Journal of Engineering and Development, Vol. ١٧, No.١, Mar. ٢٠١٣, ISSN ١٨١٣- ٧٨٢٢

Predict of residual stress behavior in aluminum friction stir welding by Leeb hardness method

Asst . Prof .Dr. Kadhim Kamil Resan
Al-mustansiriya University
Materials Engineering Department
e-mail: kadkinani@gmail.com

Abstract:

The friction stir welding method it is a modern methods for non- welding material using a milling machine and rotary pin, as a result of heat generated due to rotation of the pin, it generates stresses inherent and it is necessary to know the behavior or the value of these stresses. In this research a new method were invented to predict the behavior of the residual stresses . Three models of friction welding samples are designed at different rotating speed (١٥٠٠ rpm , ١٠٠٠ rpm and ٨٠٠ rpm) , then drawing a grid on each sample was drawn vertically and horizontally lines with spaces of ١٠ mm and ٥ mm respectively for each line, Leeb hardness were measured in each node .It found that the hardness is low in the line of welding and then increased at ٥-mm ,decreasing at ١٠ mm then another increase at ١٥ mm, these change in the value of hardness indicate a change of residual stresses value .

Keywords: *friction stir welding , Leeb hardness , residual stress*

أ.م.د. كاظم كامل رسن
قسم هندسة المواد
كلية الهندسة /الجامعة المستنصرية

الخلاصة :

طريقة اللحام الاحتكاكي من الطرق الحديثة نسبيا و التي تسخدم للحام المواد غير القابلة للحام مثل الألمنيوم باستخدام ماكنة التفريز و التحكم بالسرع الدورانية للقلم .و نتيجة الحرارة المتولدة بسبب دوران القلم فان ذلك يولد اجهادات كامنة ومن الضروري معرفة سلوك او قيمة تلك الاجهادات ,في هذا البحث تم ابتكار طريقة جديدة للتنبأ بسلوك تلك الاجهادات الكامنة باعتماد الصلادة Leeb حيث ان قيمة الصلادة تشير الى اجهادات اما شدية او انضغاطية في العينة .تم

تصنيع ثلاث نماذج من عينات اللحام الاحتكاكي باستخدام سرع دوران مختلفة: ١٥٠٠ دورة بالدقيقة و ١٠٠٠ دورة بالدقيقة و ٨٠٠ دورة بالدقيقة . بعدها تم رسم شبكة على كل عينة على شكل خطوط توازي خط اللحام و خطوط عمودية على خط اللحام و بمسافات ١٠ ملم و ٥ ملم على التوالي , وتم قياس صلادة نوع Leeb في كل عقدة و من خلال تلك القيم تم الحصول على سلوك الاجهادات الكامنة حيث كانت الصلادة منخفضة في خط اللحام ثم تزداد عند ٥ ملم لتعود بالانخفاض عند ١٠ ملم و ترتفع عند ١٥ ملم . ان هذا التغير بقيمة الصلادة هو مؤشر لتغيير قيمة الاجهادات الكامنة.

١.Introduction:

Friction stir welding (FSW) was invented at The Welding Institute (TWI) of the United Kingdom in ١٩٩١ as a solid-state joining technique and was initially applied to aluminum alloys .The rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and subsequently traversed along the joint line . Figure ١ illustrates process definitions for the tool and work piece.[١]

As a result of the tool action and influence on the workpiece, when performed properly, a solid-state joint is produced, that is, no melting.

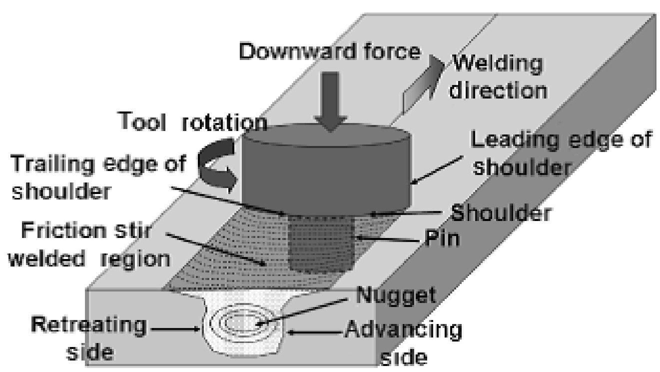


Fig. ١ Friction stir welding process [١]

C. Leitao and et al (٢٠٠٩)[٢] studied the tensile behaviour of similar and dissimilar friction stir welds in ١ mm thick sheets of two aluminium alloys (AA٥١٨٢-H١١١ and AA٦٠١٦-T٤) were analysed in their study.

P.M.G.P. Moreira and et al (٢٠٠٩)[٣] studied the mechanical and metallurgical characterization of friction stir welded butt joints of aluminium alloy ٦٠٦١-T٦ with ٦٠٨٢-T٦ was carried out. For comparison, similar material joints made from each one of the two alloys were used. Their study included microstructure examination, microhardness, tensile and bending tests of all joints.

Hakan Aydın and et al (٢٠٠٨)[٤] investigated the different heat-treated-states ٢٠٢٤ Al-alloy were friction stir welded. The tensile properties of the joints have a tendency to increase with the precipitation hardening of the base material.

P. Cavaliere and et al (٢٠٠٨) [٥] reported the effect of processing parameters on the mechanical and microstructural properties of dissimilar AA٦٠٨٢–AA٢٠٢٤ joints produced by friction stir welding .
K. Kumar and Satish V. Kailas(٢٠٠٨)[٦] investigated the influence of axial load, and the effect of position of the interface with respect to the tool axis on tensile strength of the friction stir welded joint.
K. Elangovan and V. Balasubramanian (٢٠٠٨)[٧] studied AA٦٠٦١ aluminium alloy (Al–Mg–Si alloy) which has gathered wide acceptance in the fabrication of light weight structures requiring a high strength-to-weight ratio and good corrosion resistance.
A. Scialpi and et al (٢٠٠٧)[٨] studied The effect of different shoulder geometries on the mechanical and microstructural properties of a friction stir welded joints .
Y.C. Chen and K. Nakata (٢٠٠٨)[٩] studied Al–Si and Mg–Al–Zn alloys were lap joined using friction stir welding during which the probe of the tool did not contact with the surface of the lower Mg–Al–Zn alloy sheet.
W.B. Lee and et al (٢٠٠٨) [١٠] studied the joint characteristics of friction-stir-welded A٣٥٦ alloys, especially the improvement of mechanical properties at the weld zone, with various FSW (friction stir welding) speeds.The tool produces the thermo mechanical deformation in workpiece where the frictional heating necessary for friction stirring. During the tool plunge, the rotating FSW tool is forced into the workpiece. The friction stirring tools consists of a pin, or probe, and shoulder. Contact of the pin with the workpiece creates frictional and deformational heating and softens the workpiece material; contacting the shoulder to the workpiece increases the workpiece heating, expands the zone of softened material, and constrains the deformed material.[١١]

٢. Experimental Procedure:

The experimental work, in this study includes the following points :

- Preparing the milling machine, frame and pin shoulder.
- Manufacturing stir welding specimens with different rotating speeds (٨٠٠ , ١٠٠٠, ١٥٠٠ rpm)
- Finding the chemical composition of specimens .
- Preparing the tensile test specimens according ASTM(D٦٣٨ [١٢]) Standards.
- Meshing the specimens with leeb hardness test.

٢,١ Materials and Welding:

Preparation of three pairs of equal dimension models of aluminum ٣٠٠٣ plates , with dimension ١٠٠*٢٠٠ . The milling machine was prepare and using tool was made of stainless steel with dimensions of (٦mm) pin diameter and (٢١ mm) of shoulder diameter and the length of the pin (٢,٦ mm), the shoulder will be in attach with plate the pin is rotate interface between two plate :

- Group I: including FSW specimen; the rotating speed is ١٥٠٠ and linear velocity is ٢٥ mm/sec .
- Group II : including FSW specimen; the rotating speed is ١٠٠٠ and linear velocity is ٢٥ mm/sec .
- Group III : including FSW specimen; the rotating speed is ٨٠٠ and linear velocity is ٢٥ mm/sec .

S

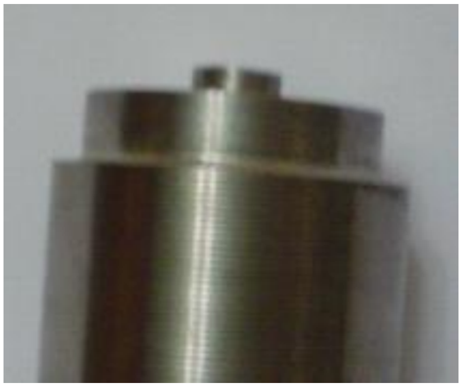
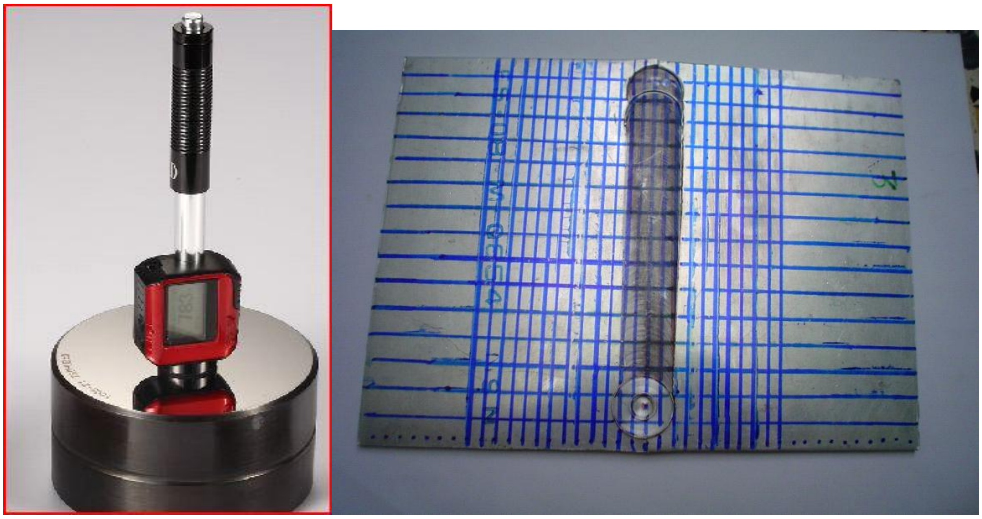


Fig.(٢) Friction stir welding tool

٢,٢ Hardness Testing and Residual Stress Behavior:

The heterogeneity in mechanical properties across the welds was evaluated by performing several Leeb hardness measurements transversely to the weld direction (Fig. ٣). Draing is a network of lines and nodes on a sample consisting friction welding and linear distance ٥ mm from each other and occasional lines about ١٠ mm from each other and the Leeb hardness is measured for each node .



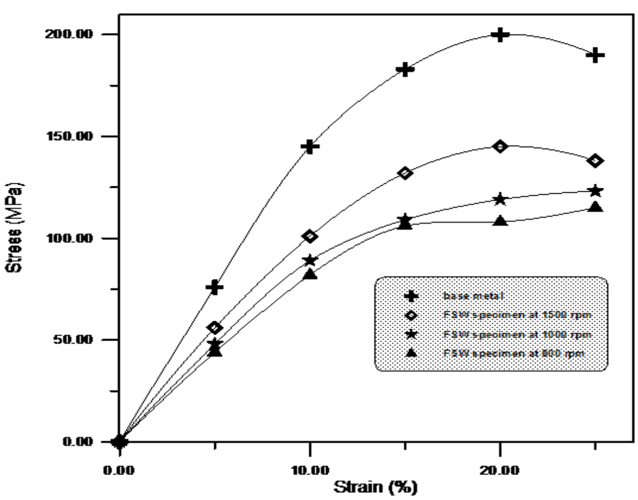
Fig(٣) Leeb hardness device and meshing stir welding specimen

٣. Experimental results and discussions:

The experimental results presented in this paper, include the mechanical properties and hardness distribution about line of stir welding.

٣,١ Mechanical Properties:

The mechanical properties of all material are shown in Fig (٤). In this figure , the strength of materials for base metal is larger than the specimens with stir welding because of some defects were generated during the friction stir welding .



Fig(٤) Tensile test results for base metal , FSW specimens at : ١٥٠٠ rpm ,١٠٠٠ rpm and ٨٠٠ rpm

٣,٢ Chemical composition :

The chemical composition of the aluminum plate alloy is present in the table(١).

Table ١: Chemical composition of the base materials

Elements	*Si*	*Cu*	*Zn*	*Mn*	*Fe*	*Pb*	*Mg*	*Ti*	*Co*	*Al*
Measured	٠,١٨٧	٠,١٠٦	٠,٠٤٢	١,٠٩	٠,٣٠٣	٠,٠٠٣	٠,٠	٠,١٥٧	٠,٠١٣	*Balance*

٣,٣ Leeb Hardness mesh results :

The lines were drawing including; four horizontal parallel lines of weld line spacing ١٠ mm and six perpendicular lines spacing ٥ mm this mesh including about ٢٤ nodes , from the node location the residual stress behavior is known , the high value of hardness comparing with base material , it mean that compression residual stress.

Figure(٥) to figure(٩) show the leeb hardness type with welding line the different value of leeb hardness due to heat generate by rotating pin on the two pieces , the heat cause different residual stress with different zone .

Fig.(٥) Leeb hardness value with distance from stir welding line at ١٠ mm from start

Fig.(٦) Leeb hardness value with distance from stir welding line at ٢٠ mm from start

Fig.(٧) Leeb hardness value with distance from stir welding line at ٣٠ mm from start

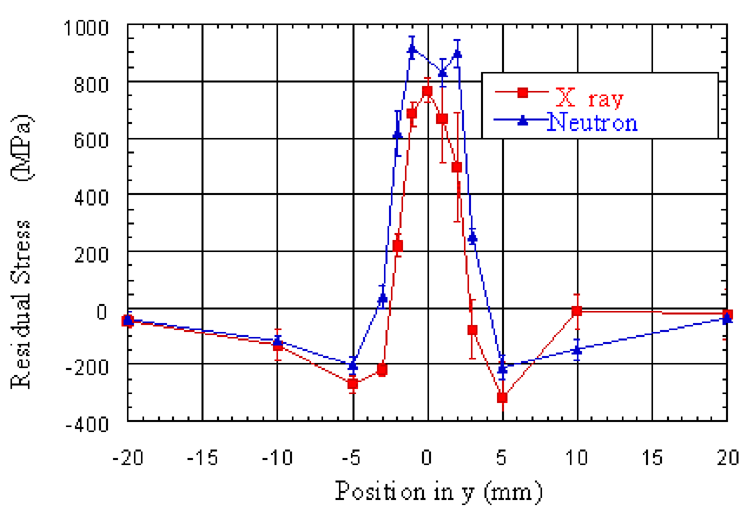
Fig.(٨) Leeb hardness value with distance from stir welding line at ٤٠ mm from start

From Fig.(٨) the hardness is increasing and then decreasing gradually at ٥ mm and then to rise slightly at ١٥ mm from the weld line, also , at speed ١٥٠٠ rpm less than the value of hardness at ٥ mm compared with ٨٠٠ rpm and ١٠٠٠ rpm, these behavior due to the heat generated at high speed significantly affect the crystal size and influence on the values of hardness,the shoulder of the tool not only provides additional heat generated by friction but also prevents plasticized material to escape.

Fig.(٩) Leeb hardness value with distance from stir welding line at ٥٠ mm from start

The variation of Leeb hardness results with distance in x-y plane due to different heat transfer between pin and base metal . These different values means the different value of residual stress . The residual value behavior depend on the Leeb hardness distribution .

Fig(١٠) The residual stress by X-ray diffraction and corrected average neutron diffraction results for residual stress in a aluminum wasp alloy linear friction weld. [١٣]



The behavior of residual stress in Fig(١٠) similar to behavior of hardness value distribution as shown in figure(٥) to figure(٩) ,That the change in the value of hardness resulting from the change in the value of the heat transmitted generated as a result of the speed of revolution of the pin and show that the values of hardness near the welding line is low then rise and then begin to decreasing gradually and then go up the value of hardness, that this behavior is similar to some extent the behavior of stresses inherent in other ways, however, in some way, as in Figure (١٠) notes that the value of hardness started yet high and then cut it all away from the welding line and then return to rise once more likely, that the main reason for this behavior is the difference in the distribution of heat in the vicinity of the end of the operation of the piece.

٥. CONCLUSIONS:

The present work has reached to the following conclusions:

١. The mechanical properties of base metal higher than stir welded specimen.

٢. The hardness in stir welding method depend on the rotating speed of pin and linear velocity when the rotating is increased the Leeb hardness is increased.

٣. The residual stress behavior was predicted from the hardness values distribution.

References:

- Rajiv S. Mishra " ***Firiction Stir welding and processing*** " copyright , ٢٠٠٧ ASM international .
- C. Leitao , R.M. Leal , D.M. Rodrigues , A.Loureiro , P. Vilac ***" Formability of similar and dissimilar friction stir welded AA ٥١٨٢-H١١١ and AA ٦٠١٦-T٤ tailored blanks*** " J of materials and design ٣٠ , ١٠١٠١٠٨, ٢٠٠٩.
- P.M.G.P. Moreira , T. Santos , S.M.O. Tavares , V. Richter-Trummer , P. Vilaça , P.M.S.T. de Castro, " ***Mechanical and metallurgical characterization of friction stir welding joints of AA٦٠٦١-T٦ with AA٦٠٨٢-T٦***" J. of Materials and Design ٣٠ (٢٠٠٩) ١٨٠–١٨٧ .
- Hakan Aydın,Ali Bayram,Agah Uğuz,Kemal Sertan Akay "***Tensileproperties of friction stir welded joints of ٢٠٢٤ aluminum alloys in different heat-treated-state***" J. of Materials & Design , Volume ٣٠, Issue ٦, June ٢٠٠٩, Pages ٢٢١١–٢٢٢١.
- P. Cavaliere[a], ,G. Campanile,F. Panella, A. Squillace ***"Effect of weldingparameters on mechanical and microstructural properties of AA٦٠٥٦ joints produced by Friction Stir Welding"*** Journal of Materials Processing Technology, Volume ١٨٠, Issues ١–٣, ١ December ٢٠٠٦, Pages ٢٦٣–٢٧٠
- K. Kumar, Satish V. Kailas ***" On the role of axial load and the effect of interface position on the tensile strength of a friction stir welded aluminium alloy"*** J. of Materials & Design Volume ٢٩, Issue ٤, ٢٠٠٨, Pages ٧٩١–٧٩٧

- K. Elangovan,V. Balasubramanian "***Influences of toolpin profile and tool shoulder diameter on the formation of friction stir processing zone in AA ٦٠٦١ aluminium alloy"*** J. of Materials & Design Volume ٢٩, Issue ٢, ٢٠٠٨, Pages ٣٦٢–٣٧٣
- Scialpi ,L.A.C. De Filippis, P. Cavaliere ***"Influence of shouldergeometry on microstructure and mechanical properties of friction stir welded ٦٠٨٢ aluminium alloy"*** J. of Materials & Design Volume ٢٨, Issue ٤, ٢٠٠٧, Pages ١١٢٤–١١٢٩
- Y.C. Chen,K. Nakata "***Frictionstirlap joining aluminum and magnesium alloys***" J. of Scripta Materialia ,Volume ٥٨, Issue ٦, March ٢٠٠٨, Pages ٤٣٣–٤٣٦.
- W.B. Lee, Y.M. Yeon, S.B. Jung "***The improvement of mechanicalproperties of friction-stir-welded A ٣٥٦ Al alloy" J***. of Materials Science and Engineering: A Volume ٣٥٥, Issues ١–٢, ٢٥ August ٢٠٠٣, Pages ١٥٤–١٥٩
- Christian B. Fuller "***Friction Stir Tooling : Tool Materials and Design*** "ASM International , ٢٠٠٧ .
- ASTM D٦٣٨-١٠ Standard Test Method for Tensile Properties of plastics, ٢٠٠٦ .
- A. Youtsos , C. Ohms ***" NDT Based on Neutron Techniques in Support of Structural Integrity Assessment "*** ٣nd International Conference on NDE in Relation to Structural Integrity for Nuclear and Pressurized Components , Nov ١٤-١٦, ٢٠٠١,Seville , Spain .