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Welding of Cylindrical Parts by using Friction Stir Technique

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ABSTRACT

The objective of this work was to investigate the mechanical and metallurgical properties in order to demonstrate the feasibility of friction stir welding for joining Al6061 and Al6063 aluminum alloys Welding was performed on cylindrical parts with different thickness 2mm and 3mm,five rotational speeds,485,710,910,1120 and1400 rpm and a traverse speed 4mm/min was applied. The tests were conducted for the study to determine the mechanical properties (maximum stress - the percentage of elongation) and hardness measurement along the welded sections using the Vickers method, was also studying the crystalline structure of welded joints .The FSW welds exhibited many advantages over traditional arc welding techniques.

كان الهدف من هذا العمل التحقيق في الخواص الميكانيكية والمعدنية من أجل إثبات جدوى لحام الاحتكاك التقليبى على سبائك الأجزاء الاسطوانية للألمنيوم 6063و606سمك 3مم و2 مم لكل سبيكة وتم تطبيق خمس سرعات دورانية(1400 1120,910,710,485لفة/الدقيقة) وسرعةخطية(4مم/الدقيقة) .
ونم إجراء الاختبارات اللازمة لدراسة الخواص الميكانيكية لتحديد(أقصى أجهاد- النسبة المئوية للاستطالة) وقياس الصلادة على طول المقاطع الملحومة باستخدام طريقة فيكرز ،وتم أيضا دراسة البنية البلورية للوصلات الملحومة.لحام الاحتكاك التقليبى للأجزاء الاسطوانية اظهر كفاءة وجودة عالية بمقارنته بطرق اللحام التقليدية.

INTRODUCTION

Aluminum and its alloys are increasingly used in many important manufacturing areas, such as the automobile industry, aeronautic and military ,because of their low-densityand good mechanical properties However, the welding of aluminum and its alloys has always represented a great challenge for designers and technologists[1].

Many difficulties are associated with this kind of joint process .It is obvious that serious problems,such as tenacious oxidelayercavities,hot cracking sensitivity,and porosity, may occur when fusion welding is applied to aluminum and its alloys.Moreover,theconventional techniques,such as fusion welding,often lead tosignificant strength deterioration in the joint becauseof a dentritic structure formed in the fusion zone[2].

The joining of aluminum alloys,especially those which are difficult to weld,has beenthe initial target for developing and judging the performance of FSW.Friction stir welding ,a process invented at TWI,Cambridge, involves the joining of metal without fusion or filler materials.It is used already in routine ,as critical applications ,for the joining of structural components made of aluminum and its alloys. Indeed, it has been convincingly demonstrated that the process results in strong and ductile joints, sometimes which in systems have proved difficult using conventional welding techniques[3-5].The processis most suitable for components which are flat and long(plates and sheets)but can be adapted for pipes ,hollow sections and positional welding.The welds are created by the combined action of frictional heating and mechanical deformation due to a rotating tool.The maximum temperature reached is of the order of 0.8 of the melting temperature[6].

A large number of research papers are available in the literature on various aspects of FS welded aluminum alloy such material flow, development of microstructure and mechanical properties in friction stir welding for plates and sheets, but the research papers that done in cylindricalparts by using friction stir techniqueare quite rare.

EXPERIMENTAL PROCEDUERS

Material: The chemical composition and mechanical properties of Al 6061 and Al6063 aluminum alloys cylindrical parts used in the present study as delivered by the Miser Aluminum company are given in Tables(1-3).

Table(1) Chemical composition (wt%) of Al6063

Chemical Composition Limits Aluminum Alloy 6063											
Weight %	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Ti**	**Others each**	**Others total**
6063	Bal	0.20-0.60	0.35 max	0.10 max	0.10 max	0.45-0.90	0.10 max	0.10 max	0.10 max	0.05	0.15 max

Table (2) chemical composition(wt%) of Al6061

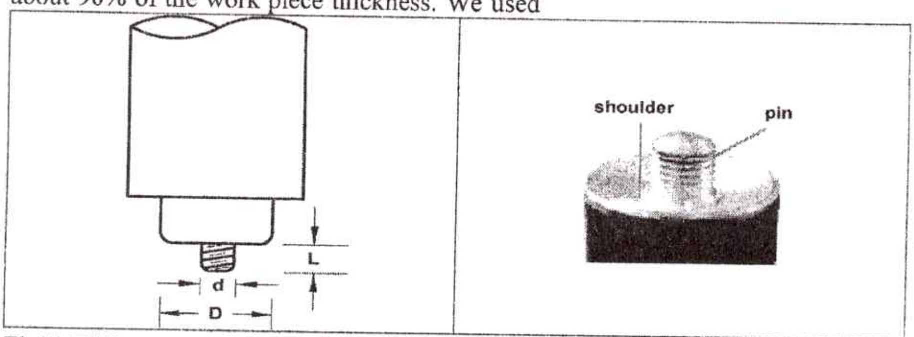
Chemical Composition Limits Aluminum Alloy 6061											
Weight %	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Ti**	**Others each**	**Others total**
6061	Bal	0.40-0.80	0.70 max	0.15-0.40	0.15 max	0.80-1.20	0.04-0.35	0.25 max	0.15 max	0.05	0.15 max

The mechanical properties of AL6063 and Al6061 in **Table (3)**

Alloy	**Ultimate Tensile Strength σ_{UTS} M pa**	**Elongation EL%**	**Hardness VHD**
6063	211.984	12.6	74.6
6061	252.690	8	86

Tool design:

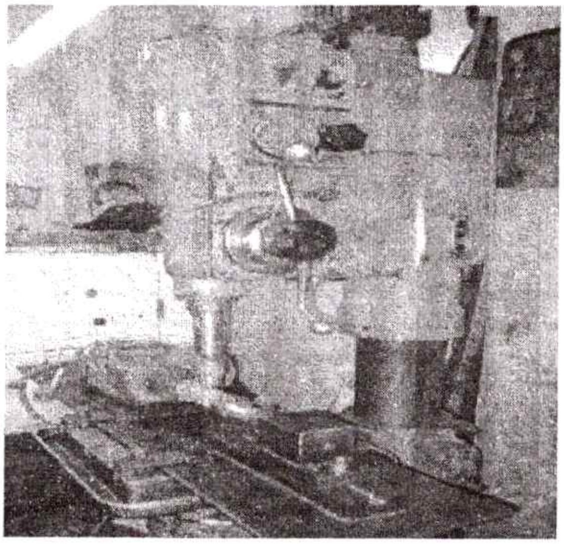
The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is high carbon steel ,sufficiently strong, tough and hardwearing, at the welding temperature. [7].The tool pin penetration depth was suggested to be at least about 90% of the work piece thickness. We used two tools with flat shoulder,Tools was fixed in the spindleof the drilling.In present study the tool length were 50mm,andtwodifferentpinlength(L)(2mmand3mm), pin diameter(d)1mmandshoulder Diameter(D)(10mm) a shownfig(3-1).



Fig(1).FSW tool dimensions.

Drilling press machine:

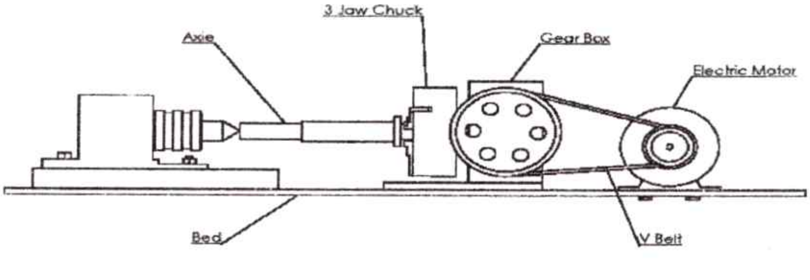
Thestandardspecificationfor the Drilling press machine is as the following data:A Bulgarian made with various speeds(28r.p.mto1800r.p.m),the table stroke is 1500mm ,the frequency of the machine is 50 HZ ,the operation voltage of the machine is 380V, the control voltage of the machine is 42 V, the connected load of the machine is 16.5K, and the nominal current of the machine is 28 Amp as shown in Fig(2).

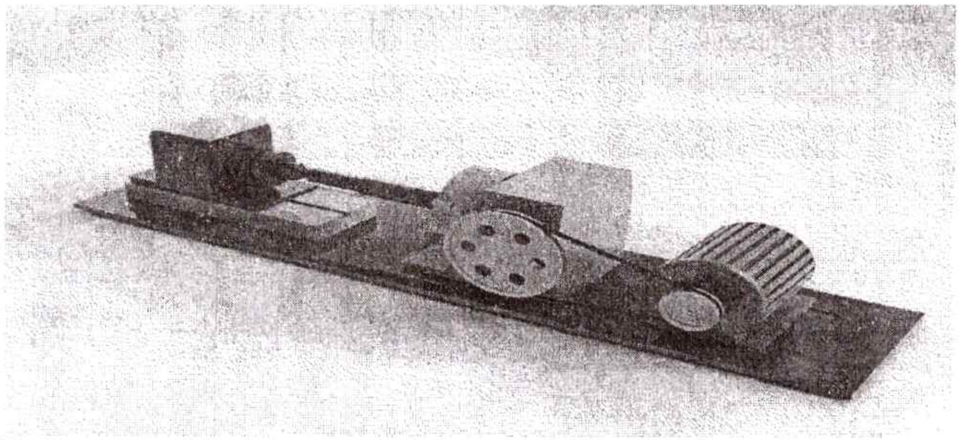


Fig(2). Drilling press machine

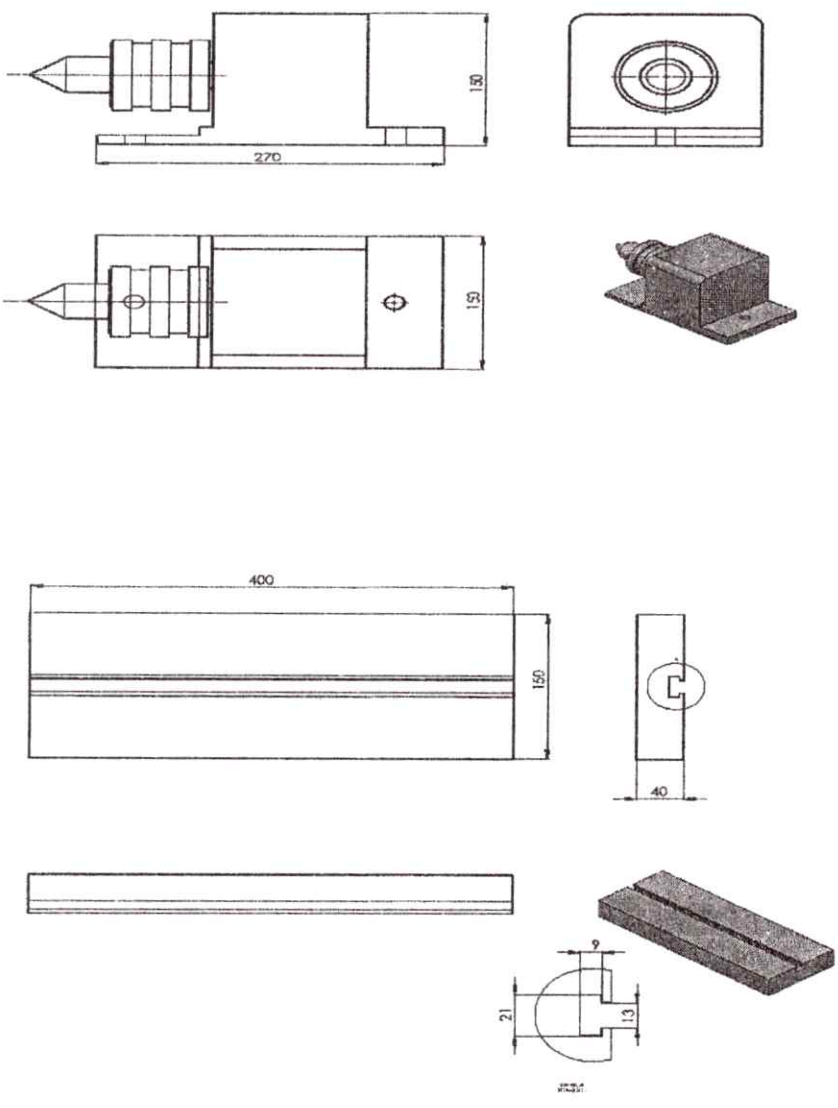
Setup friction stir welding:constructed apparatus is mounted on the drilling press machine bed to the two workpieces of the studiedmaterials which will be welded by friction stir weldingtechnique,Figures(3-6).showing Illustration DrawingandConstructionSetup friction stir welding for cylindrical parts.

Fig(3).Illustration Drawing Setup friction stir welding for cylindrical parts

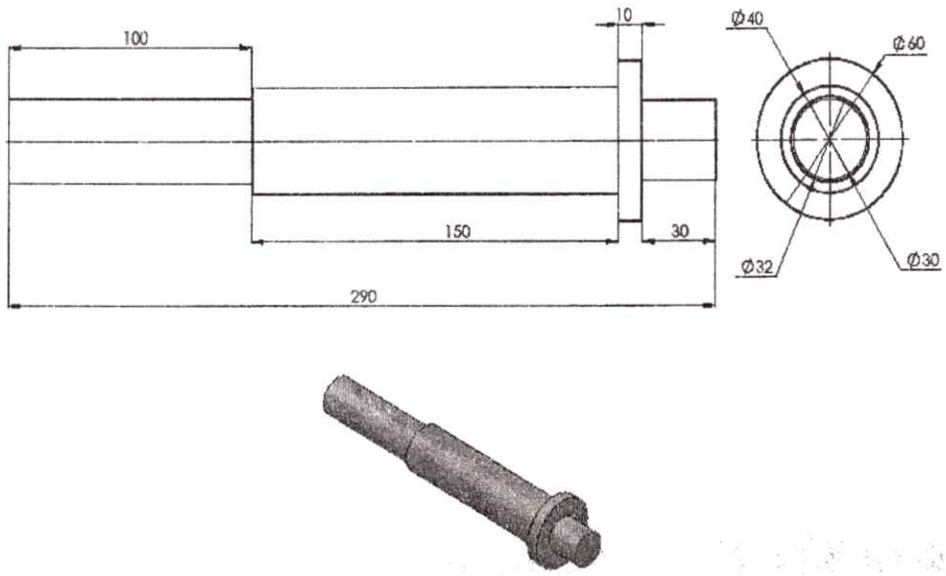




Fig(4)



Fig(5). Construction Center lathe



Fig(6).Construction Design of axis

Tensile Testing:

Tensile testing, also known as tension testing,is a fundamental material sciencetest in which a sample is subjected to uniaxial tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces.Properties that are directly measured via a tensile test are ultimate tensilestrength(UTS),maximumelongation(EL%).

RESULTS AND DISCUSSIONS

Visual inspection of the upper(external surface of welded specimens)showed uniform semicircular surface ripples , caused by the final sweep of the trailing edge of rotating tool shoulder over weld nugget ,under the effect of probe overhead pressure.The presence of such surface ripples,known as onion rings.

Vickers Hardness Testing:

The hardness number is determined by the load over the surface area of the indentation and not the area normal to the force, and is therefore not a pressure.

The HV number is then determined by the ratio F/A where F isthe force applied to the diamond in kilograms-force and A is the surface area of the resulting indentation in square millimeters.

Figures(7-8)shows the surface appearances of the weld The interface between the recrystallized nugget zone and the parent metal is relatively diffuse on the retreating side of the tool,but quite sharp on the advancing side of the tool.

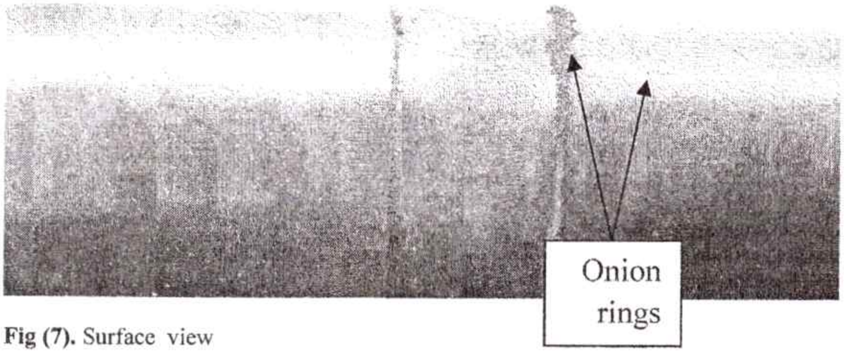


Fig (7). Surface view

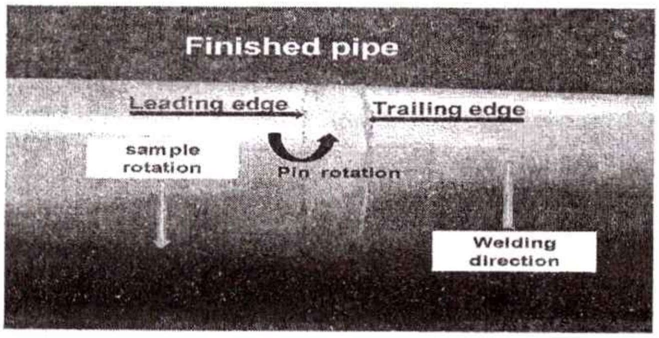


Fig (8). welded specimen showed leading and trailing edge

Macro-and microstructure of the joints:
Macro and micro structural analysis have been carried out using a light optical microscope (make:Union Optical, Japan; model: NikonSMZ 800 Zoom)incorporated with an image analyzing software .The specimensfor metallographic examination are sectioned to the required sizes from the joint comprising FSP zone, TMAZ , HAZ and base metal regions and polished using different grades of emery papers. Final polishing has been done using the diamond compound(1 lm particle size)in the disc polishing machine .Specimens are etched with Killers' reagent toreveal the macro and microstructures. Figures(9-a-c)show macrostructureof transverse cross sections of typical joints friction stir welded of Al6063andAl6061at the tool rotation speed of 485 and1400 rpm and welding speed of 4mm/min.

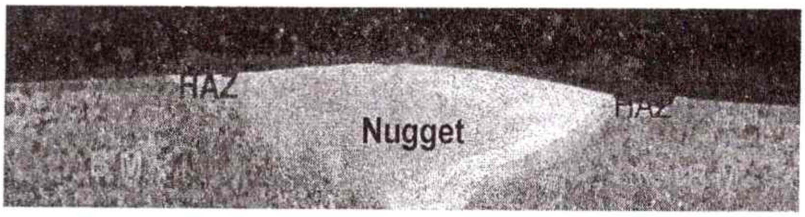


Fig. (9-a) macro weld cross-section of AL6063 at (1400 r.p.m),4mm/min

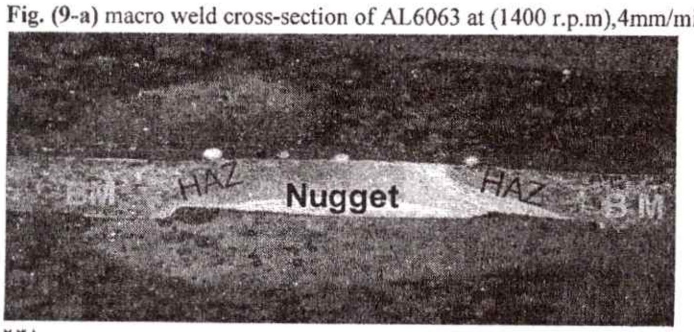


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Fig. (9-b) macro weld cross-section of AL6063 at (485r.p.m),4mm/min

Fig. (9-c) macro weld cross-section of AL6061 at (1400 r.p.m),4mm/min

Fig. (9-d) macro weld cross-section of AL6061 at (485r.p.m),4mm/min

The microstructure in Fig (10-a,b)represent the structure of base metal of Al 6063 and Al6061 atX 200.

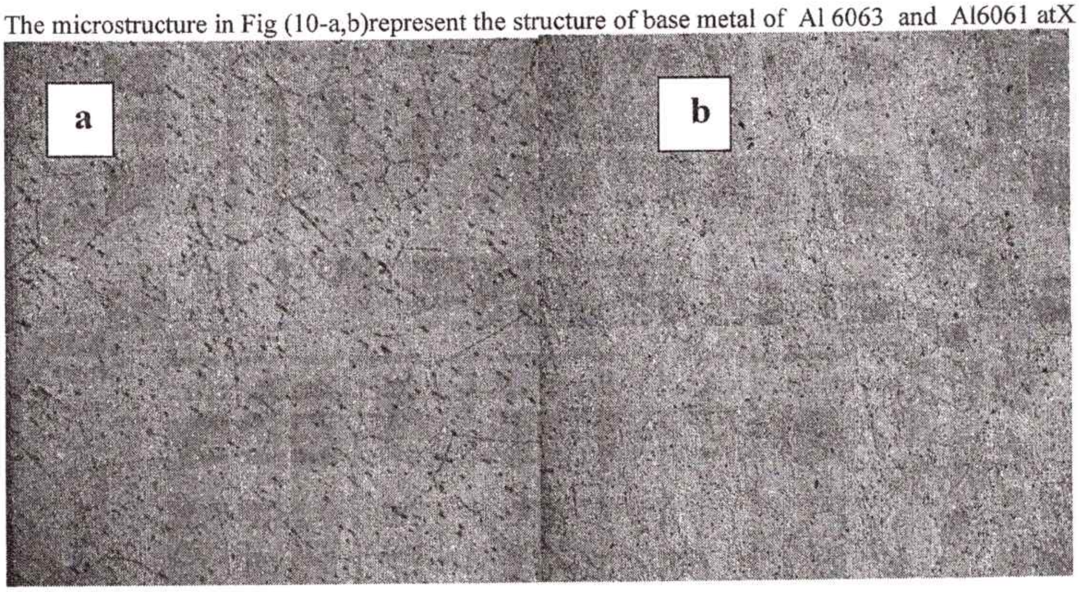


Fig. (10). Optical microstructures BMs
(a) BM of Al6063- X 200 **(b) BM of Al 6061-X 200**

The microstructures of FSW weldment in fig(11-14)which corresponds to the macrostructure given in Fig(9-a-c)exhibited four distinct microstructure zones. Considering the heat generation due to friction and the plastic deformation, a stir zone at weld centerline ,directly beneath the probe pin is characterized by strong effects of material flow and heat generation This is followed by a thermo mechanically affected zone TMAZ, which undergoes little material flow and medium temperature increase. The TMAZ experiences both temperature and deformation during FSW. The TMAZ underwent plastic deformation ,heat affected zone HAZ, loated between the TMAZ and base metal, This zone experiences a thermal cycle but does not undergo any plastic deformation

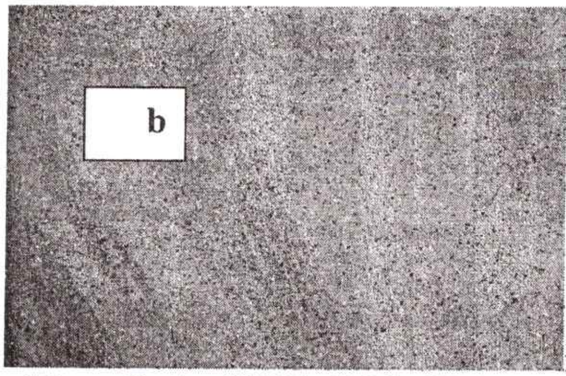
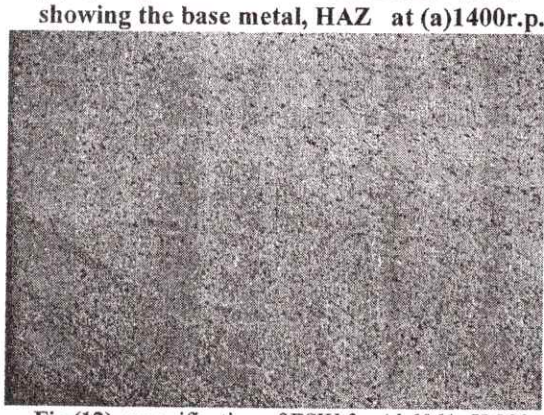


Fig (11). magnification of FSW for Al 6063 - X 200
showing the base metal, HAZ at (a)1400r.p.m),(b)485rpm



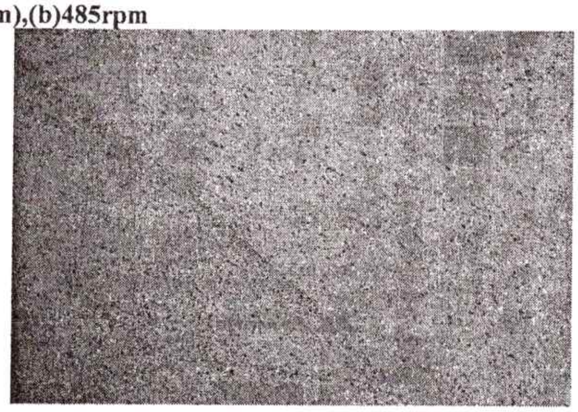
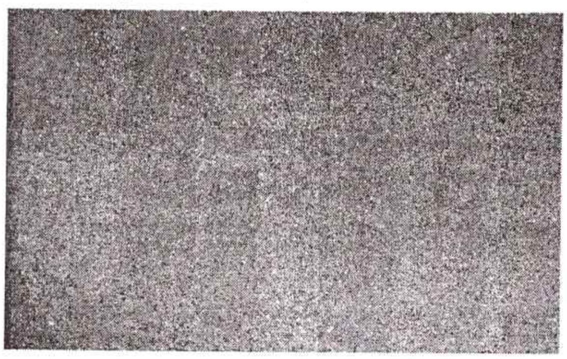


Fig (12). magnification of FSW for Al 6061- X 200
showing the base metal, HAZ at (a)1400r.p.m),(b)485rpm



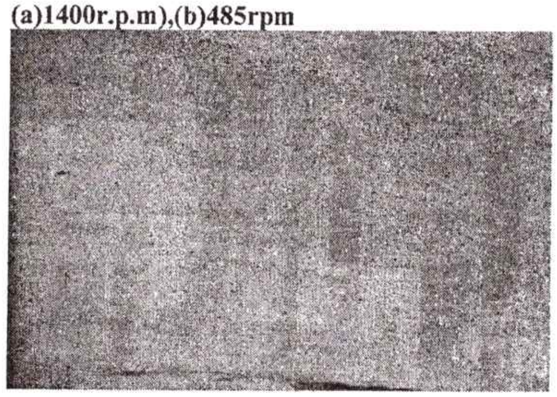
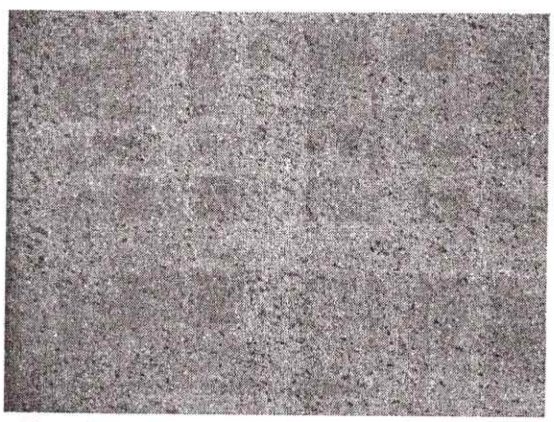


Fig (13). magnification of FSW for Al 6063- X 200
showing weld nugget zone at (a)1400r.p.m),(b)485rpm



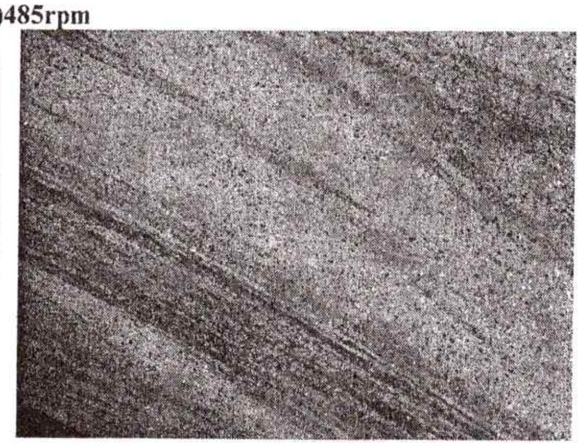


Fig (14). magnification of FSWfor Al 6061- X 200
showing weld nugget zone at (a)1400r.p.m),(b)485rpm

It can be seen that the base metal has larger grains and there is no much different between the grain size of grains in the base metal and the HAZ, and there is clear distinction between the heat affected zone and the weld nugget.

The rotational movements of stir probe may affect the size of precipitates fragmentation and dissolution processes.

Theincrease in rotational speeds decreases the viscosity of the plasticized materialduetotheincreasedin deformation temperature and the decrease ingrainsize.

Tensile strength and elongation of the stir zone of the joints:

Tensile Test Results

The quality of the welds was assessed based on tensile tests, Tensile tests were performed on the base metal and welded specimens, Transverse tensile properties such as tensile strength, percentage of elongation and joint efficiency of the FSW joints have been evaluated. At each condition three specimens are tested and average of the results of three specimens weremeasured, it can be Inferred that the rotational speed and thickness are having influence on tensile properties of the FSW joints.

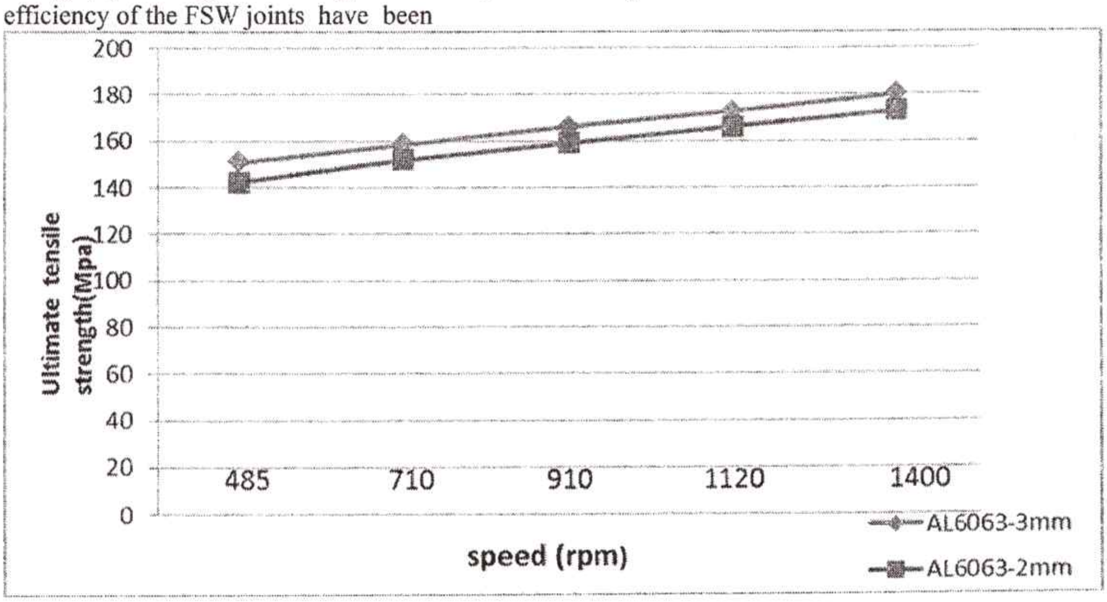


Fig.(15) Relation between ultimate tensile strength androtational speed of Al 6063-3mm,2mm

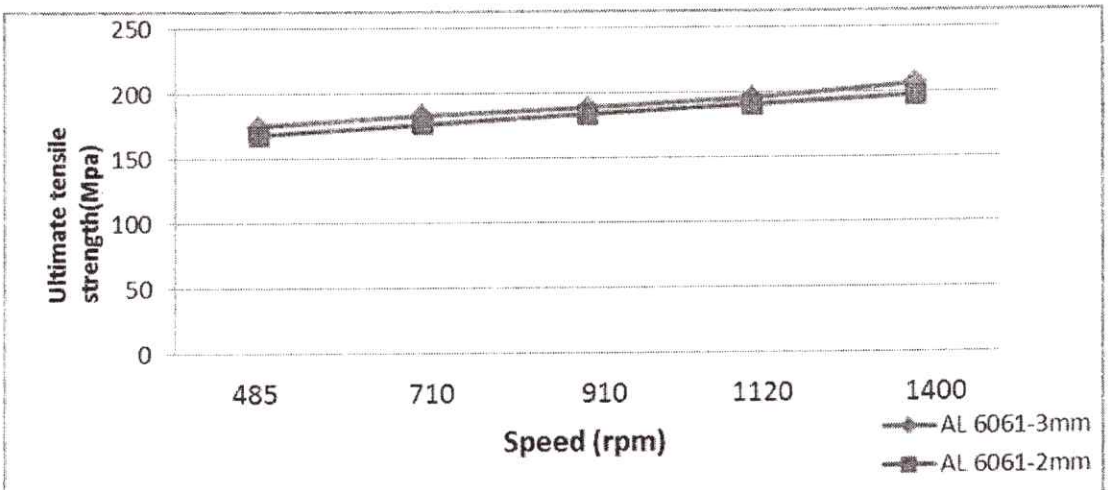


Fig.(16) Relation between ultimate tensile strength and rotational speed of Al6061-2mm

Elongation Results

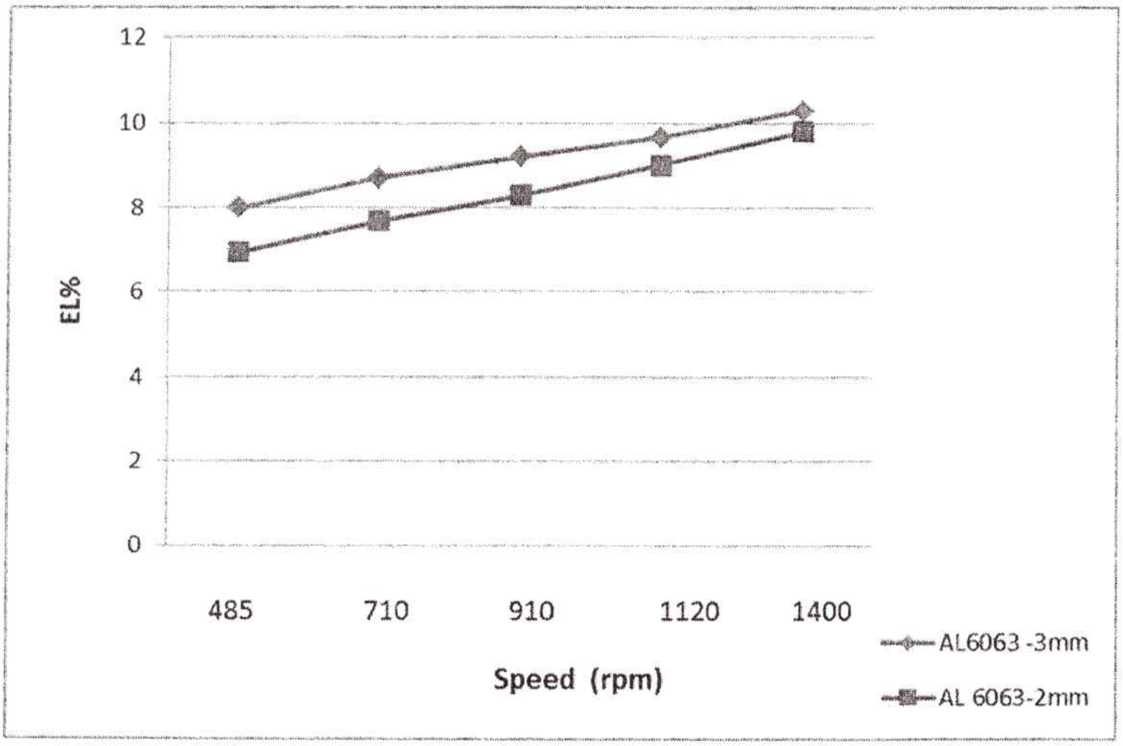


Fig.(17) Relation between elongation and speed of Al6063-3mm,2mm

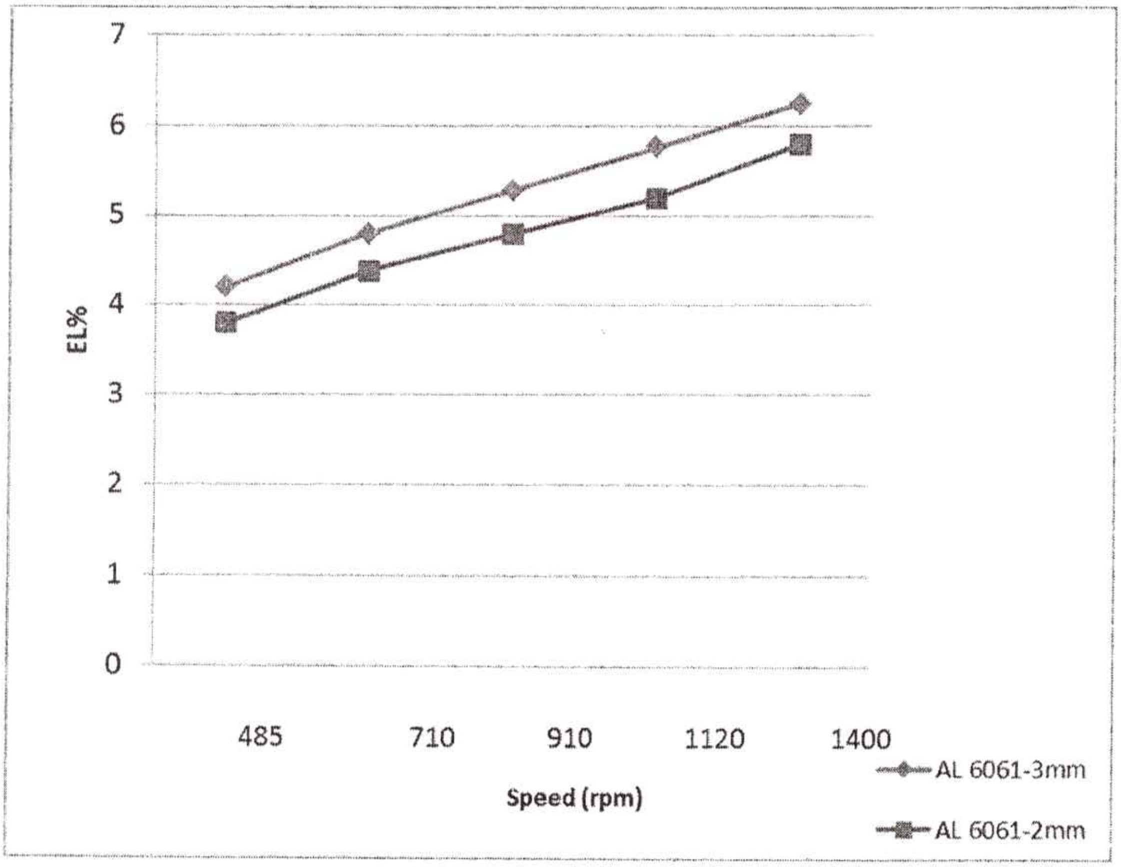


Fig.(18) Relation between elongation and speed of Al 6061-3mm,2mm

Of the twenty joints,the joints fabricated at high rotational speed(1400rpm)exhibited superior tensile properties compared to other joints. Similarly , the joints fabricated with high material thickness are showing a good tensile properties comparing to that of a less material thickness.

Hardness measurement of the joints

Hardness measurement was taken a cross the BM, HAZ and NZ, For FSW specimens it can be Inferred thatThe decrease in hardness at weld centerline increases by increasing the rotational speed. Such observation could be understood in the light of relative increase in the degree of plastic deformation an frictional heat generate at higher rotational speed, which effect the dynamic recrystallization as well as the dynamic recovery at the TMAZ . In general, the Hardnessdecreases from the base metal towards the weld centerline.

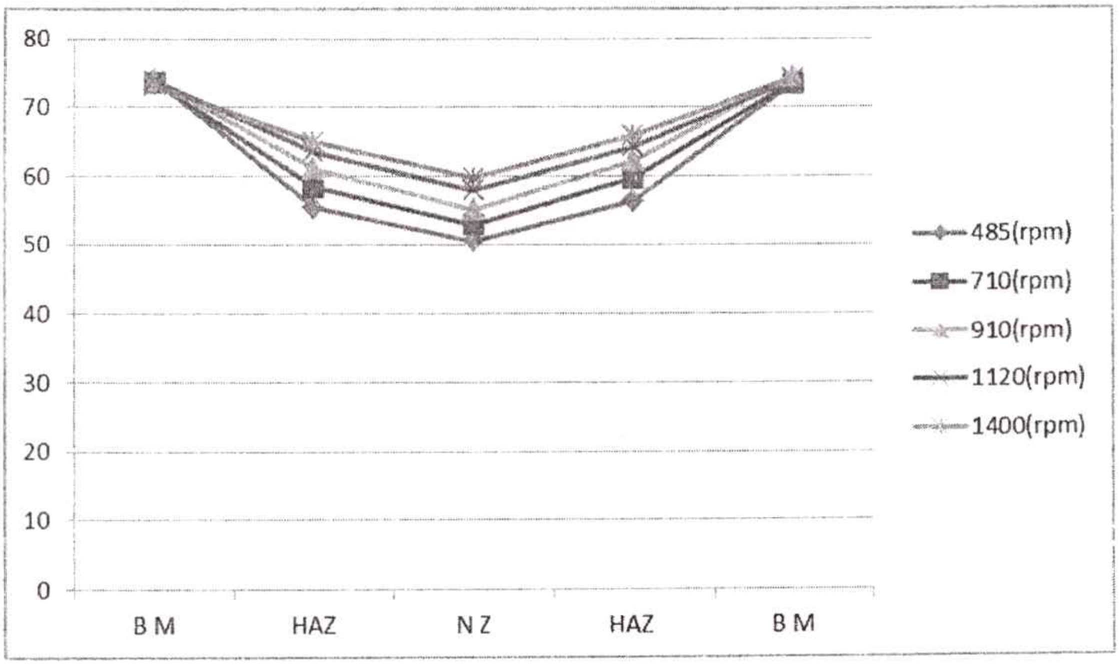


Fig.(19) Relation between hardness profile measurements and rotational speeds of Al6063-3mm

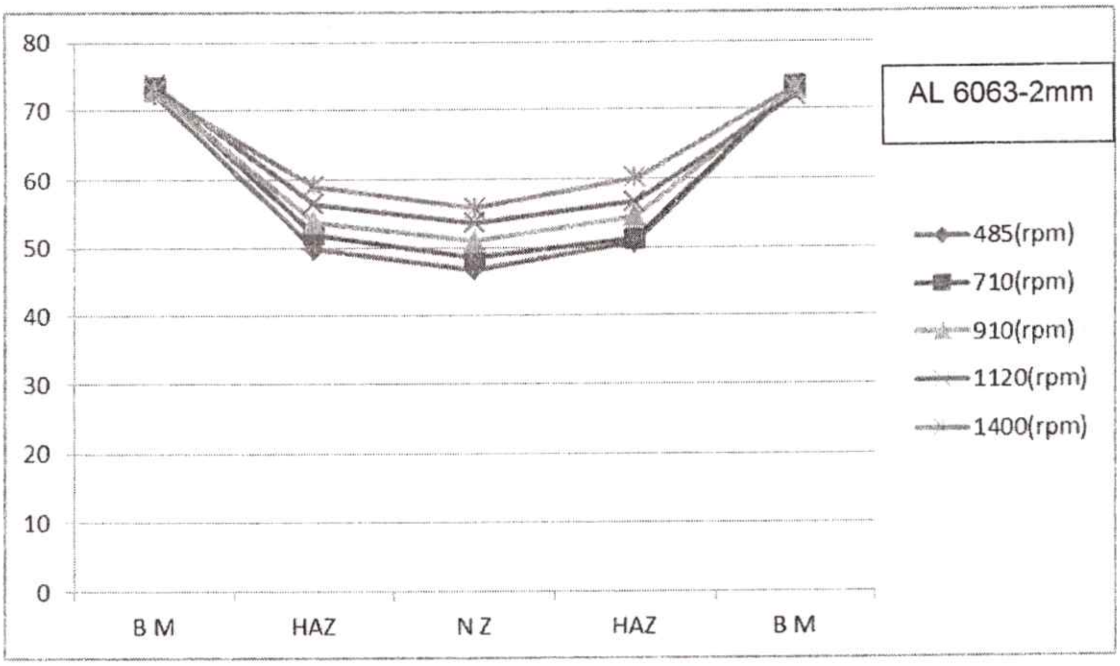


Fig.(20) Relation between hardness profile measurements and rotational speeds of Al6063-2mm

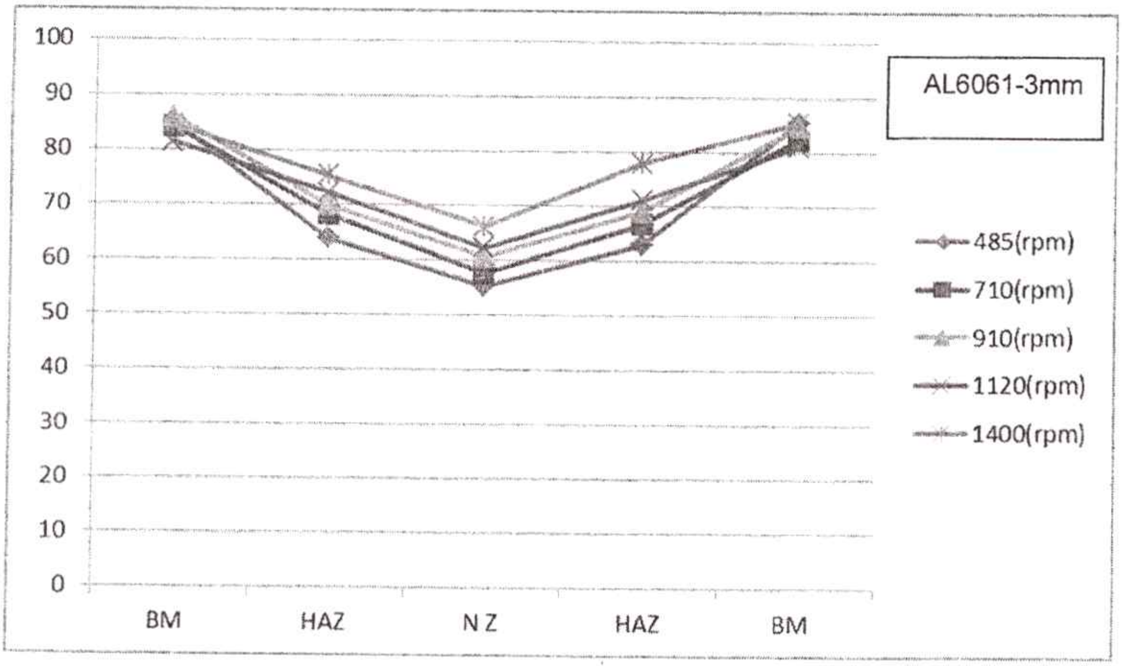


Fig.(21) Relation between hardness profile measurements and rotational speeds of Al6061-3mm

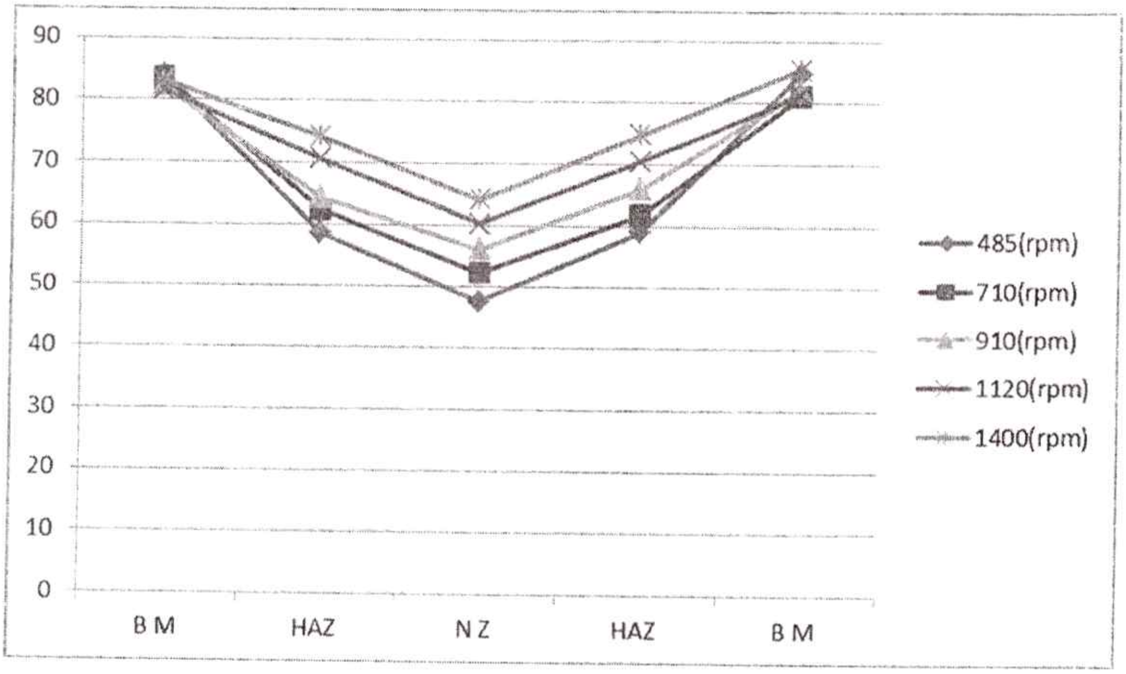


Fig.(22) Relation between hardness profile measurements and rotational speeds of Al6061-2mm

CONCLUSIONS

1-The cylindrical parts of Al(6061,6063)aluminum alloys were successfully achieved andallows toobtain the good-quality welds for application of the friction stirwelding.

2-The FSW efficiency increaseswith increase rotational speed and material thickness.

3-Theresulting microstructure hasbeen widely investigated by optical microscopy, putting in evidence the grain structure and precipitates distribution differences originated by the process.

4-Thedecrease in hardness at weld centerline increases by increasing the rotational speed.

5-Al6063 have showing a better tensile properties result to that of Al6061

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