Comparison of Wear Rate of Friction Stir Welded 6060Al and Cu with its base Metals

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***Abstract*— 6060Al and Cu were joined by Friction stir welding process, and its effect on wear rate of the welded and non-welded zones of the joint were studied in this paper. Samples of 12mm in diameter were prepared from welded and non-welded zone for wear testing Pin-on-disc type machine (Model TR-20LE CHM-800, DUCOM) was used for dry sliding wear test in conformity to the ASTM G99 standard, for different loads of 10 and 15 Newton, keeping sliding distance constant. Wear behavior of welded and non-welded zones were determined for the joint and compared on Winducom 2010 software. The lowest wear rate was observed at the welded zone of the joint, whereas at non-welded zone (i.e. base metals) wear rate was more.**

Keywords*— *Friction stir welding (FSW), Dry sliding, Wear behavior, Base metals

I. INTRODUCTION

Friction stir welding (FSW), a non-fusion welding process, invented by W. M. Thomas [1] at TWI, Cambridge, involves joining of similar or dissimilar metals with the help of non-consumable tool. Friction between shoulder of the tool and surface of the material is the only mean responsible for generating heat and softening of the material. While the tool is traversed along the weld line, it mechanically stirs or mix the softened material of the two workpieces. Vertically downward force applied by the tool forged the hot and softened metal, which ultimately improves the mechanical strength of the joint.

R.S. Sharma and Z.Y. Ma investigated in ‘Friction Stir Welding and processing’ [2] that a cylindrical threaded pin and concave shoulder are widely used welding tool features and welding parameters, including tool rotation rate, traverse speed, spindle tilt angle and target depth, are crucial to produce sound and defect free weld. Also, they proposed that there no need for edge preparation for butt and lap joint, unlike in traditional fusion welding.

P.J. Blau et al. [3] identifies that pin-on-disc was the mostly used wear test process followed by pin-on-flat. Other types of application on pin-on-disc include material wear and friction properties at elevated temperature and controlled atmosphere.

Syed Khaja Naimuddin et al. [4] examines the friction stir butt welds of AA6082-T6 and AA6061-T6, as well as FSW butt welds of each alloy. He found out that specimens taken from AA6061-AA6082 materials has less amount of weight loss and lesser amount of wear as compared to other specimens and the secondary preference is given to the friction stir welded AA6061-AA6061 because it has lesser amount of weight loss and wear at welded zone as compared to other specimens.

Vivek Gopi et al. [5] confirms that wear rate was found to decrease with increase in hardness. They further confirmed that wear rate increase with increase in load whereas it remains constant with varying speed.

Wear is not physical property, it is a system response, like friction. Wear of the FSW joint is depends on no. of factors such as applied load, sliding distance and hardness of the softer material [6]. Wear is one of the three crucial factors limiting the life of the engineering components.

In this paper, dry sliding wear behavior of the friction stir weld joint of 6060 Al and Cu with respect to its base metal were studied.

II. EXPERIMENTAL MATERIALS AND METHODS

A. Friction Stir welding

FSW process was performed on Vertical Axis Milling Machine, as it *provides* all processing parameters required for FSW process and *ease* of controlling them. A 6060 Al and Cu plates of dimension 125×50×5 mm was mounted on the clamping device which was fixed on machine bed, whereas FSW tool was mounted on head of the machine. The tool could travel along the weld line freely, without making any contact with surface of the material to ensure that tool will travel along the weld line.

The processing parameters maintained for FSW were traversed speed of 13mm/min; tilt angle of 1^0; rotating speed of 530 RPM.

Fig.1 Friction stir welding process

Fig.2 Friction stir welded plate

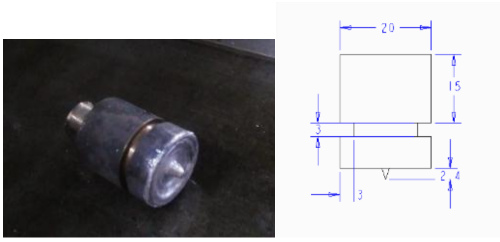

Fig.3 FSW Tool

B. *Sample preparation for wear test*

6 samples of 2 in each number from welded zone, non-welded 6060 Al and non-welded Cu of 12mm diameter and 5mm thick were prepared using *Pantograph (GK21)* machine from the FSW joint. These samples were glued over the 20mm long and 12mm diameter cylindrical rod by using *Araldite* adhesive.

Fig.4 Sample preparation for wear testing

C. *Pin-on-disc wear test*

The dry sliding wear tests were conducted on pin-on-disc machine (Model TR-20LE CHM-800, DUCOM). The prepared sample from the FSW joint plate was set stationary whereas the disc of hardened die steel with 65 HRC hardness was given a rotary motion of 300 RPM.

Table 1: Common wear testing parameters selected were

Wear Track Diameter	80 mm
Disc speed	300 RPM
Time	5 minutes
Sliding Distance	375 m
Sliding Velocity	1.25 m/s

Variable testing parameters were maintained as shown in the tables below.

Table 2.1: For 10N load

Obs.	Sample	FF (N)	Mean of Wear (micron)	SD
1.a	6060 Al	5.3	246.19	126.47
1.b	6060 Al	5	272.60	150
2.a	Cu	7	153.59	59.82
2.b	Cu	6.8	143.32	72.63
3.a	Welded Zone	5	17.25	12.07
3.b	Welded Zone	4.9	23.13	20.86

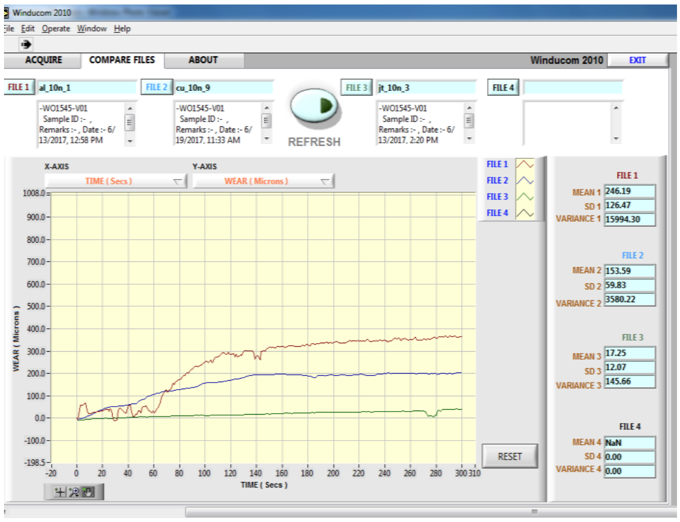

Fig.5 Wear test readings for 10N load

Table 2.2: For 15N load

Obs.	Sample	FF (N)	Mean of Wear (micron)	SD
1.a	6060 Al	6.1	391.94	59
1.b	6060 Al	6.6	322.66	79
2.a	Cu	7.7	180.25	44.02
2.b	Cu	7.0	112	63
3.a	Welded Zone	6.0	78.20	21.10
3.b	Welded Zone	5.8	82.45	28.39

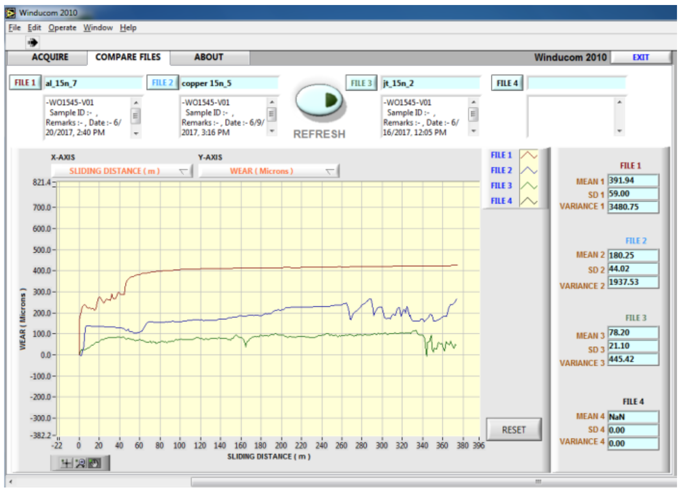

Fig.6 Wear test readings for 15N load

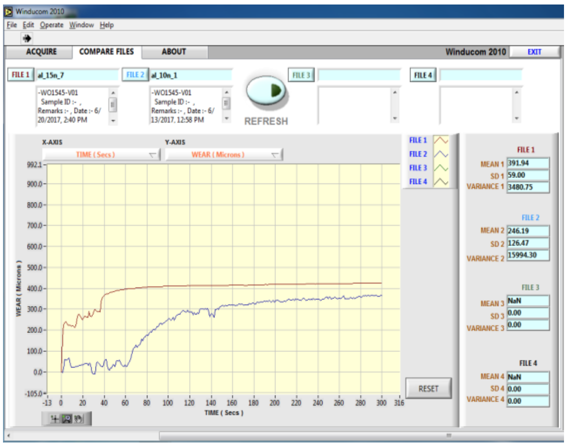

Fig.7 Wear vs Time graph of 6060 Al for 10N and 15N load

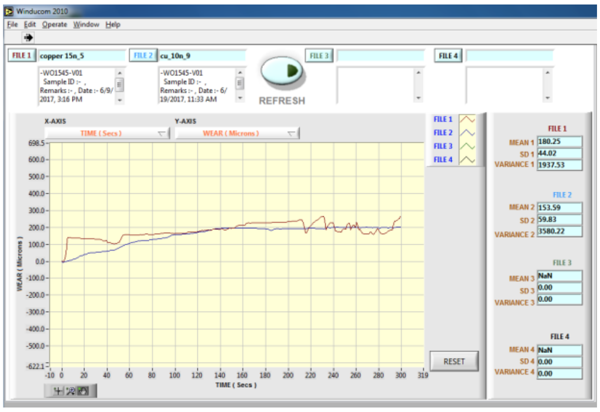

Fig.8 Wear vs Time graph of Cu for 10N and 15N load

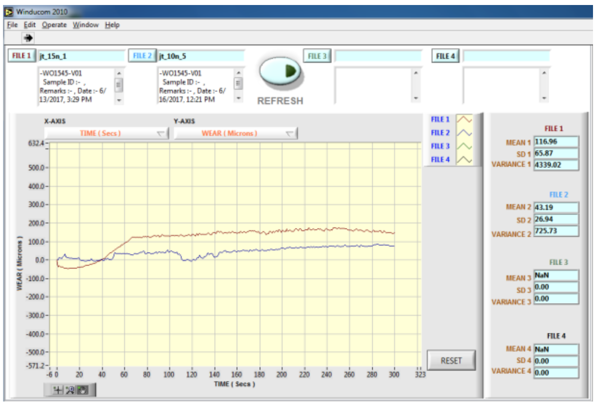

Fig.9 Wear vs Time graph of FSW joint for 10N and 15N load

III. RESULTS AND DISCUSSION

A. Wear rate

Fig. 7,8,9 shows comparison graph of wear for individual non-welded (6060 Al and Cu) and welded zone of the Friction stir welded plate for 10N and 15N load. In reference with the graph, wear increases as the applied load increases, in conformity with the relation between wear rate and applied load proposed by Archard [6]

Whereas fig.5 and fig.6 showing comparison graph of wear at non-welded (6060 Al and Cu) and welded zone for individual 10N and 15N load ensures that wear of the FSW joint is minimum as compared to base metals.

IV. CONCLUSIONS

6060 Al and Cu were joined by FSW process and the effect of FSW process on the wear behavior of the joint were studied under different loading conditions. From the experimental analysis following conclusions can be drawn.

1. Pin-on-disc type machine is best suited for wear testing for varying load under dry condition.
2. Wear of the samples increases as the applied load increases.
3. Wear resistance at welded zone is much more as compared to non-welded zone under same loading condition.

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