A Study of Influence of Parameters of Dissimilar Materials Joining on Friction Stir Welding Process by Design of Experimental

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Abstract: - The purposes of this research were study of influence of welding parameters of Friction Stir Welding process on structures and mechanical properties of dissimilar joining between Aluminum 1100 and 6063. The experimental was design on factorial design which had following interested parameters: welding speed and Welding feed. The results of research found that the all parameters had influenced on hardness, ultimate tensile strength, elongation and yield strength with significant at 0.05. The maximum of hardness as 82.08 HV, ultimate tensile strength as 100.49 MPa and yield strength as 66.373 MPa.

Key-Words: - Friction stir welding process, welding process, Dissimilar welding, Design of experimental, Aluminum Alloys Welding.

1 Introduction

At the present, Metal and Metallic Industrial had the highest technology competitions, in any high technology of equipments, tools, machineries and also included the samples production process or samples assembly by Metal and Non-Metallic Welding which can decreased several cost for getting the quality of products and all components such as airplane's component, auto's component and car production industrial etc. by considered of customers needs mainly. Selecting sample's materials and sample's production process by Metal and Non-Metallic Welding suitably was more method that could decreased the production's cost by metal welding form such as Friction Stir Welding process which was used in production and assembly process. Component's production which the materials were both of Metal and Non-Metallic such as Copper and all type of Aluminums etc.. Friction Stir Welding was welding which used friction force in moving of metal welding, it was the welding process which solid condition that was developed and invented together with registered patent at the beginning of 1990, The Welding Institute in London.[1] At the present Friction Stir Welding is the most efficiency welding process in recently metal welding method. It was invented to be able to welded metal in easy way which made several industries tried to search the studying in equipments and tools that used with Friction Stir Welding production process to be more efficiency. [2- 3] and also be the welding process that showed of production process in mechanical properties when compared with arc welding on each Aluminum materials such as 5083 6081and 2219 .[4] Although Friction Stir Welding had ability qualification in material welding altogether were Metal and Non-Metal to be same or different types, that could be able melt them in identical matter but preliminary result found that the benefit of several industries, almost came from metal welding altogether of each Aluminum materials by TIG or MIG welding form and mostly materials which used in welding had same type of grade or chemical qualification. The result from welding made rather perfectly combination into a group but if material which used in welding had different grade or chemical qualification. The affectation that gained from welding was troublesome welding which need to use advance skill ability welding and also influenced to the combination into a group welding of 2 materials not completely in weld range. But Friction Stir Welding would be less influence to mechanical properties and the result that gained from welding would have good mechanical properties. So Friction Stir Welding was a type of welding process to be able welded Aluminum in different chemical qualification or grade and had many Welding Parameters which influenced to size and figure of weld range. All mentioned parameters were Welding feed of running weld range and Welding speed of machinery which influenced to all sample qualifications.

However, each parameters controlling regard as necessary thing in Friction Stir Welding because if no structure and mechanical properties in welding especially high influenced parameters. Understanding of these important influenced parameters to structures and mechanical properties welding were regarded as necessary thing and important on quality Friction Stir Welding. For this reason, researcher had interest in Parameters of Friction Stir Welding which concerned with welding process controlling between two Aluminums altogether were Aluminum Al1100 and Aluminum Al 6063 namely Welding feed of running weld range and Welding speed to structures and mechanical properties of weld metal between Aluminum Al 1100 and Aluminum Al 6063 by Friction Stir Welding process for being the execution's data and developed later.

Objectives of research

To studying influence of welding parameters of Friction Stir Welding process on structures and mechanical properties of dissimilar joining between Aluminum 1100 and 6063.

2 Research methodology

2.1 Materials and welding conditions

This research brought 2 materials: Aluminum Al 1100 and Aluminum Al 6063to be welded by frictions stir welding process with chemical compositions as Table 1 and 2 which had the thickness 6 mm. and were studied with mechanical saw machine to had size as 60 mm. wide and 100 mm. long by milling machine which were controlled with computer. The computer was controller of samples for accuracy and equality of samples as Fig. 1 and brought them hold by stirring form as Fig. 2.

The Tool for Friction Stir Welding was used for welding made from Tungsten on 10 mm. diameter and tool's diameter (Pin) as 5 mm. and 4 mm. height in Fig. 3.

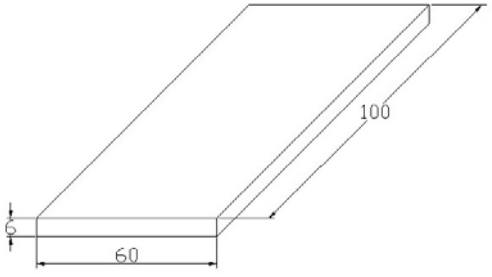

Figure 1 Work plate sample

Table 1 Chemical composition of aluminum Al 1100.

Si	Cu	Fe	Zn	Mn	A l
1.00	0.63	1.00	0.10	0.05	Balance

Table 2 Chemical composition of aluminum Al 6063.

Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
0.32	0.35	0.10	0.10	0.67	0.1	0.10	0.10	Balance

2.1.1 Design of experiment

Design of experimental of Friction Stir Welding by fixed the materials which used in the experimental were Aluminum Al1100 and Aluminum Al 6063 and used weld metal tools which made from Tungsten on 10 mm. diameter and Pin diameter as 5 mm. 4 mm. height, then tested with Universal Milling machine. This research designed the experimental with Factorials Design by fixed the Studied Welding Parameters which influenced to mechanical property of weld metal, changing of weld metal's structure and HAZ were Welding speed as 1080, 1820, 3000 and 4000 rpm, Welding feed as 8, 18, 28, 38, 48 and 58mm./min. which had designed result as Table 3.

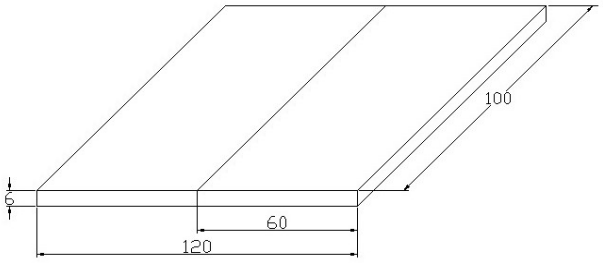

Figure 2 Samples preparation for welding

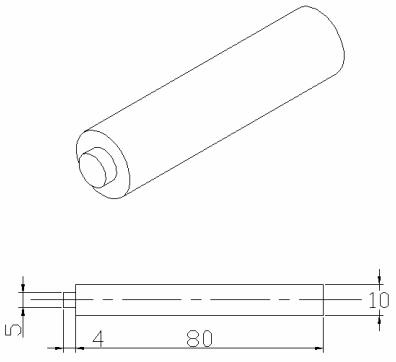

Figure 3 Tungsten pin for friction stir welding

Table 3
Design of experimental

Welding feed)mm/min(	Welding speed) rpm(								
	1080 rpm.			1820 rpm.			3000 rpm.		
	1	2	3	1	2	3	1	2	3
18 mm/min	A1	A2	A3	D1	D2	D3	G1	G2	G3
28 mm/min	B1	B2	B3	E1	E2	E3	H1	H2	H3
38 mm/min	C1	C2	C3	F1	F2	F3	I1	I2	I3

Remark of parameter testing condition
A_1 , A_2 and A_3 were Welding speed 1080rpm and Welding feed 18mm./min, B_1 , B_2 and B_3 were Welding speed 1080rpm and Welding feed 28 mm./min, C_1 , C_2 and C_3 were Welding speed 1080rpm and Welding feed 38mm./min , D_1 , D_2 and D_3 were Welding speed 1820 rpm and Welding feed 18mm./min, E_1 , E_2 and E_3 were Welding speed 1820 rpm and Welding feed 28mm./min, F_1 , F_2 and F_3 were Welding speed 1820 rpm and Welding feed 38mm./min, G_1 , G_2 and G_3 were Welding speed 3000 rpm and Welding feed 18 mm./min, H_1 , H_2 and H_3 were Welding speed 3000 rpm and Welding feed 28mm./min and I_1 , I_2 and I_3 were Welding speed 3000 rpm and Welding feed 38 mm./min

When finished all experimental conditions, then brought all samples tested in mechanical properties namely Hardness, Ultimate Tensile Strength, Elongation Strength, Yield Strength, Macro and Microstructures by prepared samples as Fig. 4-6. After that brought all experimental results analyzed statistic results with computer program for finding different parameter result which influenced to mechanical properties and microstructures.

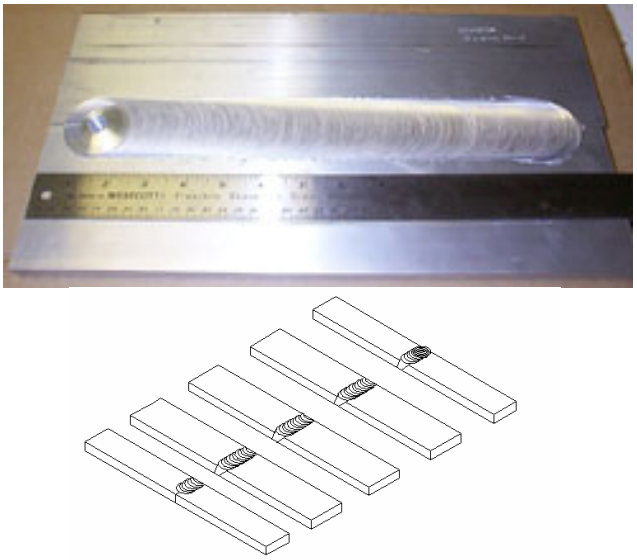

Figure 4 Sample cutting to prepared testing pieces and tested mechanical properties

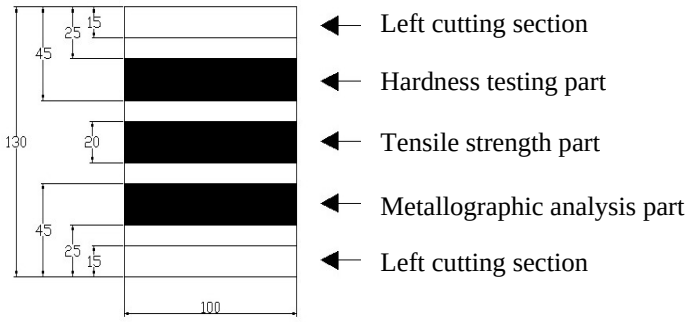

Figure 5 Section of sample for testing

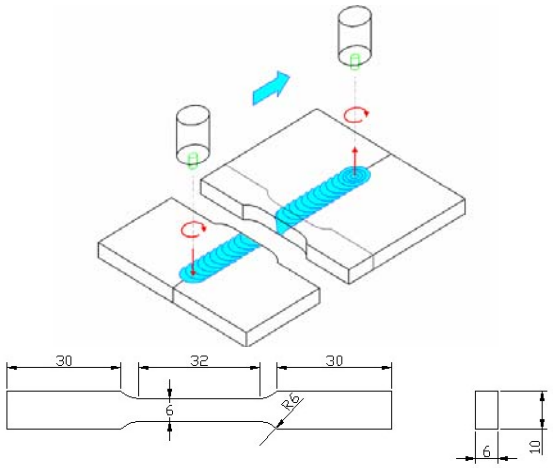

Figure 6 Strength Tested sample on ASTM E8 standard

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3 Results and discussion

3.1 Effect of parameters on mechanical properties

The effect of parameters of Friction Stir Welding at Welding Speed 1820 rpm. and Welding Feed at 18 mm/min. had the most weld range hardness as 82.08 HV., ultimate tensile strength as 100.49 MPa. and elongation as 8.44 %(shows as Fig. 8-9). For the maximum yield strength, the welding speed

1820 rpm. and welding feed at 38 mm/min had effect.(Fig. 10)

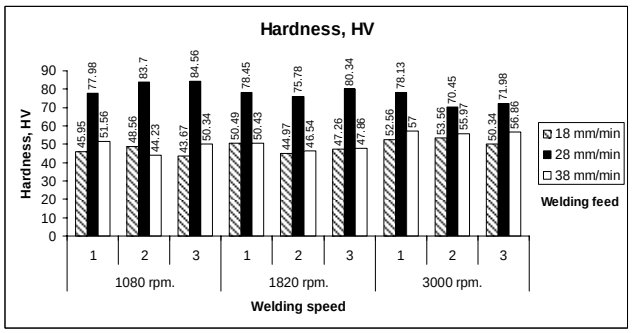

Figure 7 Hardness of friction stir weld

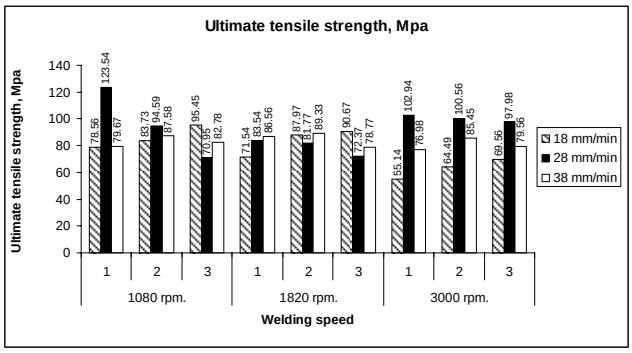

Figure 8 Ultimate tensile strength of friction stir Weld

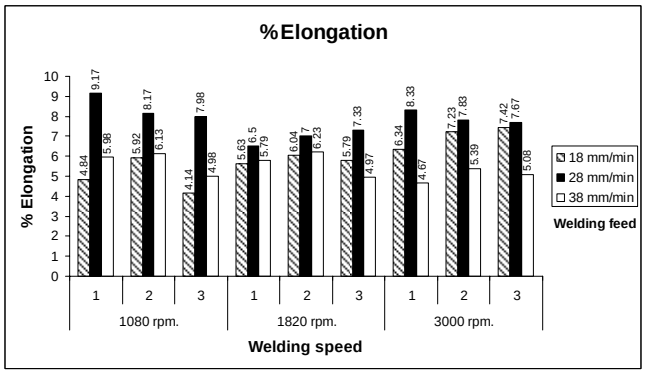

Figure 9 Elongation of friction stir weld

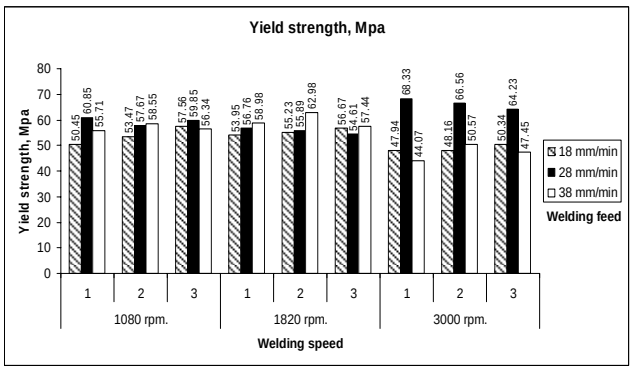

Figure 10 Yield strength of friction stir weld

3.2 Statistic analyze results of Parameters on Hardness of weld metal

The results in Table 4, the welding speed level influenced to hardness with significantly at 0.05. That was different welding speed level gave different hardness, too. As for welding feed didn't influence to hardness so different welding feed didn't make hardness be different and interaction between welding speed welding feed had altogether influence to hardness ($F(1,18)=8.525, P< 0.05$) with significance at 0.05.

3.3 Statistic analyze results of Parameters on Ultimate tensile strength

The welding speed had influence to ultimate tensile strength with significance at 0.05 shows as Table 5., that was different welding speed made ultimate tensile strength be different, too and as for different welding feed hadn't influence to ultimate tensile strength. So different welding feed wouldn't made ultimate tensile strength be different and interaction between welding speed and welding feed of which had altogether influence to ultimate tensile strength ($F(1,18) = 3.184$, $P < 0.05$) with significance at 0.05.

3.4 Statistic analyze result of Parameters on Elongation

The results from Table 6 found that welding speed had influence to elongation with significance at 0.05, that was different welding speed made elongation, too and as for different welding feed hadn't influence to elongation. So different welding feed wouldn't made elongation be different and interaction between welding speed and welding feed of running weld range which had altogether influence to elongation ($F(F(1,18) = 7.443$, $P < 0.05$) with significance at 0.05.

3.5 Statistic analyze results of Parameters on Yield Strength

From Table 7, the welding speed had influence to yield strength with significance on Statistic at level 0.05, that was different welding speed made yield strength, too and as for different welding feed hadn't influence to yield strength. So different welding feed wouldn't made yield strength be different and interaction between welding speed and welding feed which had altogether influence to yield strength ($F(1,18) = 22.558$, $P < 0.05$) with significance at 0.05.

Table 4 Analysis of effect of parameters on hardness

Source	Type III Sum of Squares	df	Mean Square	F	P-value
Corrected Model	5048.170(a)	8	631.021	80.430	.000
Intercept	94757.934	1	94757.934	12077.827	.000
SPEED	4745.518	2	2372.759	302.431	.000**
FEED	35.123	2	17.562	2.238	.135
SPEED * FEED	267.529	4	66.882	8.525	.000**
Error	141.221	18	7.846		
Total	99947.325	27			
Corrected Total	5189.391	26			

** P<0.05

Table 5 Analysis of effect of parameters on ultimate tensile strength

Source	Type III Sum of Squares	df	Mean Square	F	P-value
Corrected Model	2706.322(a)	8	338.290	2.938	.027
Intercept	191189.642	1	191189.642	1660.460	.000
SPEED	974.233	2	487.117	4.231	.031**
FEED	265.531	2	132.765	1.153	.338
SPEED * FEED	1466.559	4	366.640	3.184	.038**
Error	2072.567	18	115.143		
Total	195968.531	27			
Corrected Total	4778.889	26			

** P<0.05

Table 6 Analysis of effect of parameters on elongation

Source	Type III Sum of Squares	df	Mean Square	F	P-Value
Corrected Model	37.361(a)	8	4.670	14.951	.000
Intercept	1102.722	1	1102.722	3530.176	.000
SPEED	26.837	2	13.418	42.957	.000**
FEED	1.224	2	.612	1.959	.170
SPEED * FEED	9.300	4	2.325	7.443	.001**
Error	5.623	18	.312		
Total	1145.706	27			
Corrected Total	42.984	26			

** P<0.05

Table 6 Analysis of effect of parameters on yield strength

Source	Type III Sum of Squares	df	Mean Square	F	P-value
Corrected Model	798.780(a)	8	99.847	19.812	.000
Intercept	84516.392	1	84516.392	16770.062	.000
SPEED	301.735	2	150.868	29.936	.000**
FEED	42.300	2	21.150	4.197	.032**
SPEED * FEED	454.744	4	113.686	22.558	.000**
Error	90.715	18	5.040		
Total	85405.886	27			
Corrected Total	889.495	26			

** P<0.05

3.6 Metallographic analysis results

3.6.1 Macrostructure structure on maximum Tensile strength

From the experimental on Friction Stir Welding found that samples on maximum Tensile strength in the experimental Friction Stir Welding between Aluminum Al1100 and Aluminum Al 6063 was Parameter of Welding speed at 1820 rpm. and Welding feed at 18 mm/min. Weld range would have maximum Ultimate strength by average Ultimate strength as 100.49 MPa in Fig. 11.

Considered from Macrostructure structure of samples on maximum tensile strength found that macrostructure structure of weld metal had the most completely altogether at the area as Dept of Pin could be seen clearly from weld range. So that showed Friction Stir Welding on sample weld range with had maximum tensile was well completely seepage altogether, had enough melting in Dept of Pin phase but discontinuous matrix or hole which was result from melting Welding of 2 materials that had not enough flowed melting and also had the heat reacted with weld range while welding. That made weld range was not completely and occurred hole, other than this the entered heat also had the air from outside entered to reacted while welding so that occurred hole and caused irregularly disseminate, included while welding of two metal types occurred altogether melting by heat process. So that affected to flowed melting be successful but be altogether at Aluminum Al1100 side only because samples which used in welding experimental were two materials that be different grade and chemical property made altogether welding. An error weld range which occurred was hole from Friction Stir Welding of sample on Aluminum Al1100 side, which occurred lower melting than Aluminum Al 6063 because had chemical property which had high Aluminum then made the melting of weld range was at Aluminum Al1100 side only. As for Aluminum Al 6063 side had chemical property which Aluminum – Silicon – Manganese combined then made while material welding occurred less melting than Aluminum Al1100 and weld metal. HAZ's grain area had big size then made weld metal had less strong [5-8] as Fig. 12.

3.6.2 Macrostructure structure on minimum Tensile strength

From the experimental on Friction Stir Welding found that samples which had the lowest tensile strength in the experimental Friction Stir Welding between Aluminum Al1100 and Aluminum Al 6063 were Parameter of Welding speed at 3000 rpm. and Welding feed at 38 mm/min. Weld range would had minimum ultimate strength by average ultimate strength as 63.06 MPa in Fig. 13. Considered from Macrostructure structure of samples on minimum Tensile strength found that Macrostructure of weld metal had the most completely altogether at the phase as Dept of Pin could be seen clearly from weld range. So that showed Friction Stir Welding on sample weld range with had minimum tensile was well completely seepage altogether, had enough melting in Dept of Pin phase but hole which was result from Melting Welding of two materials that had not enough flowed melting and also had the heat reacted with weld range while welding. That made weld range was not completely and occurred hole, other than this the entered heat also had the air from outside entered to reacted while welding so that occurred hole and caused irregularly disseminate, included while welding of two metal types occurred

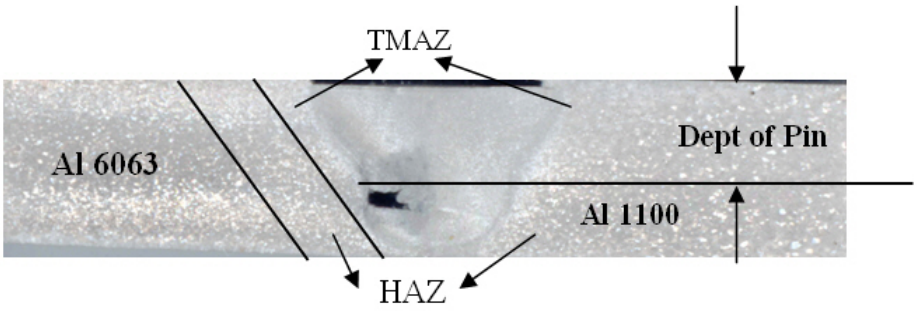

Figure 11 Macrostructure of sample on maximum tensile strength.

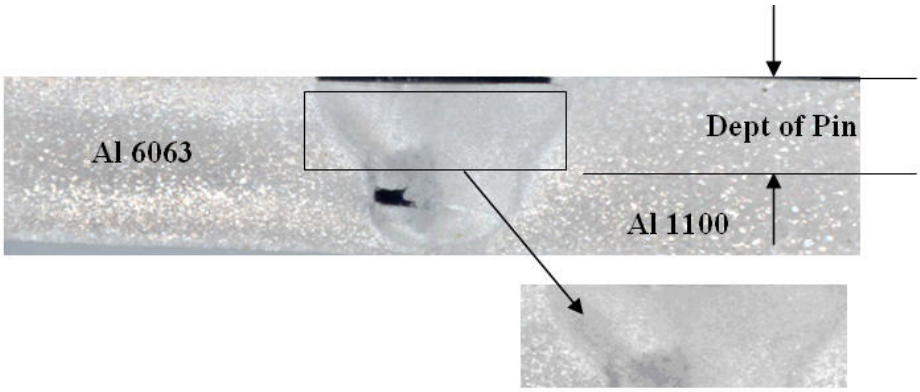

Figure 12 Partially completely of weld in Dept of Pin of sample on maximum Tensile

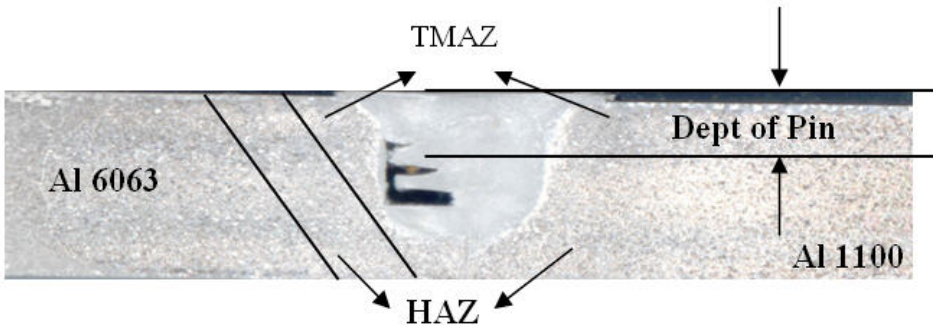

Figure 13 Macrostructure of sample on minimum tensile strength.

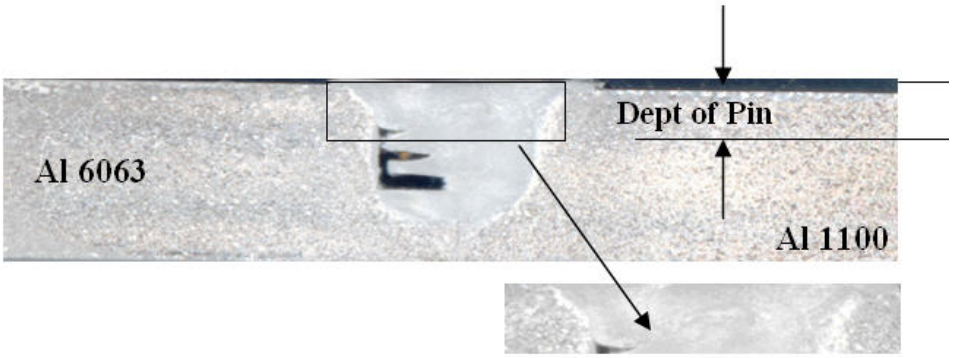

Fig. 14. Partially completely of weld in Dept of Pin of sample on minimum Tensile

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to flowed melting be successful but be altogether at Aluminum Al1100 side only because samples which used in welding experimental were two materials that be different grade and chemical property made altogether welding. A hole which occurred was hole from Friction Stir Welding of sample on Aluminum Al1100 side, which occurred lower melting than Aluminum Al 6063 because had chemical property which had high Aluminum then made the melting of weld range was at Aluminum Al1100 side only. As for Aluminum Al 6063 side had chemical property which Aluminum – Silicon – Manganese combined then made while material welding occurred less melting than Aluminum Al 1100 and weld metal. HAZ's grain area had big size then made weld metal had less strong [5-8] as Fig. 14.

4 Conclusion

From result of the experimental "Influence of Welding speed and Welding feed of running weld range to structures and mechanical properties of weld metal between Aluminum Al1100 and Aluminum Al 6063 by Friction Stir Welding process" could be summarized that parameters which influenced to hardness, ultimate strength, elongation and yield strength were welding feed and welding speed by had maximum hardness as 82.08 HV and maximum ultimate strength as 100.49Mpa. and maximum yield strength as 66.373 MPa.

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