RESIDUAL STRAIN EVALUATION OF FRICTION STIR WELDED ALUMINIUM USING NEUTRON DIFFRACTION TECHNIQUES

M. Refai Muslih[1] , Triyono[2], Tri Hardi Priyanto[1], Sutiarso[1]

[1]*Neutron Scattering Lab., Center for Technology of Nuclear Industrial Materials. Gedung 40 Kawasan PUSPIPTEK Serpong*

[2]*Mechanical Engineering Department, Sebelas Maret University, Surakarta*

e-mail address of corresponding author: rifai@batan.go.id

ABSTRACT

Residual strain evaluations have been performed in the aluminum plate due to friction stir weld (FSW) using neutron diffraction techniques. The sample size was 130x50x6 mm^3 and the welding done along the side of 50 mm. There are two pieces of samples were evaluated with variations of feeding rate, namely 13 and 7.3 mm/s. Welding performed on the both surface of the sample using 18 mm in diameter and 4 mm length and tip diameter of steering tool. Residual strain measurements performed by using DN1 installed at beamtube number 6 of RSG-GAS Serpong. The residual strain measurement had been performed on Transverse and Normal direction using hkl plane of (220) with a scattering angle around 79 degrees. Incident slit and the detector used is 2x2 and 2x10 mm^2, respectively. Residual tensile strain was observed in both samples in the direction Normal to the largest value is 1200 μm/m on samples with a feeding speed 13 mm/s, whereas the sample with a feeding speed of 7.3 mm/s is 800 μm/m. Compression residual strain was found in both samples in Transverse direction, with the largest value of 900 and 700 μm/m with feeding speed 13 mm/s and 7.3 mm/s, respectively.

ABSTRAK

Penilaian-penilaian tegaran lebihan dalam plat aluminium disebabkan kimpalan adunan geseran (FSW) dengan menggunakan teknik-teknik belauan neutron adalah dibentangkan dalam kertas kerja ini. Saiz sampel ada 130x50x6 mm3 dan kimpalan buat sepanjang sebelah 50 mm. Terdapat dua helai contoh-contoh telah dinilaikan dengan kelainan kadar makanan, iaitu 13 dan 7.3 mm/s. Kimpalan dilakukan keatas kedua-dua permukaan sampel menggunakan 18 mm dalam garis pusat dan 4 mm panjang dan mencurahkan garis pusat mengemudi alat. Ukuran-ukuran bentuk kekal mempersembahkan dengan menggunakan DN1 yang dipasang dilohongalur neutron 6 reaktor RSG-GAS Serpong. Ukuran tegaran lebihan telah dibuat pada arah 'Transverse' dan 'Normal' menggunakan satah hkl (220) dengan satu sudut penyerakan sekitar 79 darjah. Slit temuan dan pengesan menggunakan ialah 2x2 and 2x10 mm^2, masing-masing. Terikan tegangan lebihan telah diperhatikan dalam kedua-dua contoh-contoh dalam arah Normal bagi nilai terbesar ialah 1200 μm/m atas contoh dengan kelajuan penyuapan 13 mm/s, manakala sampel dengan kelajuan penyuapan 7.3 mm/s ialah 800 μm/m. Tegaran lebihan mampatan ditemui dalam kedua-dua contoh-contoh dalam arah 'Transverse', dengan nilai terbesar 900 dan 700 μm/ dengan memberi kelajuan suapan 13 mm/s dan 7.3 mm/s, masing-masing.

Keywords: Friction stir weld, residual strain, neutron diffraction, DN1

INTRODUCTION

Friction stir weld was first introduced in the 1990s by The Welding Institute. This welding method is one kind of solid state welding, where no part of the metal to be jointed is melted. The binding between the welded materials carried out at a temperature slightly below its melting point. Thus there is no change in any physical properties of the welded materials. Likewise, the heat affected zone can be minimized. Materials that are not easily connected with the melting process can be performed with this method.

The heat used for welding comes from friction between the shoulder tools and welded object. While the jointing process carried out by probe of the tool that also serves as a stirrer. The pressure is given on tools also serve as a compacting of object that are connected, so that after mixing process, the section is not scattered irregularly.

The simplest configuration of this system can be obtained using a conventional milling machine. Feeding rate, rotation speed of the tool can be easily changed to fit with the types of materials to be welded or its dimensions. Due to the compression force on the tools is a very important parameter in this process, the milling machine is no longer suitable for materials that require considerable pressure. Milling machines in general can still be used to perform FSW to the Aluminium samples with a thickness of 6 mm for one pass welding.

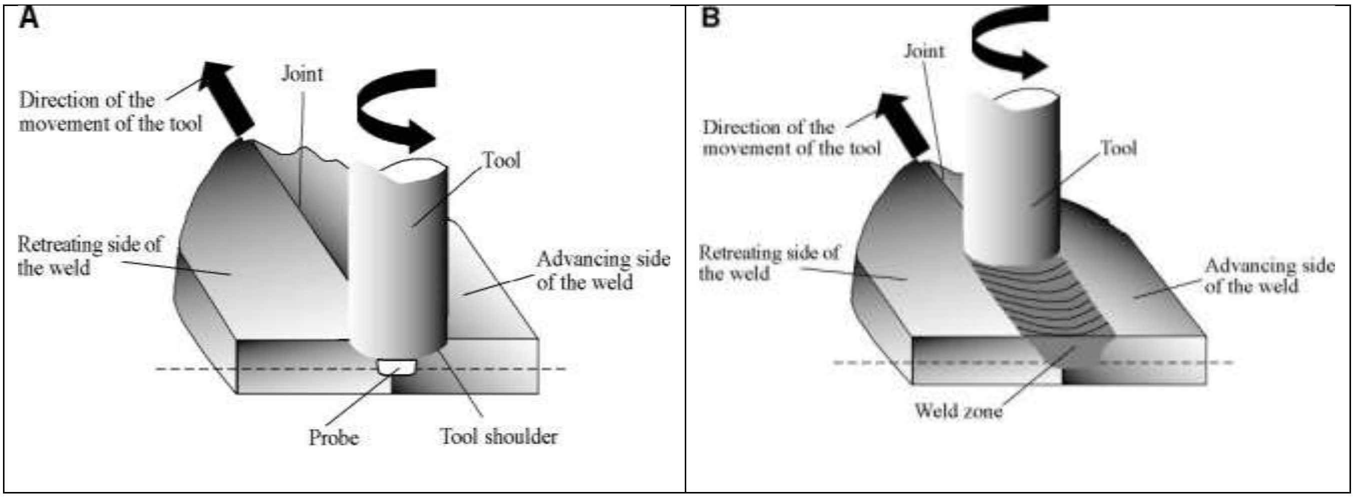
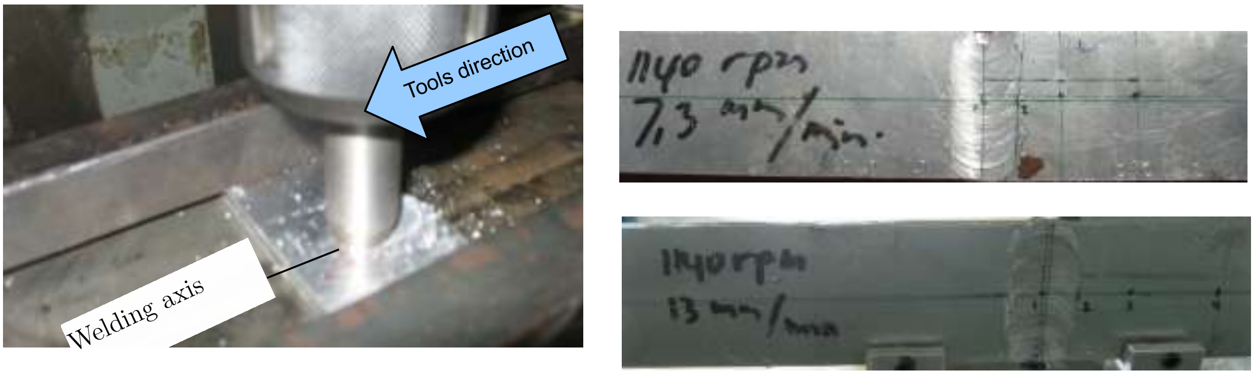


Figure 1: Schematic drawing of FSW. Two materials to be welded affixed to one another such that the connection path is crossed by the probe (A), Exposed portion of the sample to the welding process and heating caused by the shoulder (B).

METHODOLOGY

Sample plates are made of aluminum material that generally used and easily found in Indonesian market. The sample size was 130x50x6 mm^3 and the welding had been done on the side with a length of 50 mm. Before welding, the samples were characterized of the crystalline direction on the hkl plane of (220). This process is done so that samples can be measured lattice spacing them with neutron scattering in the direction parallel and perpendicular to the axis of the welding.

The welding had been done using simple milling machine at the manufacture laboratory of mechanical engineering department, Sebelas Maret University in Surakarta. The welding process and results are shown in figure 2.



A B

Figure 2. FSW welding process with a milling machine (A). Welded samples, green line perpendicular to the welding axis is the location of the measurement had been performed (B)

Two pieces of samples had been made with variations of feeding speed 7.3 mm/s and 13 mm/s and 1140 rpm rotation speed of the tools for both samples. The tools had been tilted 2° from the normal direction of the plate. The plunge depth was 0.5 mm below the plate surface. During the welding takes place, two parts to be welded held tightly by using a sample holder.

The measurements of residual strain had been performed by neutron diffraction using DN1, the neutron diffraktometer for residual stress measurement, installed at 6th neutron beam tube of multipurpose reactor GA Siwabessy Serpong. Lattice spacing measurements carried out on the hkl plane of (220) with a scattering angle of about 79°. Gage volume of the measured specimen is limited by using combination of incident slit and detector slit with size of size 2x2 and 2x10 mm^2 respectively. Lattice spacing measurement had been performed on the Transverse and Normal as shown in Figure 3. The measurement of lattice spacing in Axial direction couldn't be done due to existance of the texture in the specimen.

The measurement points and the configuration of specimen on DN1's sample table for transverse direction measurement are shown in Figure 3.

The diffractogram obtained from each measurement were fitted using Gauss distribution to obtain the peak position and its uncertainty. Stress-free samples (d0) obtained from measurements at the point as far as 60 mm from the welding axis. Lattice spacing calculation is done using the Bragg equation (1). The strain (ε) was calculated using equation (2).

$$\lambda = 2 * d * \sin(½ \, . \, 2\theta) \; .... \; (1)$$

where, λ : neutron beam wavelength (nm)

d : Lattice spacing (nm)

2θ : Diffraction angle (deg.)

$$\varepsilon = \Delta d/d = (d - d_0) / d_0 \; .... \; (2)$$

where, ε : strain

d : lattice spacing at measured position (nm)

d_0 : stress-free lattice spacing.

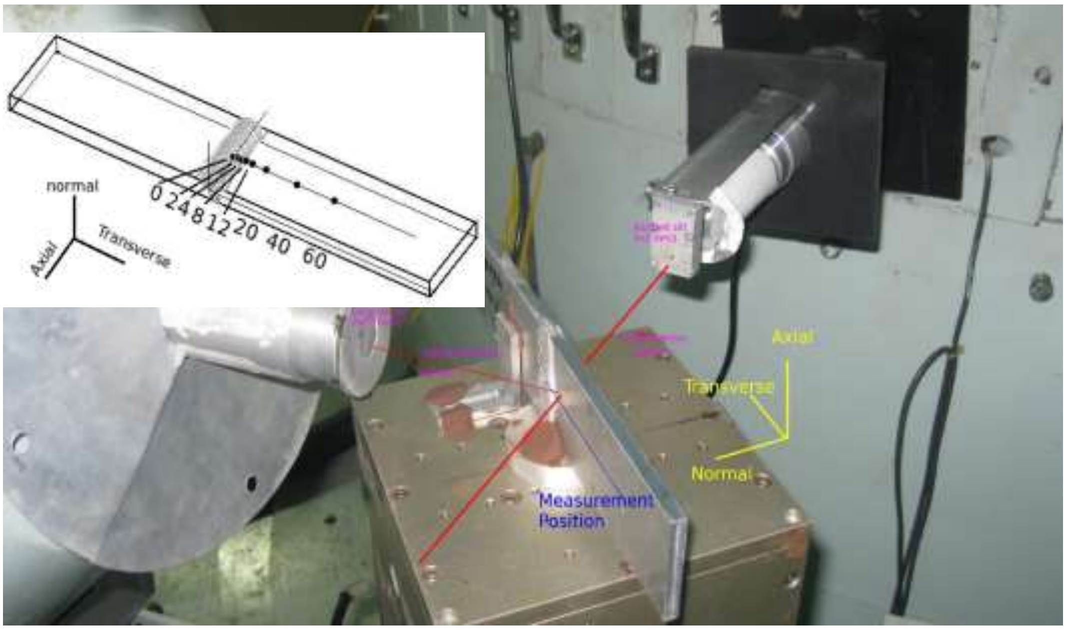


Figure 3. The position of specimen during the measurement of lattice spacing in transverse direction, the neutron beam cross section is limited by the incident slit (right side) and detector slit (left side). The gage volume positioned in the middle thickness of the sample. The principal axis of mesurement and the position started on the welding axis and move a way along the line with the distance of 2, 4, 8, 12, 20, 40, 60 mm (inset).

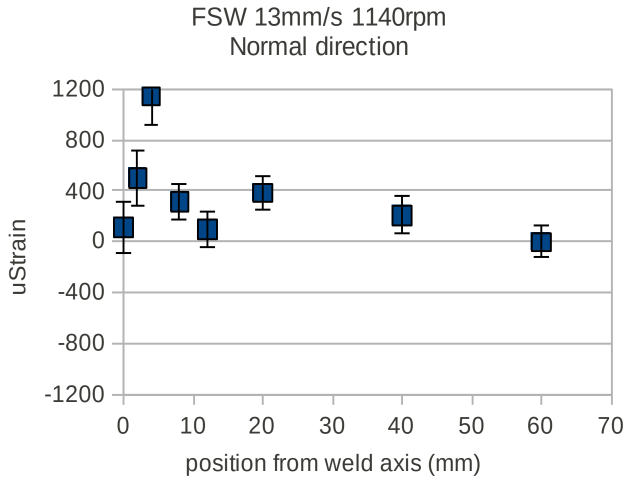
Uncertainty of strain derived from the strain equation. Strain uncertainty is calculated by taking into account only the uncertainty of the measurements obtained at every point and the measurement uncertainty of d_0. Equations to obtain the strain uncertainty is:

$$U_{\varepsilon}=\sqrt{\left(\frac{\partial \varepsilon}{\partial \theta}\times U_{\theta}\right)^2+\left(\frac{\partial \varepsilon}{\partial \theta_0}\times U_{\theta 0}\right)^2} \qquad \text{...............................(3)}$$

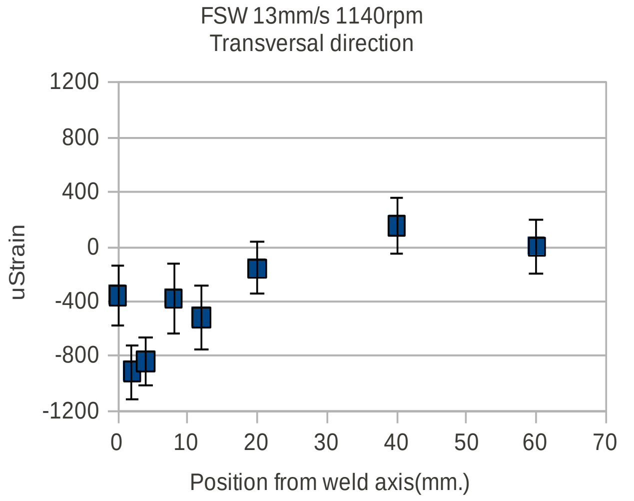
RESULTS AND DISCUSSIONS

Residual strain in the Normal direction are tensile at all measurement positions on the sample with a feeding speed 13 mm/s, whereas the feeding speed of 7.3 mm/s at a position away from the welding area is compressed. The residual strain present in the specimen is proportional to its feeding speed. The peak of residual strain position, however, sifted away from welding axis due to higher feeding speed. The peak position af residual strain is consistent with diameter of 4 mm tool's probe, so that the peak position of the residual strain at low speed is 2 mm away from the welding axis. Peak position of residual strain is further away from the welding axis at a faster feeding speed in accordance with the fact that the heat arising from the higher feeding speed is also greater. Although no numerical data regarding the rising temperature at the specimen during welding, but one can feel the temperature change is proportional to the feeding speed.

In the transverse direction, the residual strain is a compression at all points of measurement. As with the Normal direction , the rest of the transverse residual strain is also proportional to the feeding speed which faster feeding speed, greater the residual strain. Very strong binding of the parts that will experience the FSW welding does not have the opportunity to make these parts for relaxation during and after welding. This is one reason the onset of residual strain in the direction transverse press. This residual strain will be greater as the temperature rises due to increase in feeding speed.



A



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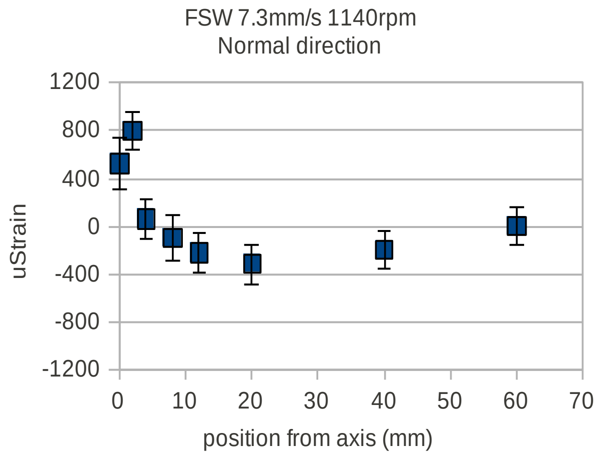

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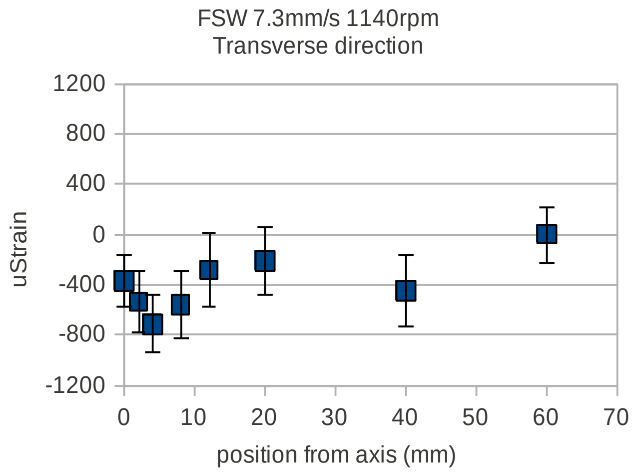

D

Figure 4. Residual strain in the sample along position line on the sample with a feeding speed 13 mm/s for: Normal direction (A), Transverse direction (B), samples with a feeding speed of 7.3 mm/s Normal direction (C), Transverse direction (D).

The presence of texture in the specimen causes the measurement of residual strain in the axial direction can not be done. Nevertheless the results of measurements on the Normal and Transverse directions have given satisfactory results in which equilibrium of residual strain can be obtained simply by summing them.

The evaluation of the residual strain will be more complete if the sample is measured with increasing number of feeding speed variation changes more and more speed. However, residual strain measurements by neutron scattering techniques of data collection takes a relatively long time. The total time required to perform measurements of these samples is approximately 35 hours.

CONCLUSIONS

The residual strain occurring in the normal direction was tensile, while in transverse direction was compression strain occurred. Both the normal and transverse directions, the highest concentration of residual strain was in the area around the tool's probe.

The tendency of the residual strain that occurs is proportional to the magnitude of feeding speed.The feeding speed also affects the location of residual strain concentration around the tool's probe.

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