A REVIEW ON IMPROVING TOOL LIFE WITH USE OF CRYOGENIC MACHINING AND DIFFERENT TOOL COATINGS

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Abstract— *In now days machining without the use of any coolant is become more popular due to safety of the environment. Because of this demands for increasing tool life without use of coolants are more. So according to this problem some of new machining techniques are considered like dry machining and cryogenic machining. Metal cutting is important in metal manufacturing process to achieve required shape and size. Many of the metal cutting industries invented different ways of improve the life of single point cutting tool in to increase the rate of the production and to reduce the cost of product, which is the major need of today's the manufacturing Industry. The goal of this paper to improve the tool life by various coatings on tungsten based cemented carbide cutting tool with cryogenic machining process. The coatings like Titanium nitride, aluminum oxide, and Titanium nitride/ aluminum oxide respectively are in use. This paper is about, the machining performance of coated tungsten based cemented carbides, were tested during plain turning of AISI 1045 steel under dry conditions.*

Keywords— Tool Coating; Cryogenics; Dry Machining; Cryogenic Machining

1. Introduction

The metal cutting industries is regularly trying to decrease its cutting costs and increase the quality of the machined objects as the demand for much accurate manufactured goods is quickly increasing. To machine more hard materials and to improve quality of machined surface with ordinary single cutting tool materials cannot meet with today's demand of metal manufacturing industries.

In the metal cutting operations the main problem is releasing of heat. Heat energy causes most bad effect on the Tool as well as work piece surface also. The temperature produce while machining is determining factors for machined characteristic of work piece. Cryogenic or Liquid nitrogen machining is used for the cooling and lubricating the work piece and tool surface while machining. But before today cryogenic machining was so costly and was not widely in use. But now days it is widely used in many industries for lubricating factor while machining. Cryogenic remove heat more efficiently from the cutting zone. In metal cutting process tool life is depends on the heat produce while machining. The main objective of cryogenic machines is it increases the processing speed with eco-friendly by product. Cemented carbides are the most popular and most common high production tool materials available today. The productivity increment of manufacturing processes is the acceleration of improved cutting tools with respect to the wear-resistance. With this result need of developing hard coating for single point cutting tools, these hard coatings are thin films of one layer to hundreds of layers. The hard coatings have proven to increase the tool life much more. This increase in tool life allows for less tool changes, therefore increasing the batch sizes that could be manufactured and in turn, not only reducing manufacturing cost, but also reducing the setup time as well as the setup cost. In addition to increasing the tool life, hard coating deposited on cutting tools allows for improved and more consistent surface roughness of the machined work piece. The surface roughness of the machined work piece changes as the geometry of the cutting tool changes due to wear, and slowing down the wear process means more consistency and better surface finish.

2. Literature Review

Coating techniques:

1. CVD = Chemical Vapour Deposition
2. PVD = Physical Vapour Deposition

1. The first technique of CVD deposits thin films on the cutting tools through various chemical reactions and coatings were traditionally deposited using the CVD technique. Another technique is PVD. This method deposits thin films on the cutting tools through physical techniques.

2. The reason PVD is becoming increasingly favorable over CVD is the fact that the coating process occurs under much lower temperature. The high temperature during the CVD process causes deformation and softening of many cutting tool substrates and especially hard steel speed (HSS).

2.1 Dry Machining:

The use of coolant to increase tool life has been an issue with different views. The brittleness of carbide tools makes possibility of damage by cracking if sudden loads are applied to their cutting edge. In traditional machining uses 500-3000 liter/hour of coolants during metal machining. This is known as dry machining. Dry machining is applied to avoid the extra costs and environmental problems associated to cutting fluids. High speed machining of hardened steel has the more potential of giving good quality of surface finish to make finishing operations such as grinding and polishing unnecessary.

2.2 Cryogenic Machining

Cryogenic machining means is the phenomenon of metal cutting at very low temp of the machining surface. It is originally from the Greek word 'Kryos' means 'Forst' and 'genic' means 'Production'. It normally works the temperature below 00. But scientifically it is assume that start at −149 °C (124.15 K; − -236.2 °F). The NIST (National Institute of Standards and Technology) has decided to consider the range of cryogenics as from temperatures below −180 °C or −292.00 °F or 93.15 K. In cryogenics mainly use the Kelvin scale for liquid nitrogen as cryogenic.

Fig 1.0 cryogenic machining setup

3. History of Cryogenic Machining

The first known application of cryogenic machining occurred in the 1950s.In 1953 Dr. Bartle found a setup for the application of high-pressure (850 - 900 psi) liquid carbon dioxide as a coolant in machining of heat-resistant steel. By applying the cryogenics in metal cutting we can obtain double cutting speeds and feeds. As all we know that liquid nitrogen and liquid carbon dioxide are two main and easily available cryogenics in today's market.

4. Cryogenic Process

This is a machining is a process of cooling the cutting tool and work piece during the metal cutting process. This process is about delivering of cryogenic Fluid instead of a cutting Fluid to the HAZ (Heat Affect Zone) of the tool and work piece, which is in the region of the highest temperature during the machining. The liquid nitrogen is also an ecofriendly.

5. Objective of this paper

The main goal of this research is to see the effect of different types of coating materials on the cutting capacity of carbide single point cutting tools with us of liquid nitrogen as a cryogenic to obtain the dry machining. To achieve this, turning tests were conducted with a lathe using available carbide cutting inserts with different coating materials such as Titanium nitride, aluminum oxide, and Titanium nitride/ aluminum oxide. The performance of the cutting tools is founded by considering the progression of tool wear and the surface finish of the work piece.

5.1 Wear

The control of wear on single point cutting tool is one of the most common problems in the metal cutting operations. The definition of worn out is someone who is really tired, or it is something that has been used so much it is breaking, performing poorly or otherwise not able to be fully functional. Tool worn out is also can said when the tool no longer performs the desired cutting action whereas total failure (ultimate failure) is defined as the complete removal of the cutting edge. Therefore, in metal machining operations, tools are considered to be worn out and are changed long before total failures to avoid incurring high costs associated with such catastrophic failures.

5.2 The tool life rejection criteria in ISO 3685:1993-:

I. Notching = 1.0-1.5 mm
II. Surface roughness (Ra) = 6.0-8.0 µm.
III. Average flank wear = 0.4-0.6 mm
IV. Nose wear = 0.5 mm
V. Maximum flank wear = 0.6-0.9 mm

Machining or shaping of metals is so complicated process. The cutting tool environment features high temperatures around 1000 ºC and high stress are produced around~700 MPa in simple turning operation. The tool may have experienced repeated impact loads during machining, and the work piece chips may have reactions with the tool materials also. The useful life of a single point cutting tool may be limited by a many of wear processes such as crater wear, flank wear or abrasive wear and nose wear. The main parts and the main types of wear on a carbide-single point cutting tool are shown in Figure below.

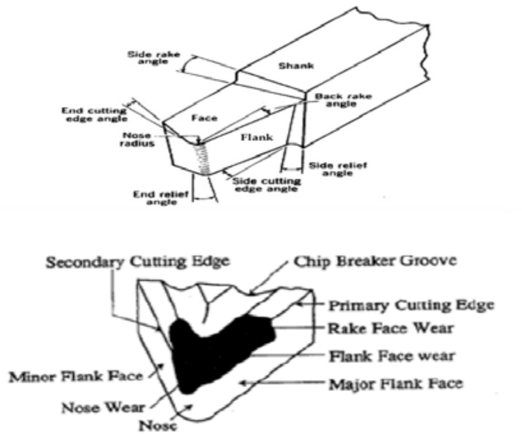

Fig 2.0 Single point cutting tool nomenclature

A. Flank wear is observed on the flank of the tool or on the clearance face of a metal cutting tool and is caused mainly by wear of the flank face by the hardness of the work piece material. This failure procedure is can mainly find out during cutting of irons and steels where the abrasive particles are mainly Fe3C and non-ferrous metals.

B. The crater wear is founded on the rake face of single point cutting tools and is caused by chemical reactions between the rake face of a metal cutting tool tip and the hot metal chip region. Depth of cut is contributed to the oxidation of the tool material.

C. Fracture is the much common mode of tool failure because it is not predictable as other failures. When machining using carbides under typical cutting and temperature conditions, the wear of the flank and rake faces is the main parts of a single point cutting tool by which a tool fails or fractured.

6. Use of Coatings

We can improve machining accuracy and efficiency is by reducing the machining time and cost of tool with high speed machining. When we done cutting operation on ferrous and hard materials such as steels, cast iron and its alloys, temperature and the chemical stability of the tool material limits the cutting speed depth of cut, feed etc. Therefore, it is necessary for cutting tool materials to wear a high-temperature, stable mechanical properties and sufficient inertness. The machining of chemical reactive and hard materials at higher speeds without cutting fluids is improved by use of single and multi-layer coatings on conventional tool materials to combine the beneficial properties of ceramics and traditional single point cutting tool materials.

The effect of coatings in conventional single point cutting tool are:

i. Reduction in heat generation, and in cutting forces
ii. Reduction in the chemically reactivity between tool and work piece in case of chemical reactive work materials.
iii. Prevention of galling (wear caused by adhesion between surfaces), at lower cutting speeds.

7. Coating Materials Used

The most common cutting tool materials used in various metal cutting operations are cemented carbide tools coated with a material like nitrides (Titanium nitride, CrN, etc.), carbides (Titanium carbide, CrC, W2C, WC/C, etc.), oxides (e.g. alumina) or combinations of these coating martials. Coating of cemented carbide tools with Titanium carbide, Titanium nitride and aluminum oxide are known for reduces the rate of flank wear. These tool coatings are contributor to the wear resistance of the cutting tools as they are all much less soluble in steel than WC at metal cutting temperatures. The hardness of these materials is beneficial in resisting the abrasive wear. Retention of hardness even at higher temperatures is very much important as the tool bit having a temperature in the range of 350-1200°C depending on the machining parameters like cutting speed, feed rate, depth of cut and the material of the work piece to be machined.

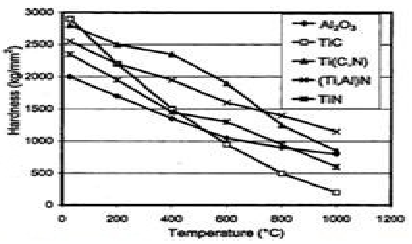

Fig 7.0 hardness with respect to temperature of different tool coatings

In today's manufacturing industries are using mostly three layers coating technique of Titanium carbide -Al2O3-Titanium nitride are widely used for machining of many types of hard steels. This three layer coating improves the wear resistance of the tool by adding the properties of the three materials in one. The ranking of the solubility products and limits of Titanium carbide, Titanium nitride and Al2O3 in iron, compared to the carbide substrate, is in the order Titanium carbide > Titanium nitride > aluminum oxide. Therefore there is less cutting forces are generated for significant diffusion and wear of aluminum oxide take place. So that, having a coating layer of aluminum oxide over a layer of Titanium carbide help decrease the dissolution/diffusion wear at the Titanium carbide coating layer. This technique improve the performance and life of the cutting tool, by including the Titanium carbide layer with a low wear rate and protecting it with a layer of Al2O3 to decrease the effect of dissolution wear.

8. Conclusions

This paper contributes the understanding of different tool shapes and tool insert used during dry machining with proper understanding of cryogenic machining by using liquid nitrogen and other cryogenic and tool coatings. Normally both the concept is eco-friendly, and good surface finish can be obtained by this machining method. This operation factor is associated with modern machining using cutting inserts with dry machining. This study evaluates the machining performance of five commercially available cutting tool inserts in turning AISI 1045 steel. Uncoated, Titanium nitride coated, Titanium nitride/Al2O3 coated and aluminum oxide coated tools were examined and their flank wear and the resultant machined work piece surface finish were analyzed. The tool coatings were founded to improve the wear resistance of the single point cutting tool. Titanium nitride/Al2O3 coated tool showed a decrease of around 69% as compared to the uncoated tools. The decrease in wear was due to the coated tool having much more wear resistance properties of the Titanium nitride and aluminum oxide materials and the high chemical stability of the aluminum oxide layer.

The aluminum oxide coated tool showed a decrease of around 90% as compared to the uncoated tool. The increased wear resistance of the aluminum oxide coated tool compared to the Titanium nitride/Al2O3 coated tool was observed to be due to the oxidation of the Titanium nitride material and the appearance of TiO2 under the aluminum oxide layer which improve the performance of the aluminum oxide layer. The Titanium nitride coated tool produced less surface roughness with a good surface appearance and finishing. At last we can say that this review helps improve the metal machining parameters like surface roughness, dimensional accuracy and also reduce the cost of metal machining as we can reduce the tool cost, tool changing time with the use of different tool coating as well as use of dry machining or cryogenic machining.

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