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Under T6 Condition, Wear Behaviour Of Welded And Non-Welded Of Aluminium Alloys (AA6061-AA6061)

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ABSTRACT: *The Endeavour of this work is to weld similar and dissimilar aluminum alloys such as AA6061-6061, AA6082-6082 & AA6061-6082 under T6 condition. Non Destructive Testing (NDT) methods like Penetrate and ultrasonic tests were used to find whether or not any weld defects present in the welded area. To find the wear behaviors i.e. wear and frictional resistance, Pin-on-disc test was carried out. Micro structure of the wear tested samples was done using Optical Metallurgical Microscope. Finally the wear and frictional resistance were compared with the samples taken from the welded and non-welded zones of similar and dissimilar welded joints. The samples showed/ lead to low wear, low frictional resistance as results.*

Key words: *Friction Stir Welding; Wear Testing; NDT; AA6061; AA6082*

1. INTRODUCTION

Friction Stir Welding (FSW) solid state joining process developed and patented by The Welding Institute (TWI) it emerged as welding technique which will be used in high strength alloys that were difficult to join with conventional techniques. Friction Stir welding (FSW) is a solid state welding process particularly employed for welding aluminum as it overcomes the difficulties in conventional welding of aluminum alloys. This process uses a non-consumable tool to produce frictional heat on the abutting surfaces. The non-consumable rotating tool is composed of a shoulder and a pin. This tool makes weld without conventional defects with good mechanical properties especially for defense applications. Tool design for Friction Stir Welding is the most important and critical areas that influences and determines the joint properties and micro structures. The welding parameters such as tool pin profile, axial force, rotational speed and welding speed etc., plays a major role in deciding the weld quality.

The samples fabricated are subjected to following testing methods Non-Destructive Testing to check the quality and reliability of the components, Wear Frictional behavior by pin on disc (pod) testing machine method, Micro Structure by optical metallurgical microscope.

1.1. NDT

NDT stands for non-destructive testing. In other words it is a way of testing without destroying. In today's world where new materials are being developed, old materials and bonding methods are being subjected to higher pressures and loads. The NDT guarantee that materials continue to operate to their highest capacity with the assurance that the supply will not fail within predetermined time limits. NDT can be used to ensure the quality right from raw material stage through fabrication and processing to pre service and in service inspection. Apart from ensuring the structural integrity, quality, reliability of the components and plants, now-a-days this process finds extensive applications for condition monitoring, residual life assessment, Energy audit etc. Non-destructive tests include visual, penetrating, magnetic particle and acoustic techniques.

1.2. Wear Testing Methods

Wear is a process of removal of material from one or both of two solid surfaces in solid state contact. As the wear is a surface removal phenomenon and occurs mostly at outer surfaces, it is more appropriate and economical to make surface modification of existing alloys than using the wear resistant alloys. Wear is the progressive loss of materials on contacting relative surfaces in motion, along with fatigue and corrosion, Wear is known as one of the three important factors limiting the life and performance of an engineering component and an engineering system, whether the system as big as a heavy machine, or as small as a tiny electronic device. These tests are used for quality control functions like as thickness, porosity, adhesion, strength, hardness, ductility, chemical composition, stress and wear resistance. Many tests for coated and uncoated cutting tools are conducted on machine tools, such as lathes, mills, drills, punches and saws. These test methods provide almost identical conditions to those experienced in manufacturing. Pin-on-Disk wear testing is a method of characterizing the coefficient of friction, frictional force, and rate of wear in between two materials. During this tribological test, a stationary disk articulates against rotating pin while applied load is constant. Pin-on-disk wear testing can simulate multiple modes of wear, consisting of uni-directional, bi-directional, Omni-directional, and quasi-rotational. The test method describes the laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus. These materials are tested in pairs nominally in non-abrasive conditions.

1.3. Metallurgical Microscopes

A metallurgical microscope is a simple form of upright Compound Microscope, used to look at not only metal samples, plastics, ceramics and other materials. Since the samples are solid (and unable to transmit light), metallurgical microscopes only have surface illumination, with more magnification options to permit the viewing of surface structure (to identify metal fatigue, for example), metallographic samples,are inspected using dedicated inverted microscopes that allow researchers to calculate the grain size and phase of metals.

2. LITERATURE REVIEW

Wang and Rack and Zhang and Alpas have shown that the rate-controlling wear mechanisms may change abruptly at certain sliding velocities and contact loads, leading to abrupt increases in wear rate. It is suggested that many of the conflicting results in the wear literature can be explained by the three modes which were identified, when wear rate is considered as a function of test load. Research conducted by Glaeser and Ruff identified pin-on-disc was the mostly used wear test processes, followed by pin-on-flat. Other types of applications of pin-on-disc include material wear and friction properties at elevated temperatures and in controlled atmospheres. Almond et al used a pin-on-disc apparatus for testing ceramics and cemented carbides on the alumina disc using the pin as the test material. In a two body abrasion test, a coated pin is pressed against a rotating abrasive paper making to a spiral way to avoid overlapping. This test process is very common for thin coatings. Using a diamond tip as the abrading tool, Kato et al used a pin-on-disc test to operate within the chamber of a scanning electron microscope (SEM) to verify abrasion effects. Scratch testing in conjunction with SEM provides a useful method of analyzing single-point wear mechanisms of coated systems through an assessment of the deformation and the fracture produced.

3. MATERIALS & EXPERMINTAL METHOD

3.1. Frictional Stir Welding

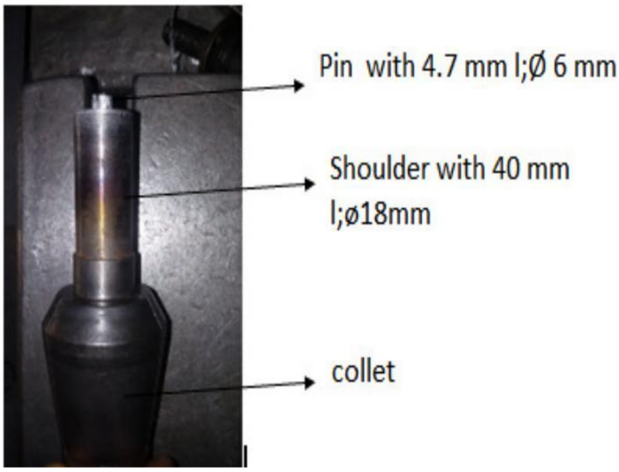
FSW is performed by taking three plates of AA6061 and 3 plates of AA6082 having dimension (200mmx100mm) with 5mm thickness was taken. The process includes welding of dissimilar and similar alloys as one piece (AA6061-AA6082). The selected parameters were travel speed of 50mm/min; tilt angle of 1°; rotating speed of 1120 rpm. In the similar manner welding of similar alloys as second piece (AA6061-AA6061) the selected parameters are travel speed of 50mm/min: tilt angle of 1°; rotating speed of 900 rpm. Welding of similar alloy (AA6082-AA6082) are made with a selected parameters were travels at a speed of 50mm/min: tilt angle of 1°: rotating speed of 1400 rpm.

Table 1.1 Properties of AA6082

CHEMICAL PROPERTIES		PHYSICAL PROPERTIES	
Magnesium (Mg)	0.60 - 1.20	Density	2.70 g/cm³
Silicon (Si)	0.70 - 1.30		
Iron (Fe)	0.0 - 0.50	Melting Point	555 °C
Copper (Cu)	0.0 - 0.10		
Chromium (Cr)	0.0 - 0.25	Thermal Expansion	24 x10-6 /K
Zinc (Zn)	0.0 - 0.20		
Titanium (Ti)	0.0 - 0.10	Modulus of Elasticity	70 GPa
Manganese (Mn)	0.40 - 1.00		
Others	0.0 - 0.05	Thermal Conductivity	180 W/m.K
Aluminium (Al)		Electrical Resistivity	0.038 x10⁻⁶Ω .m

Table 1.2 Properties of AA6061

CHEMICAL PROPERTIES		PHYSICAL PROPERTIES	
Magnesium (Mg)	0.80 - 1.20	Density	2.70 g/cm³
Silicon (Si)	0.40 - 0.80		
Iron (Fe)	0.0 - 0.70	Melting Point	650 °C
Copper (Cu)	0.15 - 0.40		
Chromium (Cr)	0.04 - 0.35	Thermal Expansion	23.4 x10-6 /K
Zinc (Zn)	0.0 - 0.25		
Titanium (Ti)	0.0 - 0.15	Modulus of Elasticity	70 GPa
Manganese (Mn)	0.0 - 0.15		
Others (Total)	0.0 - 0.15	Thermal Conductivity	166 W/m.K
Other (Each)	0.0 - 0.05		
Aluminium (Al)		Electrical Resistivity	$0.040 \times 10^{-6} \Omega$ .m



a b

Figure 1 (a) FSW plates; (b) FSW Tool

3.2. Non Destructive Testing

NON Destructive Testing is done to find the weld defects present in the welded zone after friction stir welding. Here we had done penetrate testing to find the defects at the outer surface and ultrasonic testing is done to find the defects at inner surface of the welded zone. After the test there are no defects in the welded zone and at the joints then we can proceed for the experiment work.

Figure 2 (a) Penetrating test; (b) Ultrasonic test

3.3. WEAR TESTING

3.3.1. Wear Testing Specimens

We had taken the welded plates after NDT and consider the samples for wear testing from welded and non welded zones of dimensions [height=30mm, width=5mm, thickness=5mm] by using Wire EDM. We had considered 6 samples from each [AA6061-AA6061], [AA6082-AA6082] and [AA6082-AA6061]. Two samples from welded zone and four samples from non welded zones are shown in Fig.3 & 4. The individual samples after Wire EDM are also shown in the Fig. 5.

3.3.2. Experimental Procedure for Wear Test

The dry sliding wear tests were performed using a pin-on disk type machine (Model TR 20, Ducom, India) in conformity with the ASTM G 99 standard. The stationary pin is aluminum alloys of different samples taken from welded and non welded zones, and the rotating disk is hardened die steel with Rc65 hardness. Figure shows the dimensions of the disc and specimen. Wear tests were carried out under dry sliding conditions under a normal

Table 3 1kg load at constant wear track diameter 80mm

sample	Applied load (kg)	Time (min)	Speed (rpm)	Track diameter (mm)	Weight of sample before testing (grams)	Weigh of sample after testing (grams)	Weight loss (grams)	Wear (Micrometers)
					I-6061/6082			
6061 W	1	5	640	80	1.484	1.371	0.113	1208
6082 W	1	5	640	80	1.584	1.54	0.044	751
6061 NW	1	5	640	80	2.111	2.09	0.021	714
6082 NW	1	5	640	80	2.024	2.016	0.008	19
					II- 6061/6061			
6061 NW	1	5	640	80	2.1	2.074	0.026	457
6061 W	1	5	640	80	2.181	2.173	0.008	107
					III-6082/6082			
6082 NW	1	5	640	80	1.972	1.884	0.088	951
6082 W	1	5	640	80	1.97	1.897	0.073	1174

Table 4 2kg load at constant wear track diameter 80mm

sample	Applied load (kg)	Time (min)	Speed (rpm)	Track diameter (mm)	Weight of sample before testing (mm)	Weigh of sample after testing (grams)	Weight loss (grams)	Wear (micrometers)
					I-6061/6082			
6061 W	2	5	640	80	1.931	1.547	0.384	1208
6082 W	2	5	640	80	2.02	1.593	0.427	751
6061 NW	2	5	640	80	1.894	1.588	0.306	714
6082 NW	2	5	640	80	2.028	2.01	0.018	19

					II-6061/6061				
6061	NW	2	5	640	80	2.094	2.09	0.004	58
6061	W	2	5	640	80	2.066	2.037	0.029	622
					III-6082/6082				
6082	NW	2	5	640	80	2.045	2.04	0.005	43
6082	W	2	5	640	80	1.965	1.952	0.013	291

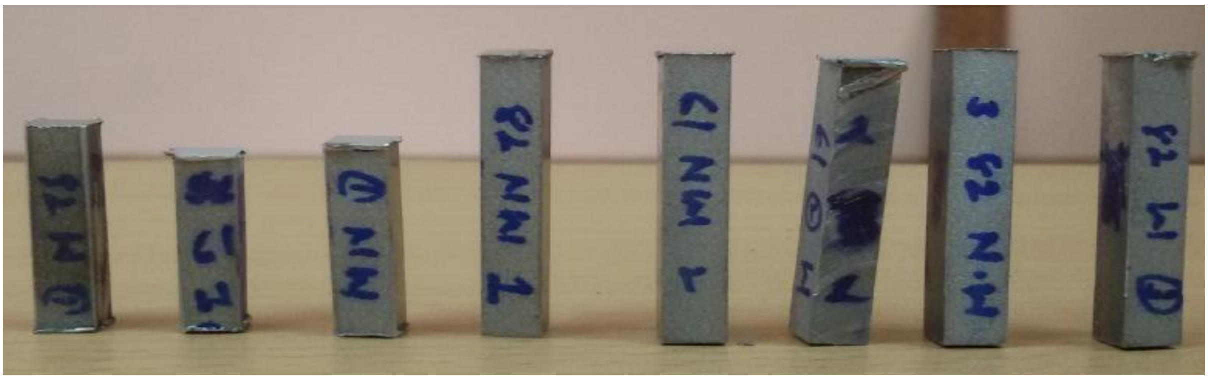


Figure 8 Front view of specimens after wear test

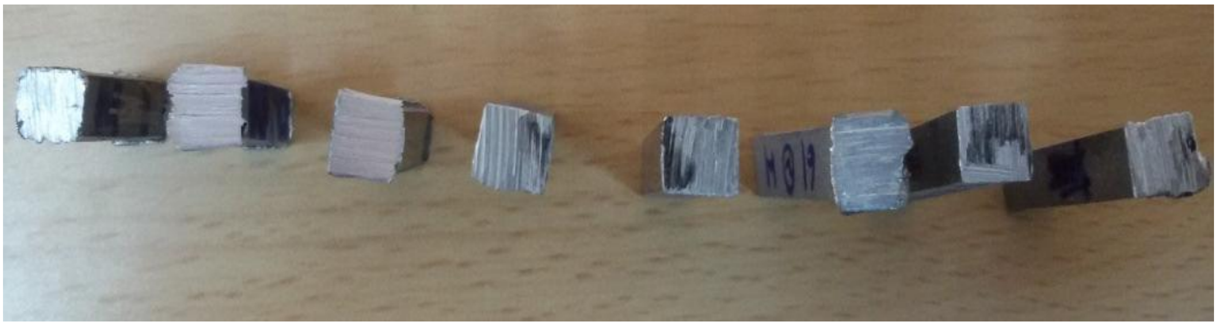


Figure 9 Top view of specimens after wear test

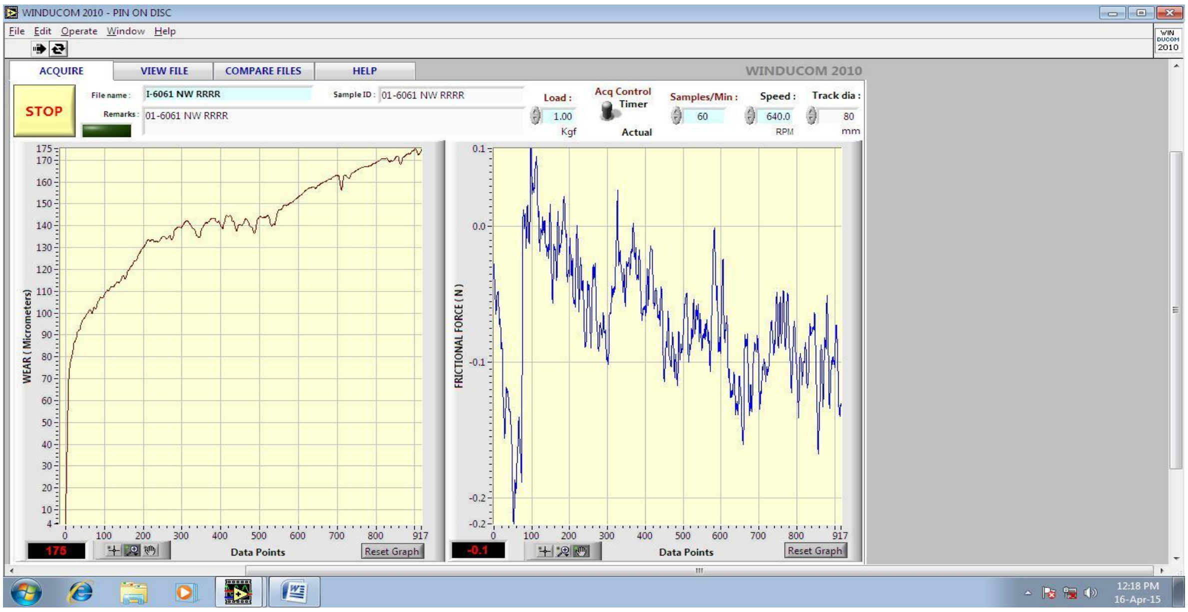


Figure 10 Values and graph of wear and frictional force using WINDUCOM Software

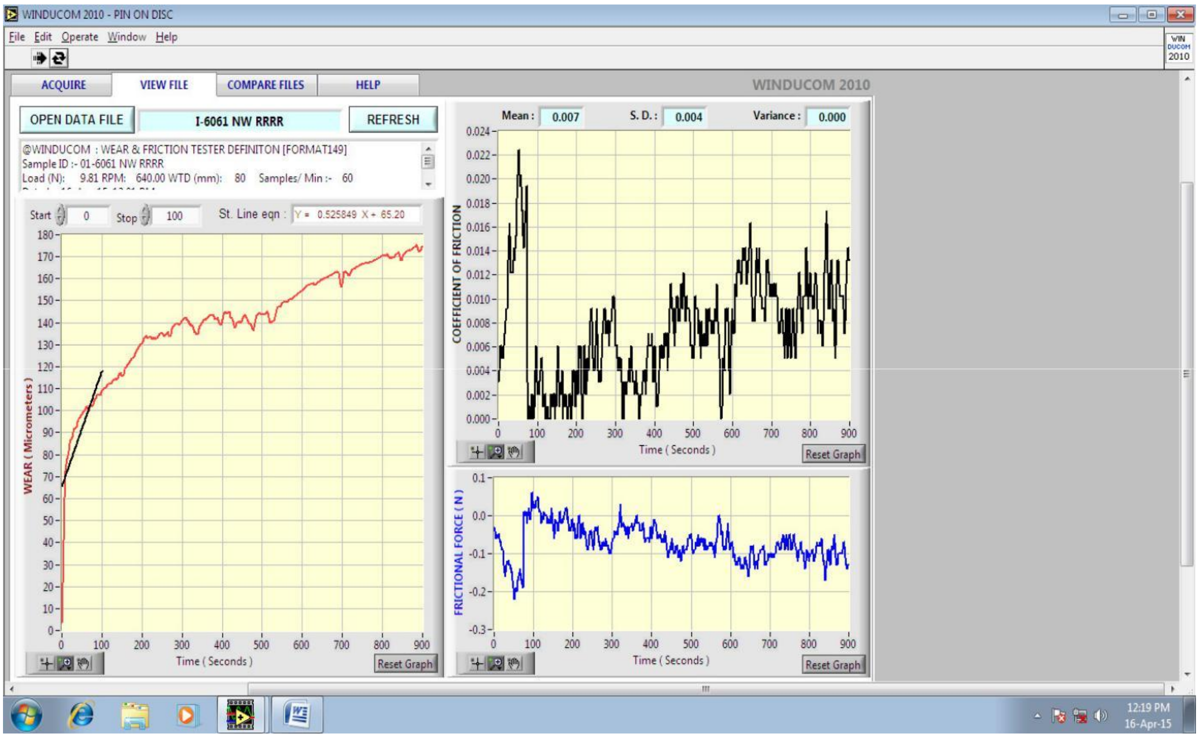


Figure 10 Values and graph of wear and frictional force using WINDUCOM Software

3.3.4. Metallurgical Examination

The wear tested samples are examined using optical metallurgical microscope and the microstructures are shown in the Fig**.**11

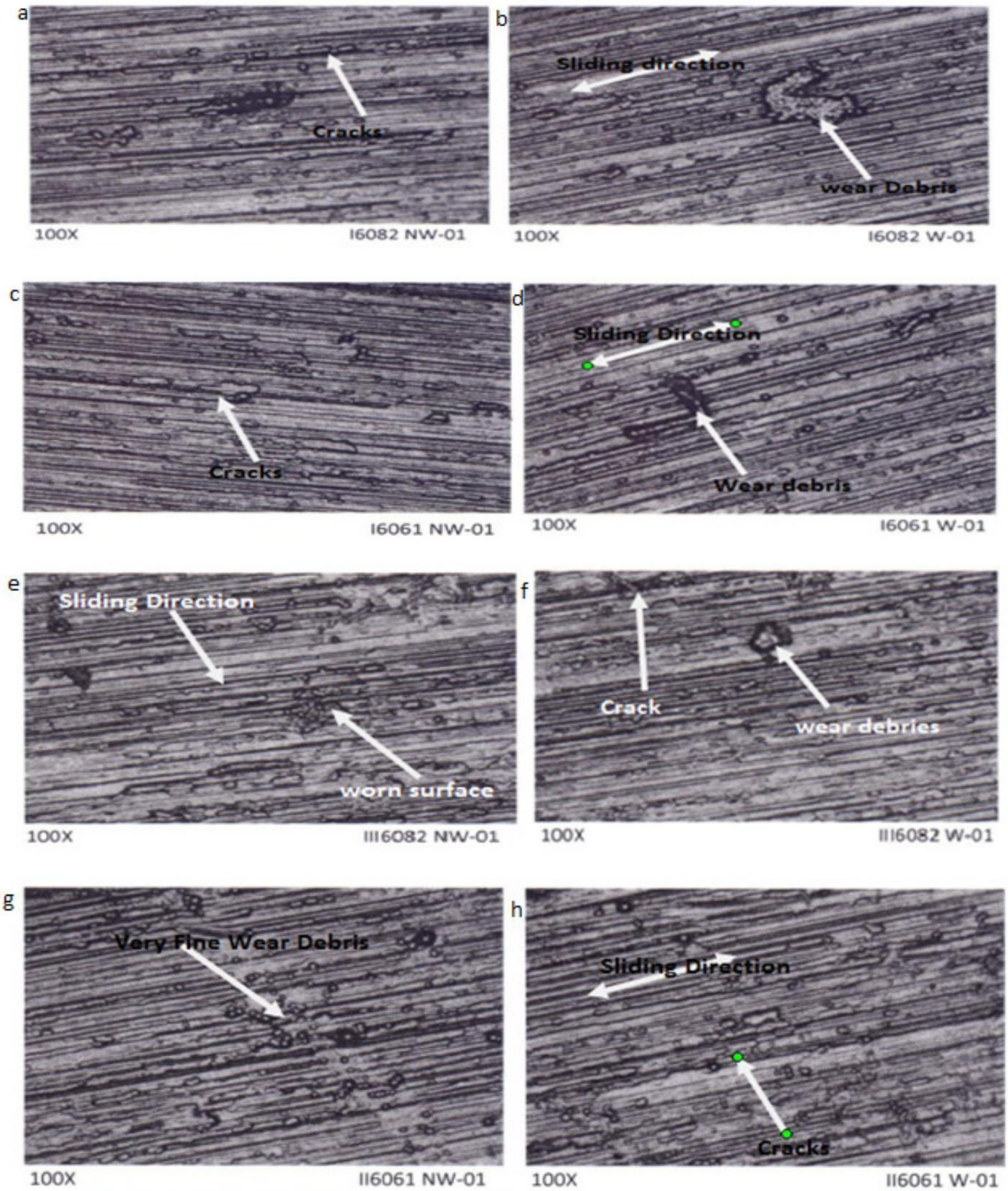


Figure 11 Microscopic observation of wear tested specimen of (a) I-AA6082NW (b) AA6082W (c) I-AA6061NW
(d) I-AA6061W (e) III-AA6082NW (f) III-AA6082W (g) II-AA6061NW (h) II-AA6061W

The microstructure shows grooves and fine scratches on the surfaces shown in Fig.11 (e). I the above Fig.11 (a), (b) & (h) shows sliding direction, cracks and wear debris on the surface of the specimens.

4. RESULTS & DISCUSSIONS

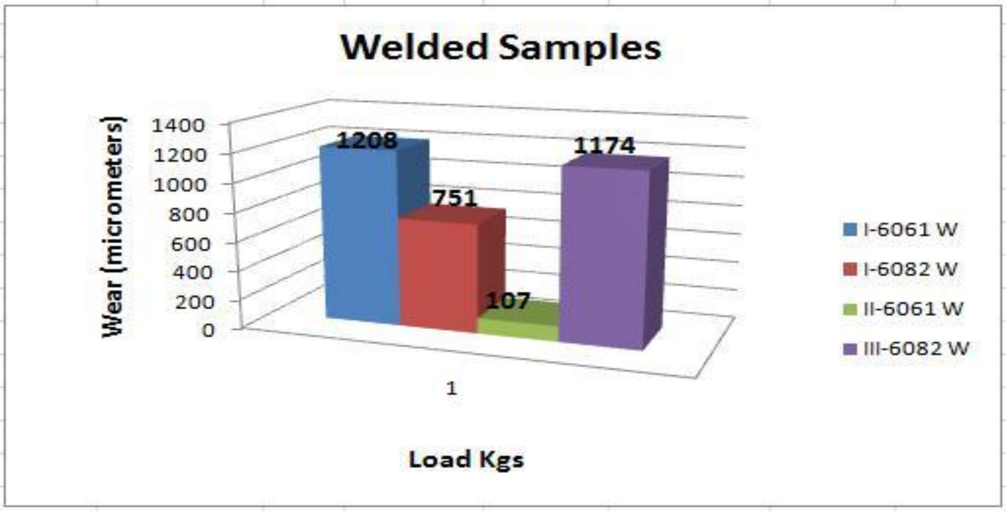


Figure 12 Load Vs Wear graph for welded samples at 1kg

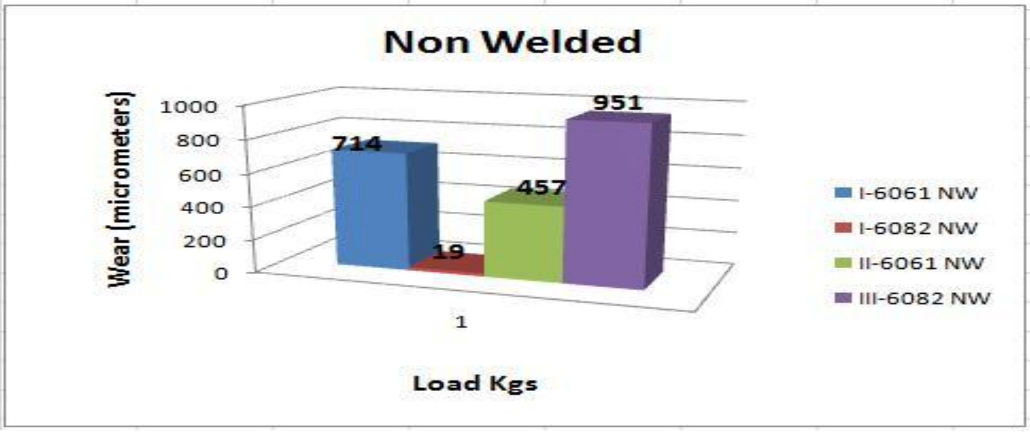


Figure 13 Load Vs Wear graph for Non-welded samples at 1Kg

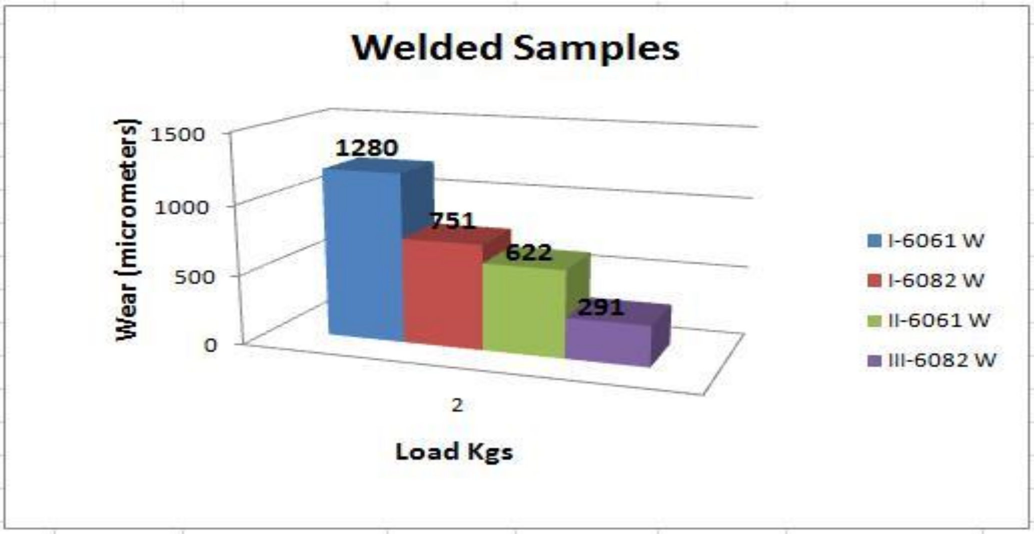


Figure 14 Load Vs Wear graph for welded samples at 2Kg

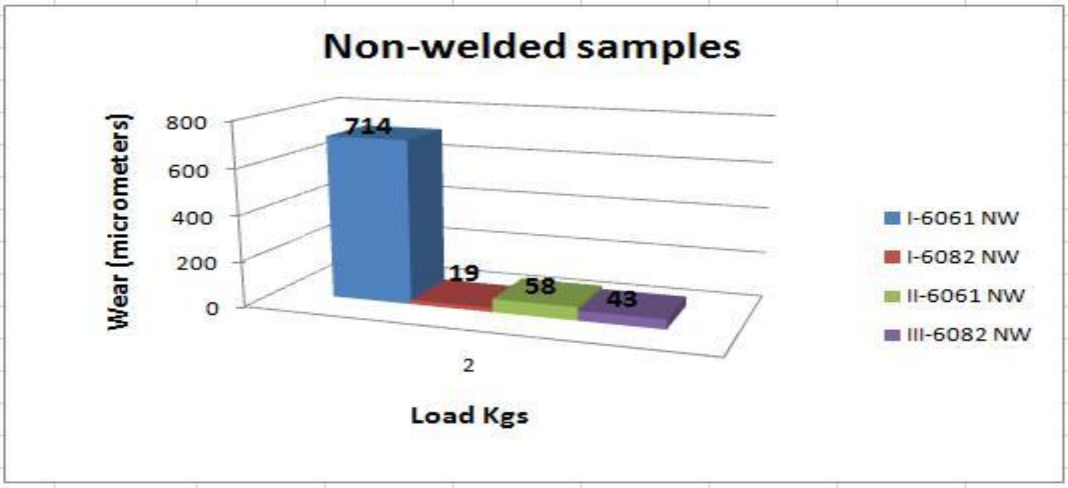


Figure 15 Load Vs Wear graph for welded samples at 2Kg

As seen in the above Fig.12 the wear for II-6061W is very less and I-6061W is very high at 1kg load compared to the other specimens taken from welded zone. As seen in the above Fig.13 the wear for I-6082NW is very less and III-6082NW is very high at 1kg load compared to the other specimens taken from Non-welded zone. As seen in the above Fig.14 the wear for III-6082W is very less and I-6061W is very high at 2kg load compared to the other specimens taken from welded zone. As seen in the above Fig.15 the wear for I-6082NW is very less and I-6061NW is very high at 2 kg load compared to the other specimens taken from Non-welded zone.

5. CONCLUSION

Friction stir butt welds of AA6082-T6 with AA6061-T6 were produced, as well as FS butt welds of each single alloy. The specimens taken from welded and non welded zones are compared with each other by conducting the experiment and the results are concluded below.

- During wear test, the specimens taken from friction stir welded AA 6061-AA 6082 material has less amount of weight loss and lesser amount of wear compared to the 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 the welded zones.
- During the wear test, the specimens taken from friction stir welded AA 6061-AA 6082 material has a better outcome in the non-welded zone compared to the other specimens
- During the wear test, the specimens taken from friction stir welded AA6061-AA6061 material has a better outcome in the welded zone compared to the other specimens
- The microstructures of pin specimen after wear test were examined by optical metallurgical microscope. The sliding direction, furrow, scratches, cracks, and wear debris are clearly visible in the microstructure.

6. SCOPE FOR FUTURE WORK

- Further we can study about the Sliding distance vs weight loss of the specimens take from welded and non welded zone of similar and dissimilar friction stir welding
- Further we can study about the XRD analysis of the specimens take from welded and non welded zone of similar and dissimilar friction stir welding
- Further we can study about the thermal conductivity of the specimens take from welded and non welded zone of similar and dissimilar friction stir welding during wear test using thermo couple.
- Further we can study about parametric optimization of wear test parameters

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