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Deep Cryogenically Treated Zinc Coated Diffused Brass Wire (ZCDBW): State of the Art and Future Prospects

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Abstract
This paper reviews various aspects of deep cryogenically treated zinc coated diffused brass wire in this paper. Deep Cryogenic Treatment is carried out at about −184ºC (78 K). Deep cryogenic treatment is carried at -184ºC with a soaking time of 12 hours. Specimens were cooled at the rate of - 0.51ºC/min until they reach the final soaking temperature of -184ºC. Previously, when the zinc material was not coated on the diffused brass wire, it gave the following particulars, such as the zinc diffused brass wire was cryogenically treated and non-cryogenically treated which were being used as cutting tools. Now, in this paper, we will demonstrate the coating of zinc with diffused brass wire, which will perform certain functions such as an increase in wear resistance, increase in tool life, stepping - up of the tensile strength, toughness and also includes the release of internal stresses. With the coating of zinc material with brass wire gives us increased performance and durability. If we use the zinc coated material with diffused brass wire, it will be treated as a lifetime product.

Keywords: *Wire Cryogenically Treated, Deep Cryogenic Treatment, Brass wire, zinc.*

I. INTRODUCTION

Cryogenics is defined as the branches of physics and engineering that study very low temperatures, how to produce them, and how materials behave at those temperatures. Rather than the familiar temperature scales of Fahrenheit and Celsius, cryogenics use the Kelvin and Rankine scales. The science and technology of producing a low-temperature environment is referred to as cryogenics. The word cryogenics has its origin in the Greek language where "cryos" means frost or cold, and "gen" means to generate. With the help of the cryogenic treatment of wire, the current carrying capacity of the wire can be increased. It is also expected that the cryogenically treated wire would have fewer chances of breakage during machining as compared to untreated wire because of the increase in its toughness. Cryogenic treatment increases product life, and in most cases, provides additional qualities to the product, such as stress relieving, toughness, etc. It is a single time permanent treatment process as well as it affects all cross-section of the material usually done at the end of the conventional heat treatment process but before tempering. Also, this treatment is not a substitute process but rather a supplement to the conventional heat-treatment process. It is believed to improve wear resistance as well as the surface hardness and thermal stability of various materials (Singh, 2011).

The Deep Cryogenic Treatment (DCT) is carried out at about −184ºC (78 K). Deep cryogenic treatment is carried at -184ºC with a soaking time of 12 hours. Specimens were cooled at the rate of - 0.51ºC/min until they reach the final soaking temperature of -184ºC. Soaking time of 12 hours is adopted to allow for complete phase transformation to take place. Then the cycle is reversed such that temperature ramps up at the rate of 0.51ºC/min up to room temperature. A typical soak segment will hold the temperature at −184ºCfor some period of time, typically twelve hours. During the soak segment of the process, the temperature is maintained at a low temperature. Even if things are changing within the crystal structure of the metal at this temperature, these modifications are relatively slow and required time to occur.

Deep cryogenic treatment on zinc coated diffused brass wire shown in Figure 1.

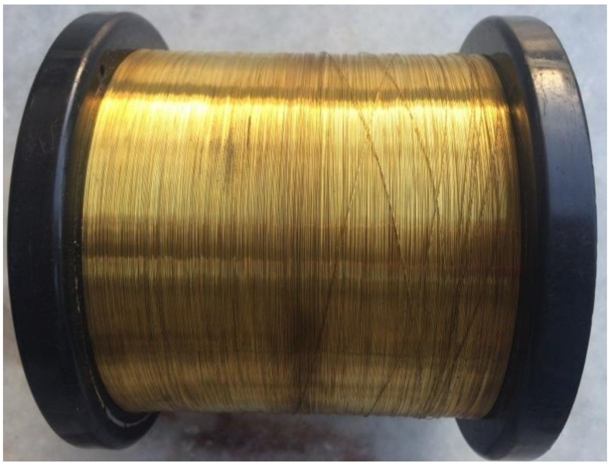

Fig 1: Zinc coated diffused brass wire

Improvements in cutting tool materials after cryogenic treatment:-

- DCT improves the physical and mechanical properties plethora types of material.

- The cryogenic treatment is a onetime permanent process.
- Uses subzero temperatures to stabilize, refine, and close grain structures.
- Internal stresses for longer wear life are released.

II. EXPERIMENTAL SET-UP

The cryogenically treated zinc coated diffused brass wire after setting the machining parameters accordingly. The wire was cryogenically treated in a cryogenic processor at Institute for Auto parts & Hand Tool Technology, Ludhiana. The diameter of the wire was 0.25 mm.

The wire electrode was used. Namely, zinc-coated diffused brass wire. In this study, the wire was cryogenically treated in a cryogenic processor (CP220LH). The cryogenic processor (CP220LH) used in this study is shown in Figure 2.

Fig 2: Cryogenic processor

III. PROCESSING CYCLES FOR DCT

The temperature was decreased at the rate of 0.51˚C per minute from room temperature. This is a known ramp down. The temperature was decreased up to-184˚C in 6 hours in the cryogenic processor. The temperature was hold at -184˚C for a period of 12 hours. The temperature was increased at the rate of 0.51˚C per minute in a ramp-up stage for a period of 6 hours. Temperature is bought to room temperature. The Deep Cryogenic Treatment (DCT) is carried out at about −184ºC (78 K). Deep cryogenic treatment is carried at -184ºC with a soaking time of 12 hours. Specimens were cooled at the rate of - 0.51ºC/min until they reach the final soaking temperature of -184ºC. Soaking time of 12 hours is adopted to allow for complete phase transformation to take place. Then the cycle is reversed such that temperature ramps up at the rate of 0.51ºC/min up to room temperature. A typical soak segment will hold the temperature at −184ºCfor some period of time, typically twelve hours. During the soak segment of the process, the temperature is maintained at a low temperature. Even though the things are altering within the crystal structure of the metal at this temperature, these changes are comparatively slow and necessitate time to take place.

IV. LITERATURE SURVEY

A. Akhbarizadeh [1] In this study, the effects of cryogenic treatment on the wear behavior of the D6 tool steel. For this purpose, the two temperatures were used: - 63ºC as shallow cryogenic temperature and -185ºC as deep cryogenic temperature. The effects of cryogenic temperature (shallow and deep), the cryogenic time (kept at cryogenic temperature for 20 hours and 40 hours), and the stabilization of the wear behavior of D6 tool steel were studied. The wear tests were performed using a pin-on-disk wear tester. Because of more homogenized carbide distribution as well as the elimination of the retained austenite, the deep cryogenic treatment demonstrated more improvement in wear resistance and hardness compared with the shallow cryogenic treatment. By keeping the samples for a period of one week at room temperature after quenching, more retained austenite was changed into martensite, and higher wear resistance and higher hardness were achieved.

A. Molinari, M. Pellizzari [2] In this study, the effects of deep cryogenic treatment on the mechanical properties of the tool steels. The effect of deep cryogenic treatment properties of tool steels through field tests and lab tests on AISI M2 and AISI H13, respectively. Cold treatment was done at 213˚C to 193˚C to improve surface hardness and thermal stability. Deep cryogenic treatment was done at 148˚C to 78˚C, which improves properties beyond the improvement obtained by normal cold treatment. It was carried out using a liquid with a cooling rate of 20-30 Kelvin/hour with a soaking time of 35 hours. The total duration of the treatment was 100 hours, and it reduces tool breakage and wears, which results in a 50% cost reduction. It was concluded that the cryogenic treatment was carried out after quenching and followed by the usual tempering cycle, its influence on the properties of steel is negligible.

KMW Seah, M. Rahman [3] In this review, the performance valuation of cryogenically treated tungsten carbide cutting tool inserts. Utilized the cryogenic treatment on cobalt-bonded tungsten carbide and found that the treated tools were superior to those of the untreated as-received inserts at the high cutting speeds. From this study, they observed that cryogenic treatment of tungsten carbide inserts increased the number of η-phase particles, a theory which they discussed with photographs taken by a scanning electron microscope. They allocated this as a reason for reducing transverse rupture strength hence greater resistance to chipping, improved resistance to the plastic deformation during cutting, and the lower toughness, after experiment valuation of comparative performance of cryogenically treated TiCN-coated carbide inserts and Keanna metal Grade KC 990 by gas infusion process.

YS. Liao, Y.P. Yu **[4]** In this study**,** investigated the study of the specific discharge energy in WEDM and its application. The workpiece materials were selected were aluminum alloy, titanium alloy, stainless steel, a cold work tool steel, a hot work tool steel, and used the flushing 5-axis CNC wire electrical discharge machine. The author was characterized by the process parameters such as discharge on time, discharge off time, wire-speed, flushing pressure, and servo voltage. It was found that the material having the close value of specific discharge energy demonstrates very similar machining characteristics such as machining speed, discharge frequency, groove width, and surface finish of the machine surface under the same machining condition. It was derived from the machining parameters and the machining characteristic such as material removal rate and the efficiency of material removed.

A. Bensely & A. Prabbakaran [5] In this review, enhancing raising the wear resistance of the case carburized steel En 353 by cryogenic treatment. The material was a selected case of carburized steel En 353. The chemical analysis was done for the composition En 353, such as a carbon 0.7%, silicon 0.19%, nickel 1.05%, and molybdenum 0.11%. This analysis was carried out in an optical emission spectroscope. The dimensions of the sample 20 mm diameter, 10 mm long, and was polished using 60-grit alumina paper. In conventional heat treatment, the machined tests samples have to undergo carburization in a liquid carburizing furnace at 1183˚C with a soaking time 5 hours followed by hardening at 1093˚C for 30 minutes, then oil quenching at 313˚C and tempering at 423˚C for 90 minutes. In shallow cryogenic treatment, the samples were heat-treated as for CHT, but without tempering. Then the samples were directly kept in a mechanical freezer at 193˚C for soaking time 5 hours, and it was followed by tempering at 423˚C and deep cryogenic treatment, respectively, for various loading 60, 70, and 80 N. It has been found that the wear resistance has considerably increased due to a shallow cryogenic treatment and deep cryogenic treatment includes much more improvement in wear resistance when compared to conventional heat treatment. It was concluded that better wear resistance, it was advisable to go to for deep cryogenic treatment.

V. Leskovsek & M. Kalin [6] In the study, investigated the influence of the deep-cryogenic treatment on wear resistance of vacuum heat-treated high-speed steel (HSS). The material was used electro slag remelting high-speed steel AISI M2 delivered in the shape of rolled, soft-annealed bar, and diameter 20 mm × 400 mm. The metallographic specimens, diameter 20 mm × 9 mm prepared from the bar, wear heat treated in a horizontal vacuum furnace with uniform high-pressure gas quenching using nitrogen at a pressure of 5 bars. After the last pre-heat, the specimens were heated to the austenitizing temperature of 1230˚C, soaked for 2 minutes. The vacuum and deep-cryogenic treatments, the eight different types of samples, were grounded and polished for further analysis and characterization. The microstructural tests were performed on the metallographic specimens using conventional optical metallographic techniques, a NI-KON optical microscope, and a JEOL JSM-35 scanning electron microscope. It was concluded that a moderate but sufficient high hardness and fracture toughness results in better wear resistance than the case when only one of the parameters in extremely high.

S.S. Gill, J. Singh [7] In this study, investigated the effect of the deep cryogenic treatment on the machinability of titanium alloy Ti-6246 in electrical discharge drilling. The material used was the alpha-beta titanium Ti-6Al-2Sn-4Zr-6Mo alloy and used the die sink EDM machining. The chemical composition of Ti-6246 such as a Al 5.5-6.5%, Sn 2.0-2.25%, Zr 3.5-4.5%, Mo 5.5-6.5%, Fe 0.15%, H_2 0.0125%, O_2 0.5% and N_2 0.04%. Two round blocks of 30 mm diameter and height of 20 mm were cut from hot forged at 950˚C and cooled in air commercially available Ti-6246 alloy rod. There were two workpieces used one was deep cryogenically treated titanium Ti-6246 alloy, and the other was non-treated Ti-6246 alloy. One workpiece was placed in a container, and the temperature was brought to -196˚C by computerized control at the rate of 0.5˚C/min. After experimenting on every hole in the drilling operation, the change in weight of workpiece and electrode was recorded from precise balance Shinko Denshi Co., Ltd., Japan, Model: DJ-150S-S and average values were used to calculate the MRR of workpiece and tool wear rate of the electrode. The surface roughness was recorded by using Mitutoyo Surftest SJ-201 portable device. The result of the study revealed the higher material removal ratio and wore ratio, lower tool wear rate in case of electric discharge drilling of DCT Ti 6246 alloy workpiece as compared with non-treated Ti-6246 alloy workpiece. It was concluded that deep cryogenic treated of Ti-6246 alloy also greatly improved the production of the holes drilled.

A. Okada, T. Yamauchi [8] In this review, investigated the effect of surface quality of brass coating wire on wire EDM characteristics. The author used a trial made thin of 50 µm in diameter. The experiments were carried out using a commercial wire electrical discharge machines with the linear motor drive (Sodick AP200L and AQ550L). The wire was newly developed for this research, in which brass was coated on high tensile strength steel wire. The metal mould steel SK D11 in Japanese Industrial Standard specifications was used as a workpiece, whose thickness was 10 mm. The coated brass wire with a copper content of 60-70% was effective, and the thickness of the coated brass is needed to be more than 1.45 µm for a high removal rate. It was concluded that the case of conventional tungsten wire when the wire tension was too high, the removal rate decreases because of unstable wire vibration.

A. Idayan & A. Gnanavelbabu [9] investigated in the influence of deep cryogenic treatment on the mechanical properties of AISI 440 C bearing steel. The element raw material was selected AISI 440 C bearing steel, and the dimensions of the specimen are 10×10 cm. In the composition, the steel was found using Optical Emission Spectroscopy. During SCT, the samples were placed in an insulated freezer at -80ºC and then soaked for 5 hours and the DCT; samples were cooled down slowly to a very low temperature -196ºC within 3 hours. The carried out was samples hardness test by using the Rockwell hardness testing machine. The Fractography analysis of the cryogenically as well as conventionally heat treated bearing steel was performed using the Scanning Electron Microscope. It was found that the deep cryogenic treated specimens, there was less amount of retained austenite than CHT, SCT, and the Fractograph analysis elucidated that facet cleavage with brittle rupture in CHT or cryogenically heated treated AISI 440C steel.

S.S. Gill, R. Singh [10] investigated the wear behavior of the cryogenically treated tungsten carbide inserts under low and wet turning conditions. Tungsten carbide inserts were placed in a container, and the temperature was brought to -196˚C in intervals by computerized control to the rate of 0.5˚C/min. The temperature was held constant for 24 hours for soaking time before the process was reversed. The hot rolled annealed steel stock (C-60) of initial diameter 200 mm and length 800 mm was orthogonally turned on an LB-17 HMT lathe for commercially available standard carbide inserts uncoated square shape cryogenically treated tungsten carbide inserts with chip breaker under both dry and wet conditions. The cutting tests were performed feed rate of 0.1 mm/rev, the depth of cut of 1 mm. The maximum flank wear, VBmax, was measured using an inverted metallurgical microscope after each cutting operation. It was found that dry and wet turning conditions of cryogenically treated tungsten carbide inserts. It was concluded that the cryogenically treated tungsten carbide inserts perform more consistently under interrupted machining mode as compared with continuous machining mode.

L.P. Singh, J. Singh [11] investigated the effects of cryogenic treatment on high-speed steel tools. The material selected was a high-speed steel tool and used a higher power rigid lathe machine. It used machining parameters such as machine tool, cutting tool, tool geometry, work material, workpiece specifications, cutting speed, feed rate and depth of cut and the surface roughness of work specimens was measured by surface roughness tester, model SURF TEST4; nose radius of both the UT and CT HSS tools was measured using universal measuring microscopic least count 0.0001 mm. The speed of the workpiece was measured with a digital tachometer, model DT-2234. It was found that cryogenic treatment of workpiece significantly improves the surface roughness.

J. Kapoor, J.S. Khamba [12] analyzed the effects of cryogenically treated wire electrode on the surface of an EN-31 steel machine by the WEDM. The workpiece material was selected EN 31 steel plate of thickness 11 mm and used the Robofil 290 CNC wire cut EDM machine. The process that was used by the authors characterized by the process parameters such as wire electrode, pulse width, and wire tension. The surface roughness values were measured with the Surf Tester (SJ201). It was concluded that kind of wire, pulse width, and wire tension significance affected the surface roughness in wire electrical discharge machine.

N. Sharma, R. Khanna [13] utilized the Taguchi method to modify the process parameters of cryogenic treated D-3 machined by the wire EDM. In this study, the material was stored in a cold environment to step up wear resistance and to relieve residential stress. More process parameters as the pulse width, the time between two pulses, maximum feed rate, and servo- reference mean voltage. It was found that the pulse width, the time between two pulses, has a significant effect on surface roughness values.

H. Singh & A. Singh [14] investigated wear behavior of the AISI D3 die steel utilizing the cryogenic treated Cu and Br electrode in the electric discharge machining. The input process parameters in these days are utilizing four different types of electrodes that are Cu, cryogenically treated Cu, Br, and cryogenic treated Br. The weight of the workpieces and electrodes was accomplished before machining and after machining on the weighing machine having the least count of 1 mg. The kerosene oil was utilized as dielectric fluid experiments. The electrodes had 16 mm diameter, and 55 mm lengths were fitted out of rods of Cu and Br for performing the experiments. After preparing the needful size, the face of each electrode was polished so as to obtain a fine surface finish utilizing dissimilar emery papers ranges between 220-2000 grit sizes. After that, electrodes of Cu and Br were cryogenically treated to improve properties. The workpiece size of 25 mm × 18 mm × 6 mm was ready-made by utilizing the wire EDM. The prepared specimen was heat-treated to improvise their hardness. Later than heat treatment, the hardness of the workpiece material was 58 HRC. The Cu electrode was a good electrode for high MRR. But cryogenically treated Cu electrode had low tool wear as analyzed to Cu electrode.

A.S. Gill & A. Thakur [15] In this review, investigated the effect of deep cryogenic treatment on the surface roughness off OHNS die steel after wire electrical discharge machining. The material was selected for OHNS die steel (oil hardened non-shrinking) and used the wire electrical discharge machining. Deep cryogenic treatment of workpiece was done using the 9-18-14 cycle. The machining time for each cut was 12 minutes, and after cutting the workpiece, the machine checked the surface roughness. It was found that cryogenic treatment of the workpiece significantly improves the surface finish of the machined surface.

N. Singh, P. Kumar, and K. Goyal [16] investigated the effects of two dissimilar cryogenic treated wires in the wire electrical discharge machining (WEDM) of the AISI D3 die steel. The workpiece material was selected AISI D3 die steel and used the Charmilles Model 290 WEDM machine. The two types of wire electrodes were the namely Br wire, and Zn coated diffused wire. The various machining parameters which were taken over for observational study are pulse width, the time between two pulses, wire feed rate, and mechanical wire tension. There was no significant effect of wire tension and wire feed rate on MRR. It was observed that the cryogenically treated zinc coated diffused brass wire generates 22.55% more than the material removal rate as compared to the plain brass wire.

D. Candane, N. Alagumurthi & K. Palaniradja [17] according to this study, investigated the effect of cryogenic treatment on microstructure and wear characteristics of AISI M35 HSS. The specimens were prepared from AISI M35 high speed steel bar of 15 mm square cross-section with a nominal composition of C - 0.889%, Mn - 0.273%, Si - 0.364%, S - 0.006%, P - 0.024%, Cr - 4.175%, Ni - 0.171%, Mo - 4.656%, V - 1.788%, W - 6.087%, CO - 4.551%. Each and everyone, the specimens were subjected to conventional heat treatment in a barium chloride salt bath furnace in the subsequent order. As the first step, specimens were pre-heated in a forced air circulation furnace maintained at a temperature of 500˚C to remove the moisture content for a period of 30 minutes. The shallow cryogenic treatment has been conceded at -85˚C with a soaking time of 8 hours. The deep cryogenic treatment has been conceded at -195˚C with a soaking time of 24 hours. There was a marginal improvement in hardness from 64 HRC to 64.5 HRC for shallow cryogenic treated specimens, and it improved further after deep cryogenic treatment to 65.5 HRC. It was concluded that also the microhardness measured in the Vickers scale shows an increase in hardness value from 920 to 934 in the case of shallow cryogenic treatment, and it was 980 in the case of DCT.

N. Singh, and P. Kumar [18] In this review, the experiment analyze of wire EDM variables on surface roughness (SR) of the AISI D3 die steel by utilizing the two cryogenically treated dissimilar wires. The workpiece material was used AISI D3 die steel and using the Charmilles Model 290 wire EDM machine. Two kinds of wire electrodes were utilized which brass wire and zinc-coated diffused wire. The various machining parameters were utilized, like pulse width, the time between two pulses, wire tension, and wire feed rate. It was observed that the cryogenically treated zinc coated diffused brass wire gives fine surface finish as considered to the cryogenically-treated plain brass wire.

M. Kumar, H. Singh [19] In this study, investigated a review on the "effect of deep cryogenic and shallow cryogenic heat treatment" on microhardness and wear resistance of different steels." The wire material was selected like gunmetal and brass. The author has used two types of cryogenic treatment like deep and shallow. There were two process variables like microhardness and wear resistance. The deep cryogenic treatment process, the material cooled temperature range is -196º C, and the shallow cryogenic treatment cooled material temperature range is -96º C. It was concluded that the microstructure of the cryogenically treated material is very fine, stable, continuous & stress-free. The hardness and wear resistance of multi-cryogenically treated samples is also quite high as compared to the untreated samples.

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V. CONCLUSIONS

To amplify the performance of these materials, different types of cryogenic heat treatments have been adopted by various researchers and concluded that:-

- The microstructure of the cryogenically treated material is fine, stable, and stresses less. The hardness of cryogenically treated wire is also quite high as compared to the without cryogenically treated wire.
- It is burgeoning in the wear resistance of a cryogenically treated wire as compared to the untreated wire.
- Cryogenic treatment affects the entire section of the component, unlike coatings.
- The surface roughness, as well as the material removal rate of cryogenically treated wire is better as compared to the untreated wire.

VI. FUTURE SCOPE

There are following future scope points are below:-

- In the future, the deep cryogenic treatment will do on the workpiece.
- The DCT will be applying on simple brass wire.
- There is a number of applications in the future like medical, manufacturing and automobile industries, etc.

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