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CRYOGENIC TREATMENT AS PERFORMANCE ENHANCING PROCESS FOR CUTTING TOOLS-A REVIEW

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Abstract - ***This paper presents the information mainly on cryogenic treatment technology as applied to cutting tools. Production costs can be reduced by enhancing the performance of cutting tools. Cutting tools are mainly subjected to processes such as heat treatment and coating in order to increase their performance. Cryogenic treatment is one of the treatments that are used to enhance the performance of cutting tools. It is also known as sub-zero heat treatment. The tool performance is affected by both the mode of application of cryogenic treatment and the type of cutting tool. Therefore, it is necessary to examine the way in which cryogenic treatment is applied to cutting tools and its effects on their performance. This study reviews the literature on the performance for the cryo-treated cermet inserts.***

Key Words: *Cermet Inserts, Cryo-treated Inserts, Cutting tools, etc.*

1. INTRODUCTION

Cutting tool cost is one of the most important components of machining costs. For this reason, tool life must be improved by using some methods such as cutting fluid, optimal cutting parameters, heat treatment and hard coatings. Recently, another one of the methods commonly used to improve tool life is cryogenic treatment. Cryogenic treatments have been employed over the last three decades in both tool and high-alloy steels to improve wear resistance. The application of these treatments to alloy steels and even to non-ferrous materials is becoming the subject of many investigations, due to their ability to reduce wear and tear. Existing tool materials can be improvised by treating them under cryogenic conditions. The word cryogenic is derived from the Greek words "Kryos" (meaning cold) and "Genes" (meaning born).The process of Cryogenic treatment is generally classified in two ways either it is called "sub-zero treatment or shallow Cryo-genic treatment" having temperature as low as in the range of (-80°C) and "deep cryogenic treatment" with the liquid nitrogen temperature at (-196°C). This is the process in which the work pieces are treated at very low temperatures generally to remove residual stresses in the material and to enhance the wear resistance.

1.1 Recent Advancements in Cryo-treated Cutting Tools

Dhar et al. [1] has studied the experiment on surface roughness, temperature during the cutting, wear rate of tool and dimensional deviation during the cryogenic machining. In this paper, the cryogenic cooling effect with the liquid nitrogen on the wear rate of tool, temperature during the cutting and surface roughness in the turning of AISI 1060 steel by carbide coated tool has been studied. The study shows the beneficial effects of cryogenic cooling on life of tool along with the surface finish and dimensional deviation. Molinari et al.[2] reported that deep cryogenic treatment on tempered and quenched high speed tools increases hardness reduces the tool consumption and downtime for the equipment set up, hence it leads to the cost reduction of about 50%. Materials such as AISI H13 and AISI M2 have confirmed the possibility of increasing the wear resistance and toughness by carrying out the cryogenic treatment after the usual heat treatment.

Silva et al. [3] reported the performance of cryogenically treated M2 high speed steel tools. The various types of cutting tools used for the process were the lathe tool, twist drill and milling cutter. Microstructure analysis, hardness tests and sliding abrasion tests were carried out to check the performance of the tools. The results shows that cryogenic treatment does not have significant effect on the hardness and micro hardness of the M2 high speed steel tools and it has been also found that during the Brandsma rapid facing test the cryogenically treated tools performance much superior than untreated tools and the difference in the performance was found to be 44% under the same cutting working conditions. The cryogenic treatment also enhances the performance of the M2 HSS twist drills. The experiments also show that depending upon the type of application cryogenic treatment may be a good alternative for increasing the productivity. Rahman et al. [4] carried out the experiments to check the effectiveness of cryo-treated carbide inserts while turning. The material used during the experimentation was medium carbon steel and two carbide inserts, one cryo-treated and other untreated were used at different cutting speeds for the process. Different experiments were performed for continuous cutting without any breaks. After the experimentation it has found that cryo-treated tools perform much better than the untreated tools. Results shows that when cryogenically treated tools subjected to higher temperature for longer period of time then, the cutting edge of the tool lose their ability to resist the wear.

Yong et al. [5] investigated the difference in tool performance between cryogenically treated and untreated tool inserts during the milling of medium carbon steel. Tungsten carbide inserts were used as cutting tool. The study shows that cryogenically treated tools shows superior tool wear resistance as compared to untreated tungsten carbide tool. Reddy et al. [6] studied the effect of deep cryogenic treatment on chemical vapor deposition (CVD) coated carbide ISO P-30 inserts in machining C45 steel. It has been concluded that the flank wear and cutting forces of deep cryogenic treated coated carbide inserts were less as compared to untreated tools. Deep cryogenic treatment of inserts shows better surface finish on work piece as compared to untreated ones. Vadivel et al.[7] investigated the microstructure of cryogenically treated (TiCN+Al2O3) coated and untreated inserts in turning nodular cast iron. It has been found that coated and treated carbide inserts exhibits better performance as compared to untreated carbide tools. The study was based on wear resistance of the tool, surface roughness, power consumption and flank wear.
Das et al. [8] investigated the wear behavior, microstructure and hardness of AISI D2 steel which were treated under sub-zero temperature. The results obtained from the experimentation shows that the retained austenite content in the steel is reduced by cold treatment and is almost completely eliminated by both shallow and deep cryogenic treatments and the sub-zero treatments also modify the precipitation behavior of secondary carbides ,lower the temperature of sub-zero treatment higher will be degree of modification, the deep cryogenic treatment refines the secondary carbides and it tends to increase their quantity and population concentration and leads to more uniform distribution and bulk hardness increases slightly but hardness of the matrix improves considerably by deep cryogenic treatment. Reddy et al. [9] conducted the machining of C45 steel work piece by using the deep cryo- treated and untreated carbide inserts. Here, the output parameters during the process were flank wear and surface finish. After experimentation, results shows that flank wear rate of the cryo-treated tools were quite low as compared to untreated inserts and also surface finish of the C45 steel was better for the deep cryo-treated tools as that of the untreated inserts. Jaswin et al. [10] studied the effects of cryogenic treatment on the tensile behavior of En 52 and 21-4N valve steels during the room and elevated temperatures. Materials were subjected to shallow cryogenic treatment at 193K and deep cryogenic treatment at 85K. The deep cryogenic treatment was conducted at the optimum conditions and it shows that there was 7.84% improvement in the tensile strength for En 52 and 11.87% improvement for the 21-4N valve steel when compared to the untreated samples. It has been also concluded that the precipitation of fine derived carbide through Cryo-genic treatment is the reason for the improved strength.

Ding et al. [11] studied the behavior of cryogenic treatment process on the cemented carbide. The cemented carbide used during the investigation was YG8 with the composition of WC- 8 wt. % Co. In this paper the effect on various magnetic and mechanical properties of the material were tested after the cryogenic treatment. It has been found that the compression strength of the treated materials was more than that of the untreated samples, whereas the other mechanical property does not show any kind of changes. The treated alloys also shows enhancement in their wear resistance and fatigue life as compared to the untreated ones.Singh et al. [12] has conducted the experiment to check the durability of cutting tool after the cryogenic treatment. High speed steel tools are the tools which are quite commonly used in medium and small scale industry. Study on cryo-treated tools shows that there are micro-structural changes in the material after the treatment, which can have substantial effect on the life of the tools. In this paper the effectiveness of cryogenically treated HSS tools were compared to that of the untreated tools. It has been also observed that speed is the quite important factor followed by feed in both the cases. Gill et al. [13] studied the effects of cryogenic treatment on M2 HSS tools. The paper summarizes that shallow cryogenic and deep cryogenic treatment can significantly enhance the service life of M2 HSS turning tools. The results shows that the tools which are subjected to deep cryogenic treatment performs better and consistently as compared with shallow cryogenically treated tool as well as traditionally heat treated tools. The results shows the maximum tool life improvement over conventionally heat treated tools for shallow cryogenically treated tools was approximately 35% and for deep cryogenically treated tools it was about 50%.

Singh et al. [14] presents the results of uncoated tungsten carbide and cryogenically treated cutting tool inserts in turning of AISI 1040 steel. Tungsten carbide inserts coated with aluminum chromium nitride (AlCrN), titanium nitride (TiN) and uncoated WC were taken and treated cryogenically to evaluate the cutting forces and flank wear. The results shows that the cutting forces increases with the increase in feed, depth of cut and decreases with increase of cutting speed in all cases and flank wear increased with the increase in cutting parameters.Cicek et al. [15] studied the effects of cryogenic treatment on the machinability of hardened and cryo-treated tool steel. No. of experiments were performed with two ceramic inserts for both under dry and wet cutting conditions on the cryo-treated AISI H13 hot-work tool steel. Mainly three categories of the hot-work tool steel were turned in the machinability studies i.e. conventional heat treated (CHT), cryo-treated (CT) and cryo-treated and tempered (CTT). It has been found from the experimental results that the minimum wear and surface roughness values were obtained during the turning of CTT samples. The use of cutting fluid slightly improved the machinability of the tool steel. Ozbek et al. [16] evaluated the effects of different holding times during the deep cryogenic treatment on tool wear while turning AISI 316 austenitic stainless steel. The cemented carbide inserts were cryogenically treated at -1450C for 12, 24, 36, 48 and 60 h. From the experimentation, results showed that flank wear and crater wear were present in the various combinations of all the cutting parameters. However, tool wear was appeared only at lower cutting speeds (100 and 120 m/min) and the best wear resistance was obtained with cutting inserts cryogenically treated for 24h. Prieto et al. [17] studied the microstructural changes and the effect of cryogenic treatments on hardness and impact toughness in martensitic AISI 420 stainless steel. In this study, it has been experimentally demonstrated that the precipitation of small carbides occurs during the cryogenic treatment and it also provides a more homogeneous size distribution. It was observed that this micro structural quality is responsible for the improvement in the mechanical properties of the material. Ozbek et al. [18] studied the effect of cryogenic treatment on the uncoated tungsten carbide inserts during the turning of AISI 316 stainless steel and it has been found that when the cutting speeds were low and medium there will be notch wear in the inserts. Whereas flank and crater wear was appeared at all the possible combinations of the process parameters selected for the process of turning. The tools which were cryogenically treated have superior wear performance as compared to the untreated ones.

3. CONCLUSIONS

In the present study performance of cryo-treated tools during the machining of hardened steel under dry conditions has been studied. The machining of hard materials at higher speeds is improved by using cryo-treated tools. From the investigation it is observed that cryo-treated tools give better results as compared to coated tools in turning. The performance of cryo-treated cermet inserts was better than that of multilayer coated cermet inserts for the surface roughness and tool wear under the same experimental conditions. Whereas material removal rate was found better with the multilayer coated cermet inserts. The experimental results show that with the selection of proper cutting parameters; the cryo-treated tools are best suitable to produce superior surface finish of products.

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