EXPERIMENTAL INVESTIGATION ON CRYOGENIC TREATMENT OF MACHINE TOOLS (DRILL BIT)

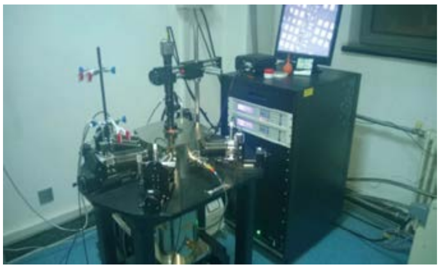
M.Mathanbabu[1] | R.Rahul[2] | K.Saravanan[2] | A.S.Sathya[2]
[1](Asst Prof, Dept of Mechanical Engg, Nandha College of Technology, Tamil Nadu, India, mathanbabb49@gmail.com)
[2](UG Students, Dept of Mechanical, Nandha College of Technology, Tamil Nadu, India, saravanankittusuresh@gmail.com)

Abstract— *Tool wear studies of friction stir welding (FSW) is imperative since FSW is of late extended to Cu, Mg, SS, Ti and MMC besides Al. H13 tool steel is the widely used tool material in FSW. Carbide forming elements like Cr, W, V, and More added to steel ingots to improve the wear resistance. These carbides are not uniformly distributed in the ingot matrix because of macro segregation. Steels produced by P/M route have better wear resistance compared to ingot steels since segregation is avoided. Cryogenic treatment of tool steels also improves the wear resistance. Hence, the present study aims at comparing the wear behaviour of AISI H13 tool steel and Bohler K390 P/M steel (9 % V) before and after cryogenic treatment. Friction stir welding (FSW) is carried out at a constant rotation speed of 1200 rpm and at traverse speeds of 50 mm/min with a tool tilt of 3° for a weld length of 14 cm on 3 mm thick copper plate. The tool design chosen for this study is a simple tool with a concave shoulder of 15 mm diameter and a plain pin with 5 mm diameter. It was found that P/M tool and cryogenically treated H13 tool could withstand very high heat input conditions and possess better wear resistance compared to the wrought H13 tool steel. This is attributed to the uniform distribution of carbides and difference in thermal conductivity of the tools.*

1. INTRODUCTION

Friction stir welding (FSW) was invented at The Welding Institute (TWI) of UK in 1991 as a solid-state joining technique, and it was initially applied to aluminium alloys[1, 2].A non-consumable rotating tool with a specially design pin and shoulder is inserted into the edges of sheets or plates to be joined and traversed along the line of joint. The main functions of the tool are (a) heating of work piece, and (b) movement of material to produce the joint. The heating is accomplished by friction between the tool and the work piece and plastic deformation of work piece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the pin to the back of the pin. As a result of this process a joint is produced in 'solid state' [3]. The tool material should possess high strength, toughness and good thermal conductivity. We are of tool is generally not considered as a severe issue in friction stir welding of aluminium alloys since aluminium is a soft metal [4,5].Tool wear is of major concern in friction stir welding of high melting point materials (copper, steel and titanium) and wearable materials (metal matrix composites)[6,7]. However, studies on the tool wear during FSW are limited. No systematic studies have been reported so far on the selection of tool material for friction stir welding of steel, titanium, copper and composites. The tool wear and shape optimization are associated with the tool materials. In the present study, two types of tool steels viz, wrought H13tool steel and powder metallurgical produced BohlerK390 steels are used for FSW of copper before and after cryogenic treatment and tool wear was studied. The strengthen in carbides are not uniformly distributed in the matrix due to macro segregation in AISI H13 steel. This segregation can be avoided if the tool is produced by powder metallurgy route (Bohler K390).

2. MACHINE SET UP IMAGE



Drill Bit

3. LITERATURE SURVEY

Methods to enhance the life of the component are based on application 12 of wear resistant materials or formation of hard, wear-resistant surface material. The wear rate of steels depends on their chemical constituents and conventional heat treatment as outlined by Suchanek and Kuklik (2009). Susheel Kaila (2010) pointed out that cryogenics is an exciting, important and inexpensive method to increase the life of the steel component. It improves abrasive wear resistance, erosion and corrosion resistance and stabilizes the strength characteristics of the steels Hasim et al (2002) pointed out that the cryogenic treatment of materials are gaining importance in recent days because of their potential to produce steel components that find enormous application in industries, nuclear power plants, fertilizer plants, medical, aerospace and avionics. Due to the fact that materials treated under cryogenic environments attain superior properties that call for operation under severe environments as indicated by Charles and Arunachalam (2006).

4. METALS AND FLOATING MATERIAL USED IN FABRICATION

CRYOGENIC SYSTEMS

A cryogenic system is an equipment which allows to control temperature in the cryogenic range into a chamber, using liquid nitrogen or helium. Until the end of the Sixties, any attempt to perform CThad been done by direct immersion into liquid nitrogen, with the catastrophic result of cracking the components. The cryogenic treatment system developed by Ed Busch (Cryo-Tech, Detroit, MI) in the late 1960s and later improved by

Peter Paulin (300 Below Inc., Decatur, IL) with a temperature feedback control on cooling and heating rate, allows toper form effective and crackles CT. As a result, many companies have developed systems to perform CT, mainly in the USA and in Canada, but also in China, India and Japan. The three most important cooling systems are describe din Heat Exchanger: the liquid nitrogen flows through a heat exchanger and the output cooled gas is diffuse dinside the chamber by a fan. There is no contact between nitrogen and samples;

□Direct Nebulization: the liquid nitrogen is nebulize ddirectly in the chamber or in a cavity around the chamber. A fan allows to obtain a homogeneous temperature distribution; the liquid nitrogen is dispersed around the samples; □Gradual Immersion: the samples are immersed into the liquid nitrogen for a specific time, then they are extracted and gradually led back to the room temperature by means of a flow of temperature controlled air. Another type of cooling system is the so-called “Hybrid System”, which combines direct nebulization and gradual immersion during different phases of the cooling process, in order to reduce liquid nitrogen consumption (i.e.

EFFECTS ON THE MATERIAL MICROSTRUCTURE

Ferrous Alloys

According to the literature about cryo-treated tool steels ,the improvement of mechanical properties can be ascribed to different phenomena:Complete transformation of the retained austenite into Martensite;Fine dispersed carbides precipitation;Removal of residual stresses.

It is known that almost all steels at 193 K transform the austenite into martensite. The use of cold treatment has been initially developed on martensitic tool steels in order to remove retained austenite with benefits on hardness.

A reduction from 5.7% to 4.2% in retained austenite volume neutron diffraction on AISI 4340 steel [12]. The temperature reached in SCT is enough to obtain this result; therefore the use of at lower temperature by DCT can only be justified if it activates some different phenomena which lead to a further improvement of the mechanical properties. In [13], a reduction in retained austenite fraction and a rod-like carbides precipitation during tempering after DCT have been observed, pointing out a correlation between the carbide dimension and the tempering temperature. Moreover the authors have obtained a greater dimensional stability of DCT components after each subsequent tempering, which is a result strictly related to the retained austenite elimination, thanks to the lower volume compared to the martensite. The dimensional stability is a desired property for some accurate applications as worn plug gages [14]. The X-ray diffract metric observations carried-out in [15] have confirmed both phenomena:25% of the retained austenite observed before DCT treatment has been transformed into martensite and fine carbides precipitation has been promoted. Most of the authors, especially in recent papers, have agreed on ascribing to the fine carbides precipitation the improvement of the wear behaviour .Precipitation of fine dispersed carbides has also been previously observed in AISI T1 and M2 high-speed toolsteels [16] and in AISI H13 tool steel [17, 18] where, after DCT, the disappearing of twinned sub microstructures present in tempered martensite has been noted. The authors have called this phenomenon “tempered martensite detwinning” but no information is available in literature about Something similar the authors have proposed a precipitation mechanism based

On the contraction and the expansion of the martensitic lattice in different directions, with a slightly shifting of carbon carbon-rich bands. The effect is an improved wear resistance ascribed by the authors to the strength and the toughness enhancement of the martensite matrix. An interesting analysis of possible phenomena inside the material during the CT is proposed in carbides in M2 steel before and after DCT, the authors have found that particles size-range and size-distribution are similar in treated and non-treated samples, but the population and the volume fraction are different and the carbides distribution

IV Non-Ferrous Alloys

Despite of the advertisement on cryo-companies websites, which promises enhancement on a wide range of materials, there are few papers in literature about CT of nonferrous materials. In [30], the DCT effects on a wide range of polymers and composites have been tested, pointing out interesting results for some of them. Using X-ray diffraction the authors have found a marginal increase in cristallinity after the DCT on Polyetherimide (PEI) and on Polyimide(PI), while no changes have been detected on Polytetrafluoroethylene

PTFE). The change in cristallinity of PEI has been confirmed by Differential Scanning Calorimetric(DCS), which has shown an increase of the glass transition temperature (Tg) from 488 K to 526 K. The authors have related the increase in wear resistance of PEI and of PI to the change in cristallinity. Moreover, Scanning Electron Microscopy (SEM) has pointed out a rougher topography for the surface of the cryo treated PEI. In order to explain these observations, the authors have suggested the development of residual stresses in the polymer as a consequence of the contraction at cryogenic temperatures and subsequent uneven expansion during the warming phase. In the case of the PTFE, the improvement in wear behaviour after the DCT has been attributed to the hardness enhancement. In addition, the SEM observations of PTFE powder have shown agglomeration and fibrillation phenomena after DCT, which the authors have related to the ductile behaviour, at low temperature too, of PTFE. Any significant or detectable change in dimension, crystallinity, tensile strength and elongation on Ultra-High Molecular Weight Polyethylene (UHMWPE) samples after DCT has been found in [31].

The heat affected zone of an unspecified aluminium alloy, which has been welded with Variable Polarity Plasma Arc (VPPA) technique, has been investigated before and after CT in [32]. Using X-ray diffractometry, the authors have detected a reduction in residual stresses, but no microstructural analysis has been performed.

DCT has also been performed on 7075 aluminium alloy samples [33], but the authors did not find any enhancement in tensile, impact and hardness properties and no further carried out.

5. EFFECTS ON THE MECHANICAL PROPERTIES

An extensive collection of CT test results is reported in concerning hardness and wear resistance of a wide range of steel grades. This series of papers represents a milestone in the CT field. The papers [37, 38] show wear and hardness results for respectively twelve tool steels, three stainless steels and four other steels. By comparing the results obtained with 189 K SCT and 77 K DCT, the author shave observed a significant abrasive resistance increase for the tool steels subjected to the colder treatment, whereas the stainless steels have shown a difference of less than 10% and the plan carbon and the cast iron did not improve with either SCT and DCT. After the investigations carried out in papers many works reporting test results on CT materials have been published, but each one has focused on one or on few materials instead of collecting data from many of them. As a consequence it can be helpful to summarize the published results in order to have an overall picture of the measured effects.

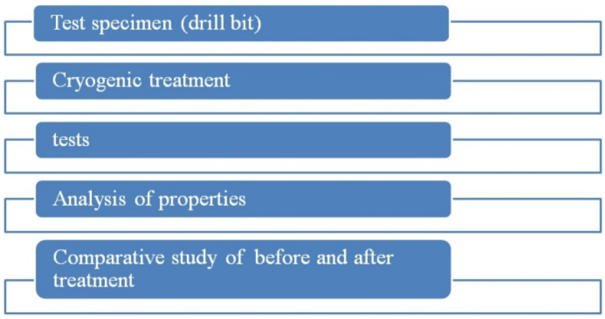
VI Wear Resistance

Wear resistance represents an important property of a material when it is used in applications that lead to reciprocal moving of in-contact components, such as machining tools, bearings, gears, brake rotors, piston seals, etc. Among the listed above micro structural changes related to CT, both retained austenite reduction and carbide precipitation can lead to an improvement in wear resistance by the increase of the steel hardness. It is almost impossible to carry out a complete comparison between the results obtained in literature, because of different test conditions (such as sliding velocity, distance.

VII Hardness

Many hardness tests about CT are reported in literature because this property is related to the wear resistance. Hardness properties are usually measured through indentation tests and they are expressed in different scales depending on the penetrator shape. The most used methods are the Rockwell and the Vickers ones. While the first method is a macro indentation test, the second one can be performed both as macro or micro-indentation, depending on the applied load, as performed in The hardness of a tool steel is mainly influenced by retained (soft) austenite and in this way CT can play an important role. However, when compared to wear results, hardness test results (see Table **4**), indicate that the mechanisms can be different for different materials. For instance, in [17] a little increase (+0.13%) in hardness has induced a –51% in wear rate for AISI M2 and the authors have concluded that AISI M2 wear resistance improvement can be attributed to hardness increase. The same test on AISI H13 tool steel has shown an improvement of 6.9% in hardness related to a decrease of 29% in wear rate and, according to the authors, the wear resistance improvement has been correlated to the enhanced toughness of the CT material. The paper [13] suggests that playing on carbides fraction and dimension and on retained austenite allows to achieve an optimized ratio between hardness and toughness in high speed steels. Interesting results on HSS base composites reinforced with Nb and Ta carbides have been obtained, with about 10% increased hardness [20].Concerning non-ferrous materials, no significant changes in hardness of aluminium alloys [32, 33] and of Ultra-high Molecular Weight Polyethylene [31] have been detected, while PTFE, PEI, PI, PU and PC have shown important changes in Shore D hardness [30].

6. DESIGN PROCESS



7. WORKING ON EFFECT OF CRYOGENIC TREATMENT ON THE TOOL MATERIAL

In Friction Stir Welding of Pure Copper 100-200C

Figure 1 (a), (b) shows the AISI H13 tool before and after welding (1200 rpm and 50 mm/min traverse speed)respectively. Figure 1(b) shows that AISI H13 tool cannot withstand such a high heat input condition and the pin was broken. The tool material should be sufficiently strong, tough and hard wearing, at the welding temperature. It should have a good oxidation resistance and allow thermal conductivity to minimize heat loss and thermal damage to46the machinery. Hot- worked tool steel such as AISI H13 has proven perfectly acceptable for welding aluminium alloys within thickness ranges of 0.5-50 mm [4] but more advanced tool materials are necessary for more demanding applications such as highly abrasive metal matrix composites[8] or higher melting point materials such as copper, steel or titanium. AISI H13 is widely used for welding of copper. However, the high conductivity of copper impairs the wear resistance at high heat input conditions leading to the tool breakage. Powder metallurgically produced Bohler K390steel possess good wear resistance because of theuniformdistribution of the carbides and the low thermal conductivityof (21.5 W/m.K) compared to wrought AISI H13 steel (25W/m.K). Figure 1(c), (d) shows the Bohler K390 tool before and after welding at the same welding conditions. A good weld was obtained with the powder metallurgical produced tool at the same welding conditions. In AISI H13 steel, the rich alloy content, (Cr, Mo and Si) provides improved wear resistance and fine grain. However the alloying elements prevent full transformation of austenite into hard martensite, leaving the part at less than optimal hardness. Cryo-treatment converts the retained austenite crystals precipitate to martensite.

Figure 2 shows the optical images of cryo-treated AISI H13 steel and Bohler K390 steel tools. Both tools resulted in good welds. Cryotreatment of AISI H13 steel and BohlerK390 converted the retained austenite into hard martensite thus improving the wear resistance. At the same welding parameters, non-cryo treated AISI H13 tool broke. The tool wear is to be studied by photographic method and the amount of retained austenite converted into martensite In both the tools is to be analysed by XRD studies in the future.

8. CONCLUSIONS

According to the literature, the initial mistrust about CT effect on mechanical properties of materials appears to be now cleared up, especially in the field of tool steels. The most relevant conclusions through a literature examination can be summarized as follows: Cryogenic systems allow controlling important cycle parameters such as cooling rate, minimum reached temperature and soaking time. The choice of optimal treatment parameters requires specific investigations on each material, but in the case of steels some use full indications can be inferred from published works;Wear resistance and hardness improvement have been widely confirmed by published papers, especially by the ones concerning tool steels. Beneficial effects of CT on toughness and fatigue behaviour have also been claimed by some authors. With few rare exceptions, no noticeable effects on tensile properties have been found in literature;Fine dispersed carbides precipitation appears to be effective on the wear resistance DCT improvement of tool steels rather than the retained austenite elimination ,that is reached with SCT too; The only proposed microstructural mechanism for fine carbides precipitation in tool steels is the martensite contraction, due to thermal stresses during cooling, which leads carbon atoms to segregate near lattice defects;In the fatigue strengthening field, further investigations are necessary, for example, on the nano martensite formation mechanism for austenitic steels, on the dislocation pinning effect produced by a field of fine hard carbides in martensitic steels and on the contribution of retained austenite and of residual stresses;

REFERENCES

[1] Thomas.W.M, Nicholas.E.D, Needham.J.C, Murch.M.G, Smith.P, Dawes.C.G "Friction Stir Butt Welding". G.B. Patent Application No. 9125978. 8. International patent application No. PCT/GB92/02203, 1991.

[2] Dawes. C and Thomas. W TWI Bulletin, Vol.6, 1995, pp124.

[3] Mishra. R.S. and Z.Y. Ma "Friction stir welding and processsing" Mater. Sci. Eng. R, Vol.50, 2005, pp1-78.

[4] Prado.R.A,. Murr. L.E, Shindo.D.J, Soto.H.F "Tool wear in the friction stir welding of aluminium alloy 6061+20% Al2O3: A preliminary study", Scripta Materialia, Vol.45, 2001, pp75-80.

[5] Prado. R.A, Murr. L.E,Shindo. D.J, McClure. J.C in: Proceedings of the First International Symposium