USING FRICTION STIR PROCESS (FSP) TO IMPROVE THE PROPERTIES OF AA7020 ALUMINUM ALLOY WELDMENTS WELDED BY TUNGSTEN INERT GAS (TIG).

استخدام عملية الخلط الاحتكاكي (FSP) لتحسين خواص ملحومات الالومنيوم (AA720) الملحومة بطريقة لحام القوس الكهربائي المحمي بالغاز الخامل (TIG)

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ABSTRACT

One technique that may be used for repair of defects arising from process upsets is simply re-welding using the nominal process parameters. In such a case, it is important to know whether or not using a different welding process is capable of repairing defects in the already welded material (which will presumably have somewhat different properties as compared to the base metal). To examine this issue , three TIG weld passes were performed in aluminum AA7020 strips(6 piers of strips with 25 *200 *9.5 mm dimension) by used (Al Mg 5 Cr) filler metal according to AWS (A- 5.10) standard .Then friction stir weld pass were performed in exiting TIG welds (for only 3 piers of welded strips) with a tool rotation speed of (1000 rpm) and moved straight speed (welding speed) of (14 m /min). Microstructure and Vickers hardness testes were done for weldments in three regions (base metal , TIG and FSP weld metals) to comparison .

Results indicate that for this material and these conditions weld control parameters its possible to use another welding process to reduce defects in upsets process. Weld metallurgy is only slightly changed in the interface between TIG and FSP structures due to refining in exiting TIG welds structures. While there is no change in metallurgy of other TIG passes and base metal. Hardness in the weld metal after FSP pass increased by about 120% of the base metal.

KEY WORDS;Friction Stir welding ,Friction Sir Process,Tungsten inert Gas Welding , AA7020 Aluminum alloy, Al Mg 5Cr Filler Metal , Welding Defects.

الخلاصة

أحد تقنيات معالجة العيوب التي تظهر في عملية التطبيق هي أعادة اللحام بأستخدام احد الطرق المعروفة ،في هذه الحالة يكون من الضروري معرفة فيما اذا كانت طرق اللحام المختلفة قادرة على معالجة العيوب في منطقة ملحومة (والتي تكون لها خواص نوع ما مختلفة عن معدن الاساس). ولفحص هذا الهدف ،تم اجراء ثلاث تمريرات لحام القوس الكهربائي المحمي بالغاز الخامل TIGعلى اشرطة من الالمنيوم AA7020 (ستة ازواج من الاشرطة بأبعاد 25*20*9.5 ملم) وباسنخدام معدن الحشو نوع (Al Mg 5 Cr) وتم اللحام حسب المواصفة الامريكية القياسية (AWS (A – 5.10، ثم تم اجراء تمريرة لحام احتكاكي (FSP) على ثلاث ازواج من الاشرطة الملحومه مسبقا بأستخدام اداة تدور بسرعة (1000 دورة / دقيقة)وتتحرك بسرعة خطية (سرعة اللحام) تساوي (14 متر/ دقيقة) . ولغرض المقارنة بين الاشرطة الملحومة تم اجراء الفحص المجهري ،الصلادة فيكرز في المناطق الثلاثة (معدن الاساس ، ومعدن اللحام TIG ، ومعدن اللحام الاحتكاكي FSP) .
بينت النتائج لهذا المعدن وضمن نفس هذه الظروف امكانية استخدام طريقة اللحام اخرى لتقليل من عيوب اللحام اثناء التطبيق.
كذلك اشارت النتائج بوجود تنعيم بالبنية المجهرية للطبقة العليا للحام TIG عند اجراء اللحام الاحتكاكي عليها مع الاحتفاظ بنفس البنية المجهرية للطبقات البعيدة من لحام TIG ومعدن الاساس .اما بالنسبة للصلادة لمعدن اللحام بعد اجراء اللحام الاحتكاكي FSP فقد زادت حوالي 120% من قيمة الصلادة لمعدن الاساس .

الكلمات الدالة: اللحام الاحتكاكي ،عملية الخلط الاحتكاكي، اللحام بقطب التنجستن والغاز الخامل ،سبائك الالمنيومِ AA7020، سلك الحشو AlMg5Cr، عيوب اللحام .

SOMPALES

Friction Stir Welding (FSW) ,Friction Stir Process (FSP), Tungsten Inert Gas (TIG) ,The Welding Institute (TWI) , American Welding Society (AWS) .

INTRODUCTION

TIG welding is a traditional technology for aluminum alloy welding ; hoverer , some problems would be formed , such as hot cracking in fusion zone due to segregation of alloying elements during solidification ,as– cast coarse microstructure [1] , which result in the obvious decrease of mechanical properties of the joints .The welding structure can turn out to be the restrictions on the aluminum alloy in aerospace applications [2] .

Friction stir welding (FSW) was invented at The Welding Institute (TWI) , OK in 1991 . Friction stir welding is a continuous , hot shear ,autogenously process involving non – consumable rotating tool of harder material than the base material [3,4]. This process reduces the manufacturing costs due to elimination of any defects filler materials and costly weld preparation. Furthermore, friction stir welds of aluminum alloy exhibit better mechanical properties than fusion welding [1] . Therefore , defect – free welds with good mechanical properties have been made in a variety of aluminum alloys [5,6].

Most of the published papers are focusing on the effect of (FSW) parameters and microstructure formation [6 - 11] , and comparisons between (FSW) and (TIG) welding properties of aluminum alloys have been widely investigated
[12 – 15].

Comparing the results with conventional (TIG) welding techniques with (TIG and stired welding) microstructure have been investigated in the present paper.

EXPERIMENTAL WORK

Materials

A heat treatable aluminum alloy AA 7020 with (9.5 mm) thickness was used , its chemical composition is shown in (T**able – 1)** .This alloy is used for aircraft frames . Also filler metal type (Al Mg 5 Cr) was used , its chemical composition is shown in (T**able –2)** . This filler metal is recommended to use in welding aluminum.

(Table 1) Chemical composition of AA7020 aluminum alloy .

Element / Material	Zn%	Mg%	Mn%	Fe%	Cr%	Si%	Zr %	Ti%	Cu%	Al %.
Nominal chemical composition [16]	4 -5	1 - 1.4	0.05 - 0.50	<0.4	0.1 - 0.35	<0.35	0.08 -0.2	0.08	<0.2	Bal.
Actual chemical composition	4.61	1.29	0.11	0.27	0.213	0.166	0.14	0.04	0.142	Bal.

(Table 2) Chemical composition of Al Mg 5 Cr filler metal.

Element / Material	Si%	Fe%	Cu%	Mn%	Mg%	Zn%	Ti%	Al%
Nominal chemical composition [17]	0.50 Si+Fe	-	0.10	0.05-0.20	4.5-5.5	0.1	0.06-0.2	Bal.
Actual chemical composition	<0.25	<0.40	<0.05	0.15	5	<0.1	0.11	Bal.

Samples Preparation & Welding

All samples of AA7020 were prepared by cutting machine (12 strips with 25*200*9.5 mm dimension), then strips were chamfered to 45˚angle (V- joint).

Chamfered strips were clamped , and spaced by a gap about (2mm) to allow molten filler metal to diffuse .

Gas tungsten arc welding torch (AC-DC Lencolen Type Machine) was used to welding each two chamfered strips with filler metal type (Al Mg 5 Cr) . Welding procedure schedules(according to AWS (A -5.10) for 9.5 mm thickness) was used as shown in (T**able – 3)** [17] .

(Table 3) Welding procedure schedules for Ac – TIG welding of Aluminum [17].

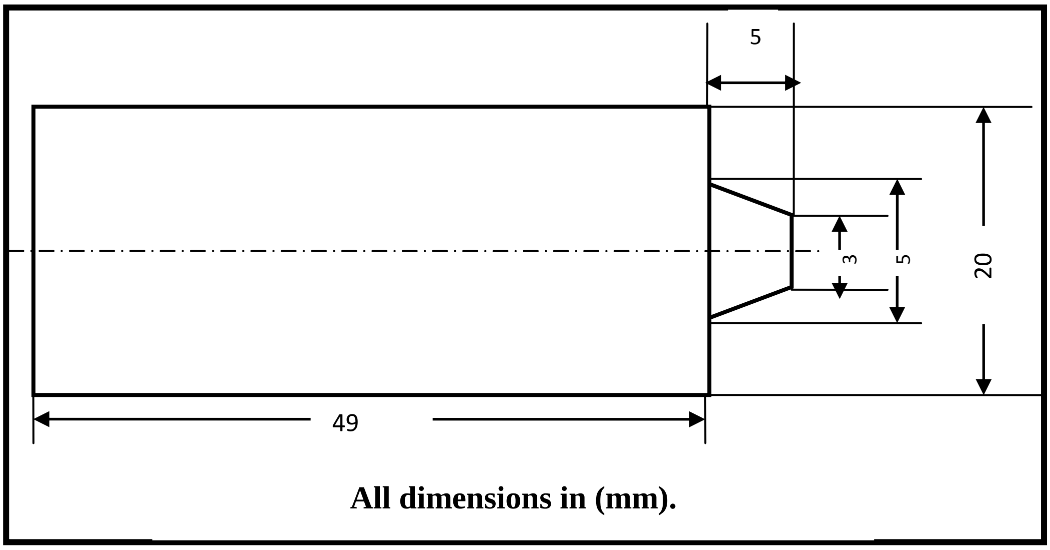
Item	Value
Material thickness (mm)	9.5
Type of weld	Vee groove 45˚
Tungsten electrode diameter (mm)	4.8
Filler rod diameter (mm)	4.8
Nozzle size inside diameter(mm)	1.27
Shielding gas flow rate (L / min)	16.5
Welding current Ac (Amp)	250
No. of passes	3
Travel speed per pass (mm / min)	250

Milling and drilling a hole (6.5 mm) was down for three (TIG) weldment to prepared them for friction stir process (FSP) .

Friction stir process (FSP) was down by milling machine (TOS OL OMOUC EZ Mohelonic Type)with used stirrer that dimensions are shown in (**Fig. 1)**. The revolution speed for milling was (1000 r.p.m.) and the feed rate was (14 m /min) . The weldments carried out are three samples for each case.

Mechanical test

Micro hardness test and microstructure were down for all samples ,Vickers micro hardness equipment with (500 gm load and 10 sec loading time) was used for test the hardness of weldment. The average of (5) hardness reading were taken from each side and middle of welding line .



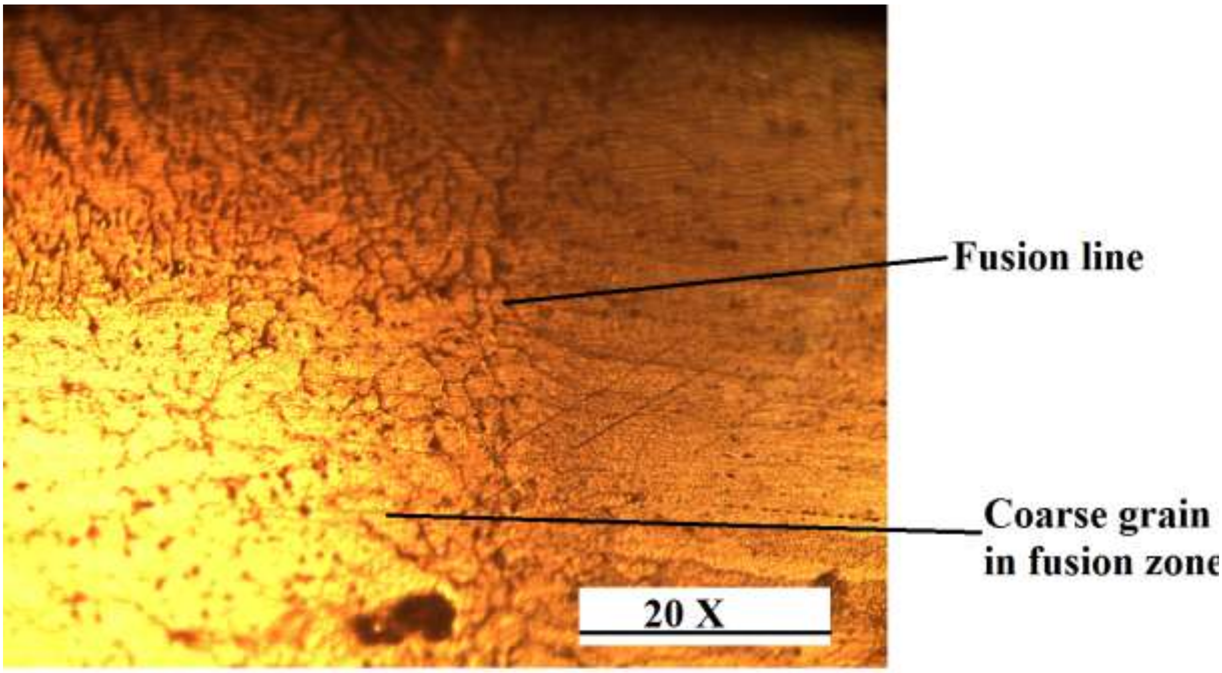
(Fig. 1) Pin geometry and dimensions that used in (FSP) in this research.

RESULTS AND DISCUSSION

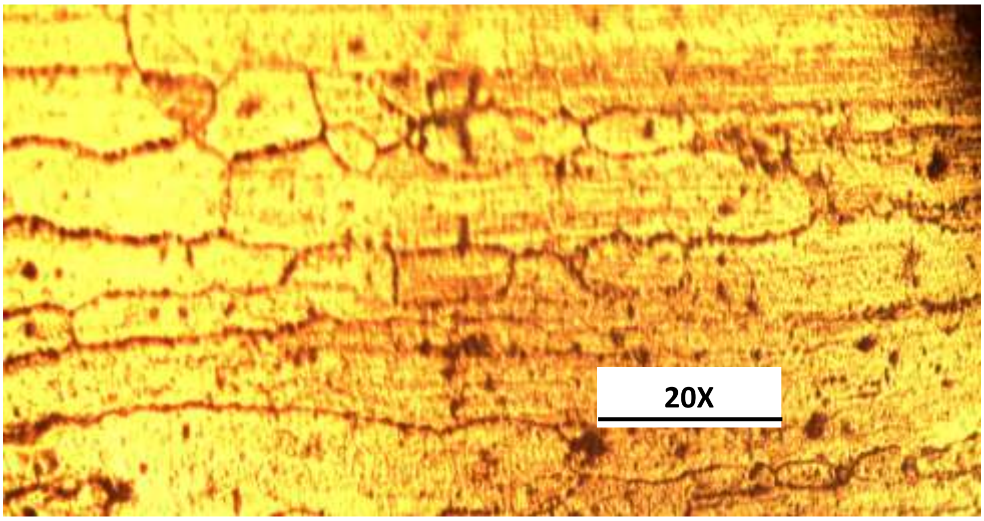
Microstructures

The fusion welding of aluminum alloy by using filler metal alloy will produce a grain growth at heat affected zone and almost coarse grains structure at fusion zone as shown in **(Fig. 2)**, Classical fusion structure was appear by using same filler metal (in comparing with base metal) .

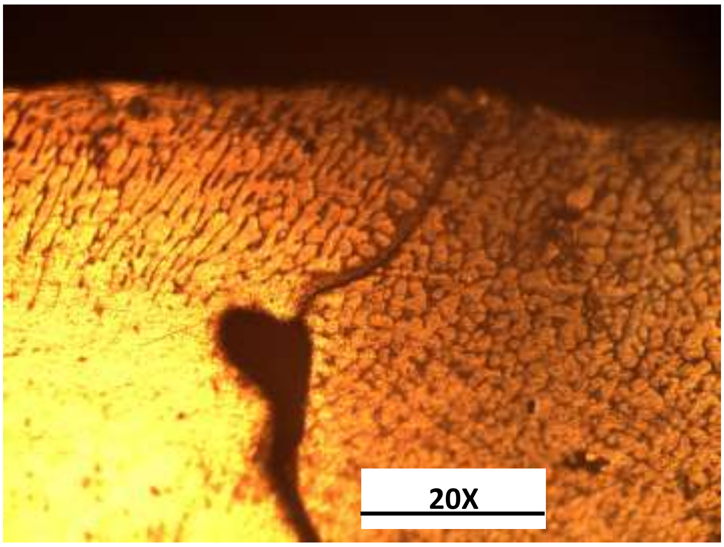
(Fig. 3) shows the base aluminum alloy as rolling structure , while **(Fig. 4 a& b)** shows and pointing out the almost common defect in aluminum fusion welding which is inclusion by porosity . **(Fig. 5 a& b)** represents the fusion zone which reveal a dendritic structure with large grains .



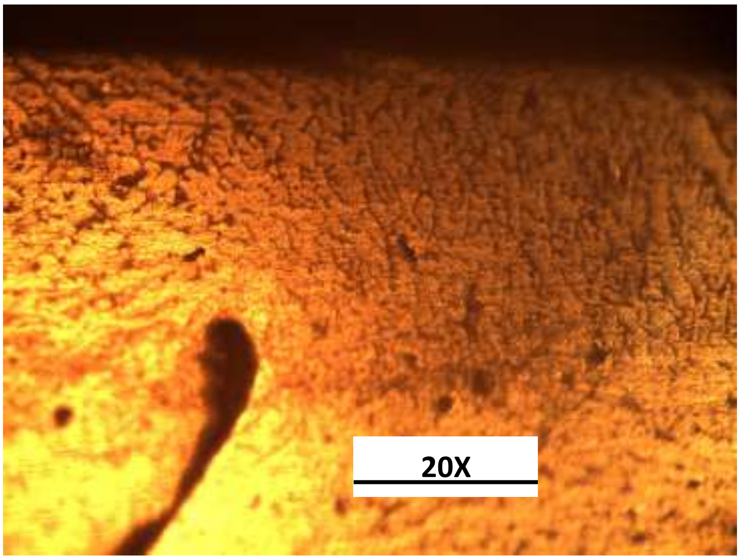
(Fig. 2) Shows fusion line and coarse grains of fusion zone for aluminum alloy AA7020 sample TIG welded.



(Fig. 3) Shows the micro-structure of base metal AA7020 aluminum alloy

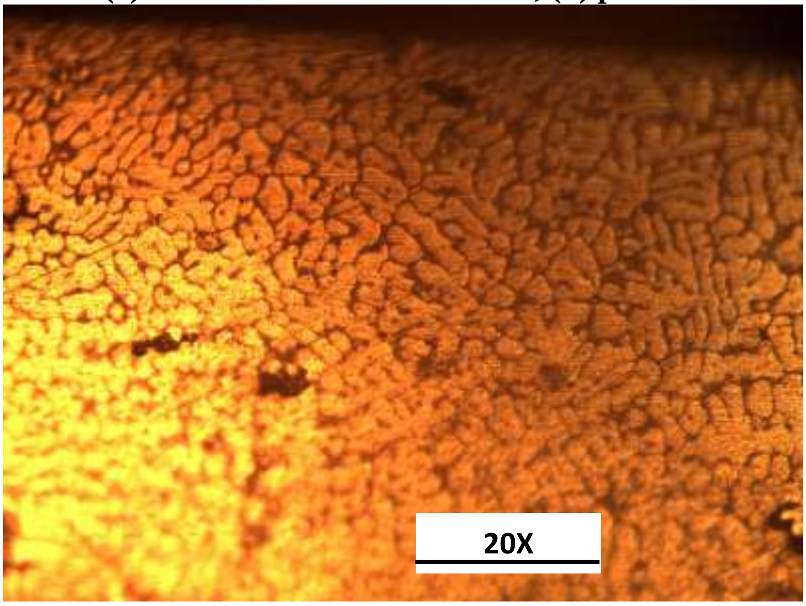


(a)

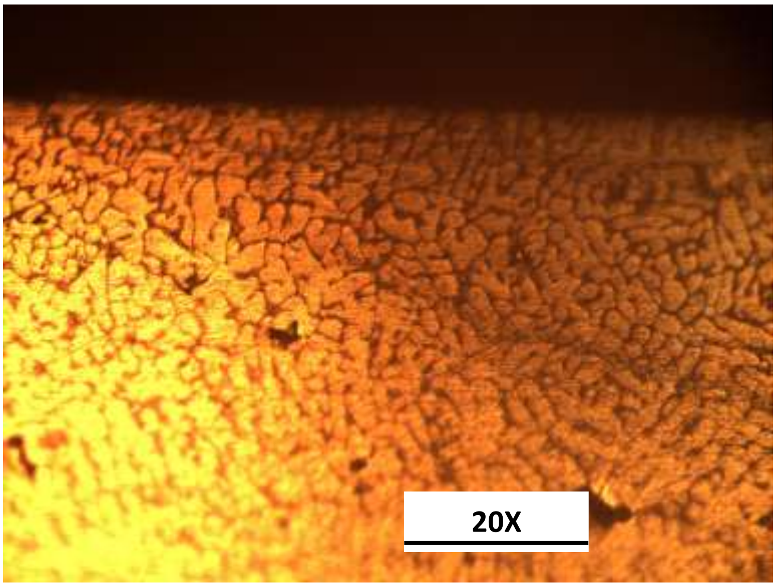


(b)

(Fig. 4) Shows (a) External crack in fusion one, (b) porosities in fusion one.



(a)

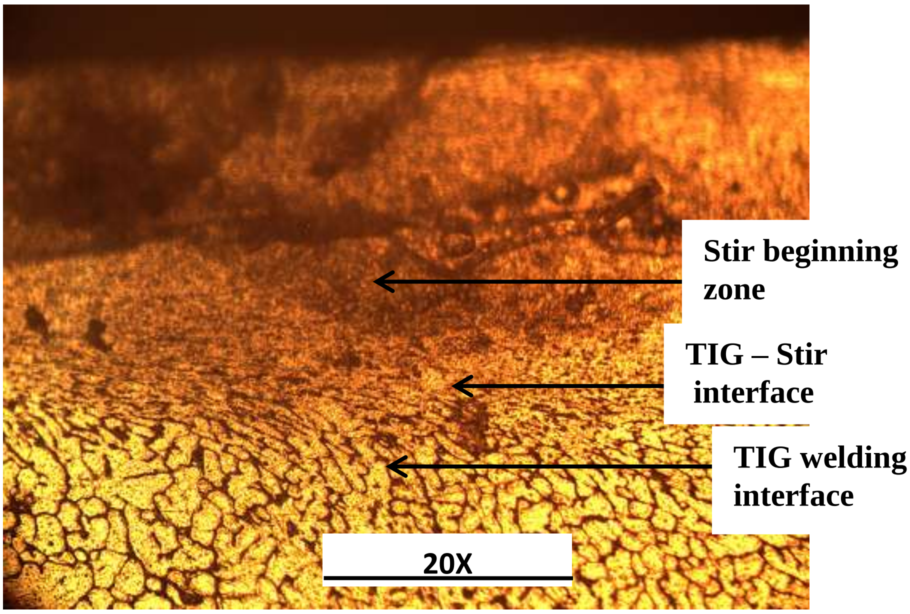


(b)

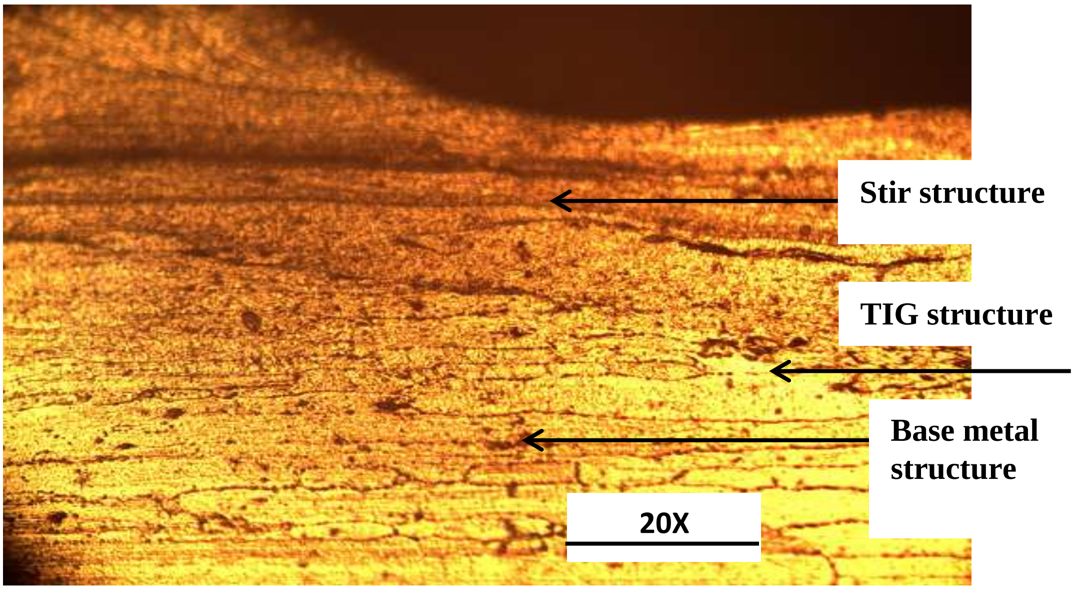
(Fig. 5 - a & b) Shows the fusion zone which reveal a dendritic structure with large grains in TIG welding

(Fig. 6) Shows the interface between friction stir structure and the TIG welded structure , which explain the refining output in comparing with the two TIG and base structure , this mechanism is the main goal of this work .

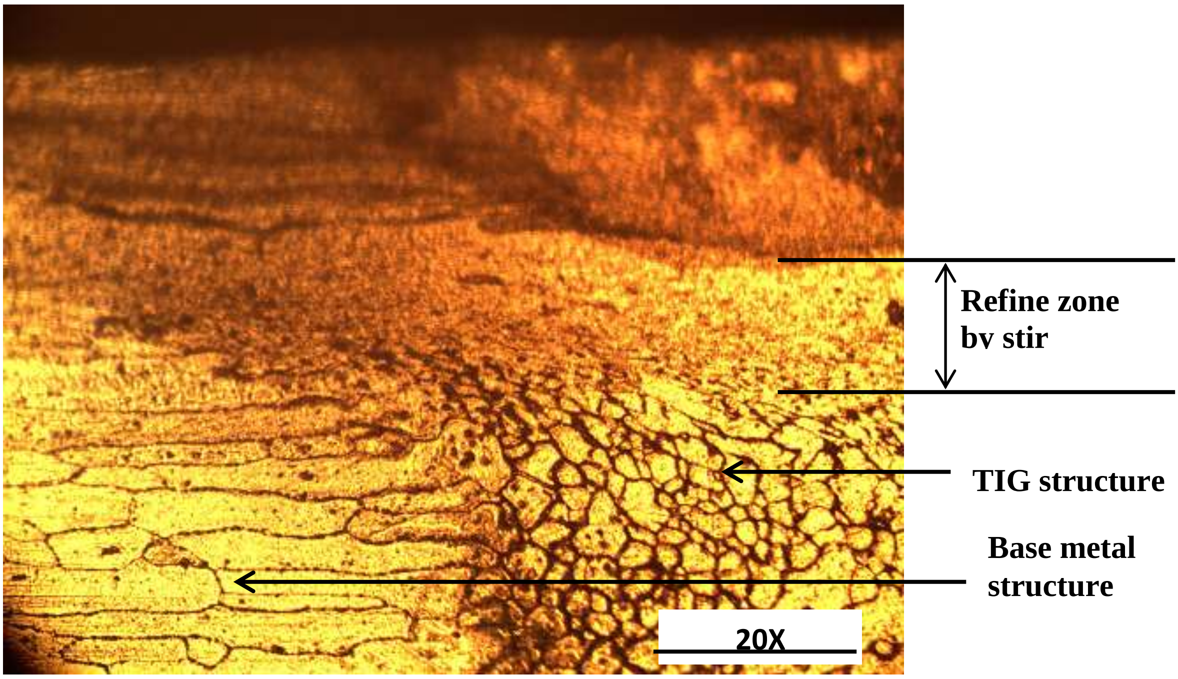
(Fig. 7) is the complete picture for the three structures (base metal , TIG and stir welding) . **(Fig.8)** carried out the objective of this research of refining grain structure by using friction stir technique over TIG welding structure for aluminum alloy to overcome some metallurgical problems which always presented by fusion welding . Also its clearly observed by **(Fig. 9 a& b)**.



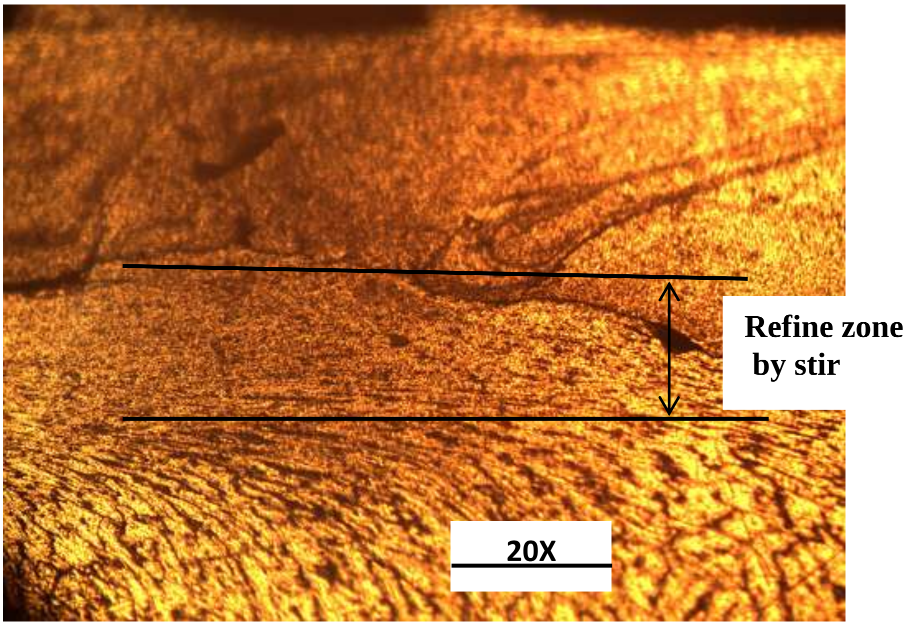
(Fig. 6) Shows the interface between stir structure and TIG structure.



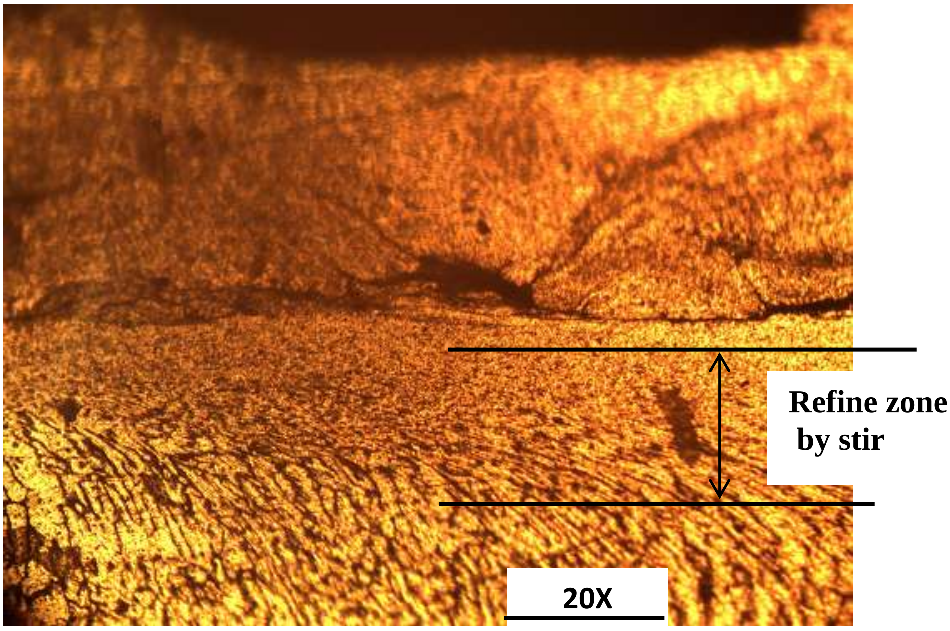
(Fig. 7) Shows the three structures (base metal , TIG and stir welding)



(Fig. 8) Shows the refine zone by stir .



(a)



(b)

(Fig. 9 a & b) Shows the refine zone by stir .

Micro-hardness

The average micro hardness of base aluminum alloy is about (127 HV) , while the average micro hardness of TIG welding layer by using (Al Mg 5 Cr) as filler metal alloy is about (111 HV) . The friction stir process that processed over the TIG layer reveal average micro hardness is about (131.5 HV) as shown in

(Table 4). This represent the main objective of this work which is to produce fine grains with modified hardness , and by this process the hardness increased by about (120%) of the base material .

(Table 4) Results of HV hardness test for weld metal & base metal Aluminum alloy AA7020 .

Sample conditiones	Hardness reading (HV)	The averge hardness reading (HV)
Aluminum base metal without welding.	127 ,127,127 ,127 ,127	127
Aluminum weld metal with TIG welding	105 , 106 ,108 ,111,125	111
Aluminum weld metal with TIG and FSP in advance and retreating zone	120 ,131 ,133 ,133, 141	131.5

CONCLUSION

1- For this material and these conditions weld control parameters, its possible to use another welding process to reduce defects in upsets process.
2- Weld metallurgy is only slightly changed in the interface between TIG and FSW structures due to produce fine grains in exiting TIG welds structures. While there is no change in metallurgy of other TIG passes and base metal .
3- Hardness in the weld metal after FSW pass increased by about 120% of the base metal .

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