Effect of Cryogenic Treatment on the Tool Material in Friction Stir Welding of Pure Copper

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***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 Mo are 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.**

Keywords: Cryogenic treatment, welding condition, wear resistance, melting point.

1 INTRODUCTION

Friction stir welding (FSW) was invented at The Wel- ding Institute (TWI) of UK in 1991 as a solid-state joining technique, and it was initially applied to aluminum alloys [1, 2].

A non-consumable rotating tool with a specially de- signed 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. Wear of tool is generally not considered as a severe issue in friction stir welding of aluminum alloys since aluminum 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 compo- sites) [6,7]. However, studies on the tool wear during FSW are limited. No systematical 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 H13 tool steel and powder metallurgically produced Bohler K390 steels are used for FSW of copper before and after cryogenic treatment and tool wear was studied. The stren- gthening carbides are not uniformly distributed in the ma- trix due to macro segregation in AISI H13 steel. This segregation can be avoided if the tool is produced by pow- der metallurgy route (Bohler K390).

2 EXPERIMENTAL DETAILS

The material used in this work is commercially available Cu with the nominal composition (in wt %) Cu - 99.86, Zn- 0.0092, Pb- 0.005, Ag- 0.0017, P- 0.0224, Ni- 0.0011, Sn- 0.0041. The Cu plates (600 x 250 x 3 mm) were friction stir processed with an Intelligent Stir Welding for Industry and Research (I-STIR) Process Development System (PDS) de- signed by MTS Systems Corporation with a nonconsumable unthreaded tool made up of high- speed tool steel (H13) and powder metallurgically prepared tool steel (Bohler K390) before and after cryogenic treatment at a constant rotation speed of 1200 rpm and traverse speed of 50 mm/min with a tool tilt of 2°. The weld was made to a length of 140 mm. The chemical composition of the tools used is shown in Table.1

Table 1 Chemical composition of the tools

Compo- sition	C	Si	Mn	Cr	Mo	Ni	V	W	Co
Bohler K390	2.5	-	-	4.0	4.0	-	9.0	1.0	2.0
H 13	0.39	1.10	0.4	5.2	1.4	-	0.95	-	-

A simple tool with a concave shoulder of 15 mm diameter and a plain pin with 5 mm diameter were used. Both tools were hardened and tempered. The tools were austenitised at 1020°C and air hardened. Cryogenic treatment was done at -160°C for 30h and then tempered at 150°C. Optical images of the tool were taken after welding with Olympus GX71 optical microscope.

3 RESULTS AND DISCUSSION

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 a low thermal conductivity to minimize heat loss and thermal damage to the 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 advan- ced tool materials are necessary for more demanding ap- plications such as highly abrasive metal matrix composites
[8] or higher melting point materials such as copper, stee l 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 K390 steel possess good wear resistance because of the uniform distribution of the carbides and the low thermal conductivity of (21.5 W/m.K) compared to wrought AISI H13 steel (25 W/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 metallurgically produ- ced tool at the same welding conditions.

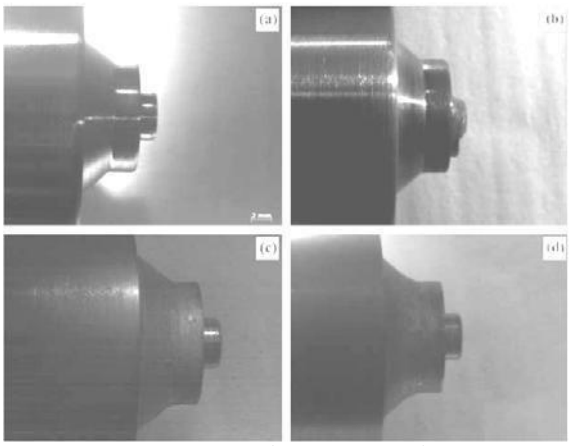
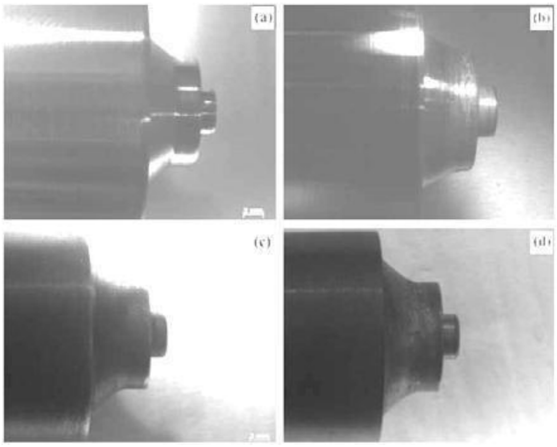


Figure 1 Optical images of (a) AISI H13 before welding
(b) AISI H13 after welding (c) Bohler K390 before welding
(d) Bohler K390 after welding

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.



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.

4 CONCLUSION

The following conclusions were derived from the present study.
b) Powder metallurgically produced Bohler K390 has better wear resistance compared to the wrought AISI H13 tool steel. This is attributed to the difference in thermal conductivity of the tools and the distribution of carbides in the matrix.
b) Cryotreatment of both the tool steels improves the wear resistance by conversion of retained austenite to hard phase (plate) martensite.

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