tools; surface roughness

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1. Introduction

Present day metal cutting and forming industries are not clean. Moreover the workplace is not that safe and healthy in these industries. Recent trends in the manufacturing world indicate that this situation is not acceptable in the future and considerable effort is essential to meet the strict environmental regulations [1]. Modern machining and forming processes face continuous cost pressure and high quality expectations. Green machining is becoming increasingly popular due to the concerns regarding cleanliness, safety of workers, cost and quality of the work piece.

Due to relative motion between cutting tool and work piece in the machining process, there is friction and heat is

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developed in the cutting zone. Cutting fluids are employed to control friction, reduce the cutting temperature, prevent adhesion between tool and work piece and wash away chips. Thus cutting fluids play a important role to obtain a stable machining process, an improved tool life and good surface finish of the work piece. For a long time, because of the limitations of tool materials, the use of coolants and lubricants were considered as an essential part of metal cutting and forming industries. All the undesirable effects associated with the use of coolants and lubricants were considered as a necessary evil. Manufacturing industries were developing methods to minimize the ill effects of cutting fluids and lubricants though the progress is far less than desired. Cutting fluids cause toxic vapours, unpleasant odours, smoke fumes skin irritations and its bacteria culture has its effects on operators and environment. Manufacturing industries were using mist lubrication to reduce cutting fluids and were successful to some extent. However mist in the manufacturing environment may have serious respiratory effect on the operator.

The problem of procuring, storing, pumping, handling and disposing the cutting fluids is evident in manufacturing industries and which in turn results in more overheads for manufacturing industries. The available options in dry machining are development of surface coatings on cutting tools that possess high hot hardness, reduce cutting speed considerable so as to get desired tool life and economics of machining. The high temperatures involved in machining (around 1000° C) especially at higher cutting speeds necessitate the use of cutting tools with high hot hardness. In this paper the performance evaluation of poly crystalline cubic boron nitride towards the goal of dry machining is presented..

For effective dry machining one has to be well informed about both cutting tool material and work piece material. Grey cast iron is particularly suitable for dry machining by virtue of discontinuous chips, low cutting temperatures and forces as well as the lubricating effect of the embedded graphite. Aluminium is critical in dry machining because of its thermal conductivity and coefficient of thermal expansion. Surface coated tools are well suited for dry cutting of Aluminium [2].For machining hardened steel, dry machining is highly recommended with surface coated tool with high hot hardness. The high cutting temperature in dry machining of hardened steel will soften the work piece material leading to better chip production, stable cutting and high surface finish of work piece[3]. Machining without cutting fluid (Dry machining) is desirable for a clean, safe, cost effective process with high quality products. Green or dry machining find acceptance only when it is possible to ensure that the part quality and machining times achieved in wet machining are equaled or enhanced

Jaharah.A.Ghane et al performed a comparative study of machining performance of dry and wet machining of ductile cast iron using coated carbide tools with respect to tool life and surface finish. It was observed that the tool life was more in wet machining when compared with dry machining. Surface roughness was almost identical for both wet and dry machining. The best performance of green machining can be achieved by selecting suitable cutting tool type, higher cutting speed , low feed rate and depth of cut[4].N.I.Galanis compared the wet and dry machining of stainless steel and reported in general that for wet machining, surface roughness and tool temperature had smaller values than the dry machining. Good surface quality can be achieved in green machining by choosing accurate cutting conditions which needs to be higher cutting speed and lower feed rate[5].

According to Neil Canter, Advances in the types of coatings applied to cutting tools have been the major factor in improving the feasibility of dry machining [6].Narutaki developed a new ceramic tool material using pure alumina powder with submicron size, no binder and sintered at 1230 ° C [7].This new alumina is stronger, harder and more wear resistant than conventional alumina in dry milling of carbon steel. P.S.Sreejith gave an overview of the recent developments in dry machining. Dry machining will be implemented in industries only if this technology is improved further [8].

2. Experimental Details

Table 1. Machine tool specifications

Manufacturer	Heindenrich & harbec, Hamburg, Germany
Height of the centres	225 mm
Turning Diameter over bed	520 mm
Spindle speeds	140-5600 rpm PIV Drive
Main motor power	15 KW

Table 2. Cutting tool specification

Cutting tool material	PCBN
Tool Insert	SNMA 120408-PB-250 WIDIA
Tool Holder	PSS NR 2525 DOC (WIDAX)
Rake angle	-6º
Clearance Angle	6°
Approach Angle	75°
Nose radius	0.8 mm

The work material for this study was AISI 4340 steel with a tensile strength of 1540 MPa and heat treated to 46 HRC.The machinability studies were conducted for a wide range of cutting speeds from 70 to 170 m/min, feed rate of 0.0355 to 0.1 mm/rev and depth of cut of 0.1 mm.All the machining were carried out without coolants. The dry machining performance is monitored by monitoring of surface finish and cutting temperature. A perthometer is used to measure the surface finish. The perthometer is a microprocessor based fixed datum instrument consisting of a stylus transducer, an amplifier, a chart recorder, a LED display unit and a traverse unit. An infra red pyrometer senses the cutting temperature. The machining experiments were conducted in a high speed lathe whose specifications are given in Table1. The cutting tool specifications are given in table 2

3. Results and Discussion

Good surface finish and adequate tool work interface temperature are sought to be obtained in the present investigation using PCBN tool without coolants. The finish machining of hardened steel requires that a significantly high level of attention to be paid to cutting speed and feed. At low cutting speeds, insufficient material plastification results in reduction of tool life and leads to lower surface qualities. In contrast high cutting speed causes problems with regard to the hot hardness of cutting tool material. The accuracy achieved in finish turning depend on various factors like stiffness and stability of machine tool, cutting fluids, cutting tool geometry and cutting tool, material.

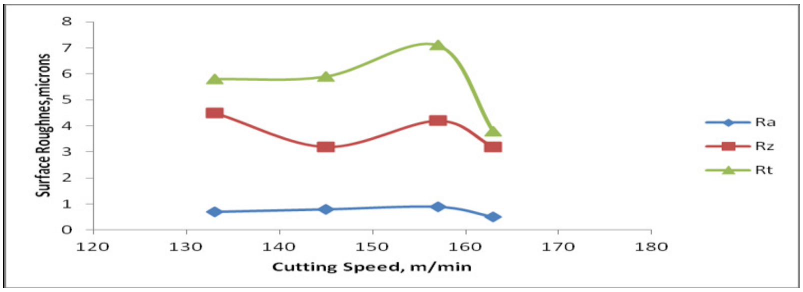

Fig1 Variation of surface roughness with Cutting speed

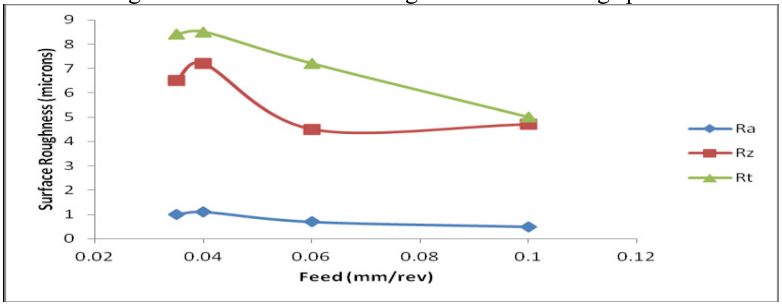

Fig2. Variation of surface roughness with feed

The variation of surface roughness with cutting speed is shown in Fig 1.Fine finish is obtained at higher speeds.With increased cutting speed, cutting temperature will rise resulting in flow stress reduction and chip production and adiabatic shear. This can lead to improvement in surface finish. N.M. Vaxevanidis analyzed the surface roughness in high speed dry turning of tool steel and concluded that surface roughness becomes better as the cutting speed increases for same feed rate and depth of cut [9].The Fig2 shows the variation of surface roughness with feed. For feed rates between 0.03 and 0.06 mm /rev, the roughness values are more since the feed rates are low when compared with recommended feed. This is probably due to rubbing action of tool cutting edge with work piece. Feed rate of 0.1 mm/rev deliver best quality surface (Ra value less than 1µm) and this probably due to increased heating and better chip production. Cutting speeds between 145 to 160 m/min and feed rate of 0.1 mm/rev are found satisfactory for this too work combination in dry machining conditions.

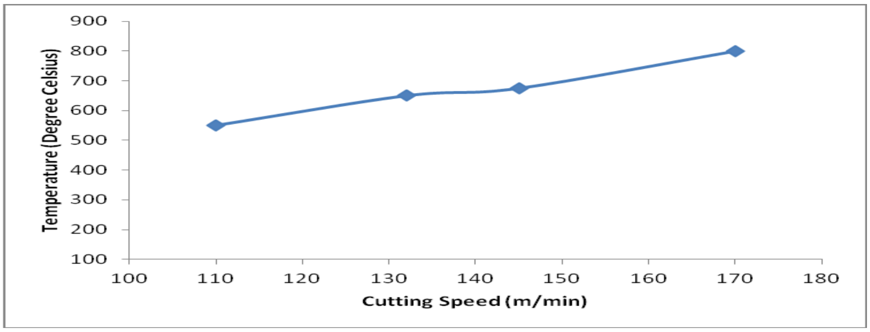

Fig3. Influence of cutting speed on cutting temperature

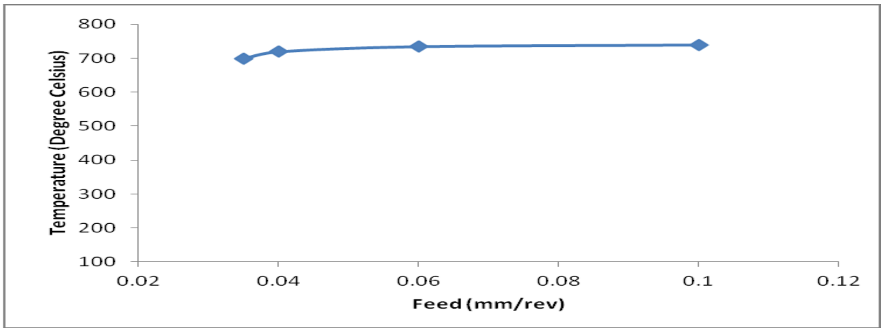

Fig 4 Influence of feed on cutting temperature

Fig 3. shows the influence of cutting speed on temperature. It is observed that the cutting temperature rises with cutting speed. At higher cutting speed, a large proportion of heat is carried away by chips and a small proportion of heat is conducted to tool and work piece.. It was observed that below 109 m/min, the cutting temperature is less than 550° C which may not be adequate for softening the work piece material which is necessary for effective machining of hardened steel. At 170 m/min the cutting temperature is 810° C and at this temperature the bulk work piece temperature increases. Moreover, PCBN is thermally stable up to 1100° C. Fig. 4 &5 shows the influence of feed and depth of cut on cutting temperature. It has been found out that the influence of feed and depth of cut with temperature is not as great as cutting speed.

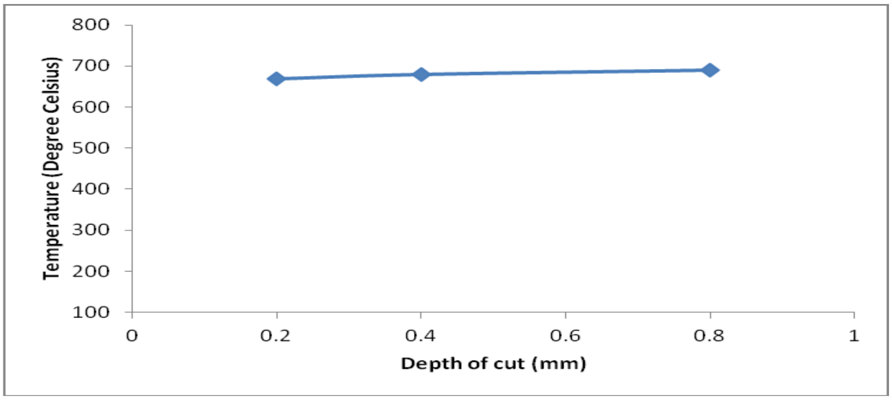

Fig.5 Influence of depth of cut on cutting temperature

4. Green Metal forming

Sheet metal forming is a process that is characterized by severe sliding contact between blank and die. The tribological system designed for a sheet metal forming process should impede the direct contact between die and the blank. The separation of die and blank surfaces minimizes the adhesion thereby reducing tool wear. Lubrication which is required to realize the die-blank separation and friction reduction depend strongly on the tribological loads that appear in the process. Although these lubricants are effective in reducing the wear of die, they are extremely hazardous. Chlorinated paraffin often form dioxins, zinc based additives give problems in waste water treatment and sulphur based additives are incompatible with non ferrous components of machinery.[10]

In addition to the lubricants, unhealthy degreasing agents are used to remove lubricating oil from sheet metal parts. The disposal, recycling and handling of these residual lubricants and degreasing agents is a problem faced by metal forming industries To avoid the harmful effects of liquid lubricants various surface treatment methods like fine polishing, nitriding and plasma-nitriding of forming tools have been proposed. These hardening and polishing may reduce the average coefficient of friction between the tools and die but repeated forming resulted in increased friction and wear. Moreover these hardening methods take long time to process and they are not reliable in achieving appropriate friction conditions and in improving the formability of sheet metal.

Green or dry metal forming can be implemented by modifying the surfaces of dies with solid lubricant. Coating techniques are currently implemented to improve deep drawing die life though it is difficult to meet the many coating requirements of excellent bonding, adequate thickness, and absence of flaws, suitable mechanical properties, thermal shock resistance and high temperature stability [11]. In this study a thin film of Molybdenum Disulphide was deposited on High speed steel substrates in Vacuum thermal Evaporator coating unit. The working pressure in the vacuum chamber was kept at 5×10^{-6} Pascal. The substrate was heated to 160° C. Quartz crystal is used to monitor the thickness of the deposited film and also to control the rate of evaporation. A thin film of MoS_2 of approximately 1 µm was deposited on HSS substrate.

The metallographic study and chemical composition analysis of thermally evaporated MoS_2 coatings were conducted using scanning electron microscope integrated with energy dispersive x-ray spectroscopy. The SEM images of uncoated HSS sample is shown in Fig 6.The microstructure consists of carbides in a marten site matrix. These carbides are probably the types M6C (where M is either molybdenum or tungsten) and vanadium carbide. The SEM image of MoS_2 coated sample is shown in fig 7 and a homogenous microstructure is seen. A significant difference in microstructure is seen in the SEM images of coated and non coated sample. A well adherent surface coating can be deposited on sheet metal forming die steels by controlling the coating process parameters, coating properties, coating film thickness and possibly a multi layer coating

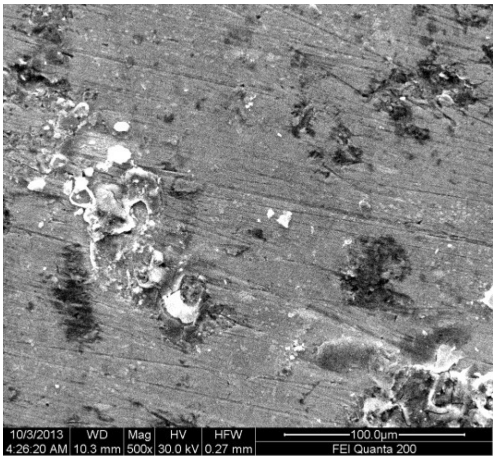

Fig 6. SEM image of non coated sample

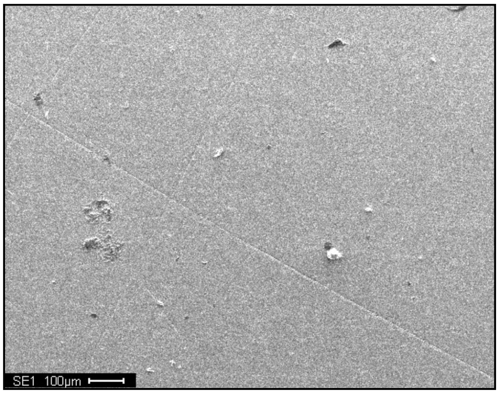

Fig 7. SEM Image of coated sample

Conclusion

This paper evaluates the performance of PCBN cutting tool in machining hardened steel under dry machining conditions. The most preferred cutting speed is 160 m/min for this tool work combination. It was observed that at cutting speeds more than 160 m/min, the cutting temperature reaches a critical value so that the cutting tool material starts losing its hot hardness and the bulk work piece temperature increases which is undesirable. Feed rate of 0.1 mm/rev deliver high quality surfaces. Green machining can be implemented by industries by choosing ultra hard cutting tool materials, tools with surface coatings and selecting appropriate cutting conditions. However, the production rate, tool life, cost and surface finish of dry machining should be comparable with that of wet machining. Development of thin hard coating technologies and hard coatings are indispensable for the development of dry forming processes, to alleviate the environmental loading and eliminate hazards to the production personnel and the metal forming industry.

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