Mechanical and microstructural characterization of ST 37 butt joints by friction stir

by Sulardjaka Sulardjaka

Mechanical and microstructural characterization of ST 37 butt joints by friction stir

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Abstract. The aim of this research is to investigate mechanical and microstructure characteristic of ST 37 Friction Stir Welded (FSW) butt joints. The rolled plate of ST 37 steel was used as the base material. Tungsten carbide (20 mm on diameter) was used as the tool. The FSW process was conducted on a CNC milling machine. FSW joints were produced at 1500 and 2000 rpm of rotational speeds variation and the transverse speed is constan at 40 mm/min. Furthermore, the influence of rotational speed on the microstructure and mechanical properties of the joints were investigated based on parameters mentioned above. The tensile test was done based on JISZ 2241 standard. Microhardness was investigated based on ASTM E 384. Joint microstructure was also analyzed by optic microscopy. As a result, FSW joint at 2000 rpm tool rotation shows higher tensile strength, yield strength and percentage of elongation in compare to 1500 rpm rotaton speed. In addition, its tensile strength is about 5 % lower than Base Material (BM) which its ductility decreases up to 30 %.

1. Introduction

Friction Stir Welding (FSW), one of newly welding processes is unveiled by The Welding Institute (TWI), England at 1991 [1]. It utilizes friction produced by contact between tool and specimens in solid-state. It is might be promising welding process which helds precision joints better than the one encountered in fusion welding [2]. In its development, researchers tend to conduct research in stainless steel [3-5], aluminium [6-7], and steel [8-14]. Its principle is joining two plates which is similar or dissimilar in shape using tool that rotates and passes through along the plate. It performs under conditions which are shoulder is fully contacted and the pin is completely inserted and moves in transverse direction towards the weld. Consequently, the transverse and rotated effects of the pin and shoulder breed heat which softens the specimen in solid-state and welds the plates [15]. Some findings explore microstructure and mechanical properties of dissimilar materials such as joining ST 37 and stainless steel 304 [16]. Due to this, we have intention on delving into further information of mechanical properties and microstructure study of weldments performed in high rotational speed on carbon steel ST 37. The reason why we chose ST 37 because of some considerable advantages such as light in weight and good in formability.

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2. Experimental procedure

The material used in the research was rolled plate of ST 37 (100x70x30 mm). The shouldered pin tool is cone-pin shaped tool made form Tungsten Carbide as shown in **Fig.1.** FSW processes were done by contacted the rotating tool into the material surfaces with feeding depth 0,02 mm. Then, the rotating tool was moved in transverse direction with velocity 40 mm/min. The FSW products are shown in **Fig.2.** Tensile test of FSW joint was conducted on Shimadzu UH1000 kNI tensile machine based on JIZ 2241 standard test. Microhardness of FSW joining was tested based on ASTM E 384 by Mitutoyo Micro Vickers Hardness Testing Machines HM-210. The microstructure was analyzed by optic microscopy on HNO_3 and CH_3OH etched specimens.

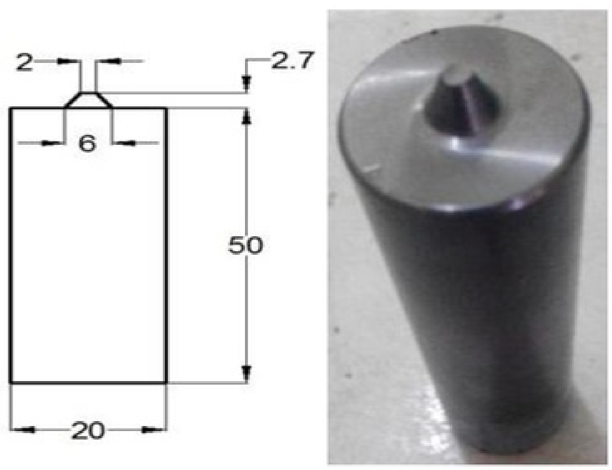
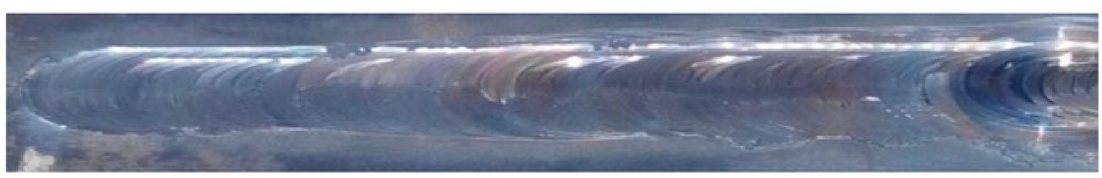
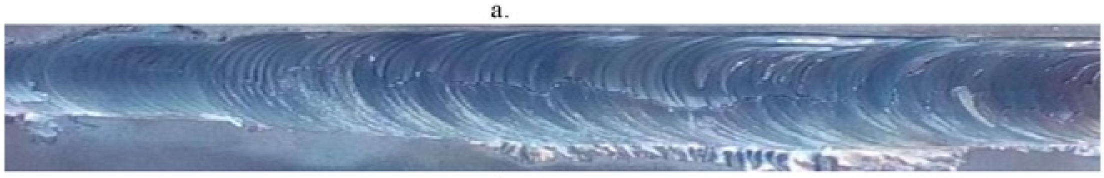


Fig. 1 Dimension of the tool



a.



b.

Fig 2. FSW joinning products (a) rotational speed 2000 rpm (b) rotational speed 1500 rpm

3. Result and discussion

3.1. Tensile test

St 37 with a 30 mm thickness were successfully welded at all given welding conditions. The tensile strentgh of raw material, FSW joinning at 2000 rpm and 1500 rpm rotational speed is shown in **Table 1**. Yield strength (YS) and ultimate tensile strength (UTS) of the stirred zone tend to increase with an increasing tool rotating speed. The yield strength of specimens carried out under 2000 rpm reached a peak at 329 MPa which was higher than other specimens were about 315 MPa and 280 MPa respectively. On the other hand, the Ultimate Tensile Strength (UTS) of raw material peaked up at 372 MPa which higher than other performed specimens of different rotational speed which are 350 MPa for 2000 rpm and 331

MPa for 1500 rpm. To sum up, specimen which welded by 2000 rpm has better elongation at value 25% which compares to 1500 rpm at value 10 %.

Table 1. Tensile properties of raw material, FSW 1500 rpm and FSW 2000 rpm

Specimen	YS (MPa)	UTS (MPa)	Elongation (%)
Raw material ST 37	315	372	36
FSW 2000 rpm	329	350	25
FSW 1500 rpm	280	331	10

3.2. Hardness test

Microhardness result was processed in 15 points which were started at a point in the middle of Stir Zone (SZ) and 7 points every 1 mm in range on each side where it was located on Thermo-Mechanical Affected Zone (TMAZ), Heat Affected Zone (HAZ) and Base Metal (BM). It was illustrated in graph that was shown in **Fig. 3.** A SZ with a tool rotating speed of 1500 - 2000 rpm showed a high hardness are around 250 Hv, while the hardness of the BM is around 150 Hv. However, it is found that SZ of 1500 rpm was higher than that 2000 rpm speeds. The SZ points of specimens in variance of rotational speed had highest hardness, they reached peaks at 240.7 HV and 239.0 HV for 1500 rpm and 2000 rpm respectively. Otherwise, the lowest hardness was found in BM.

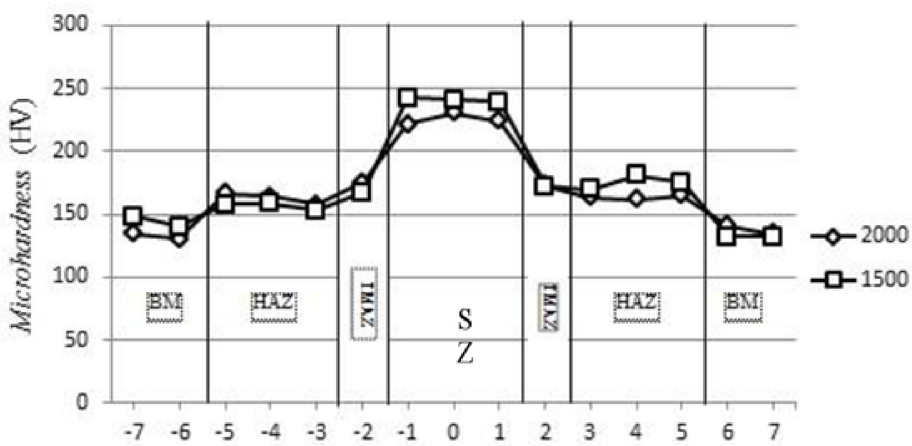
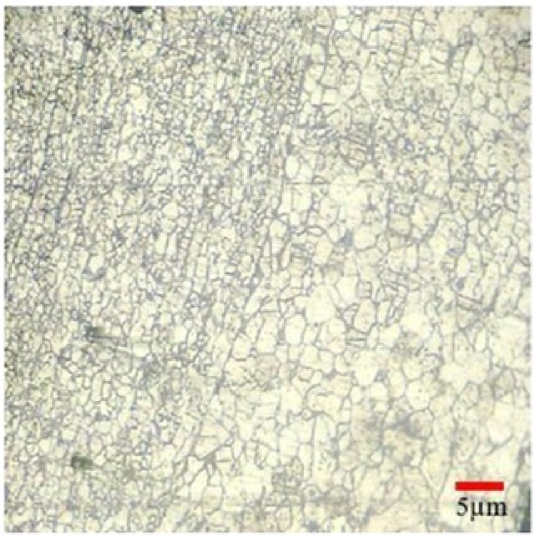
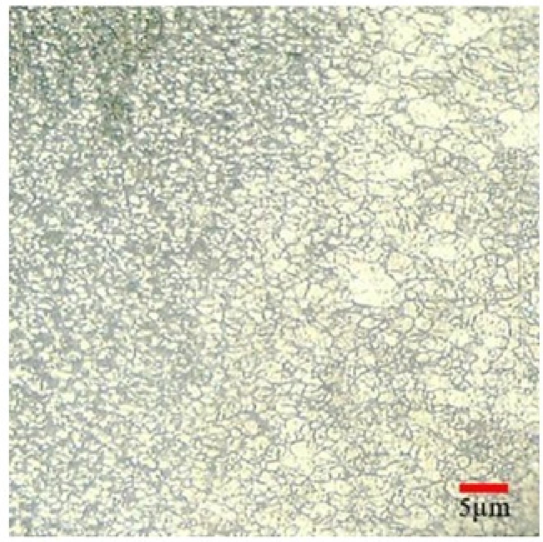


Fig. 3. Hardness distributions of friction stir welded St 37 steel at various tool rotating speeds

3.3. Microstructure study

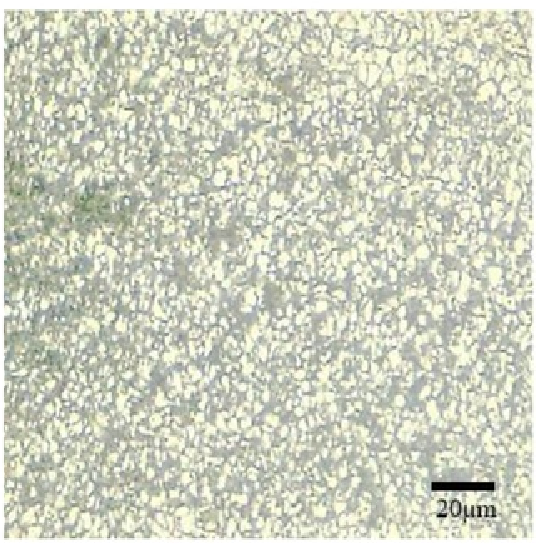
Optical micrographs of friction stir welded St 37 steels in the transverse cross section are shown in **Fig. 4**. and **Fig. 5**. The microstructure of SZ and WZ defines a change in the shape of ferrite and pearlite grains where the ferrite and pearlite grains are getting smaller than BM.

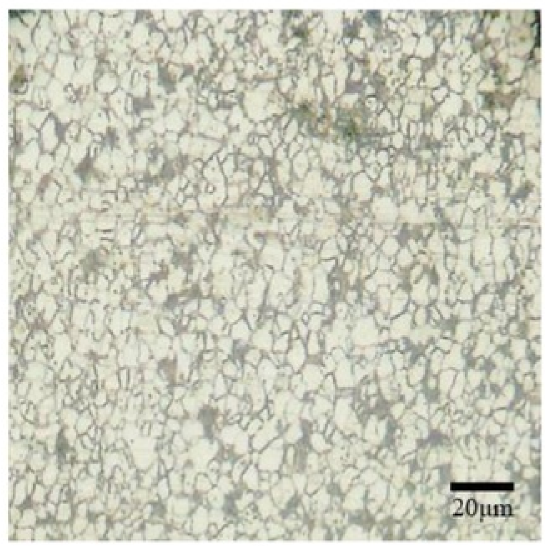




a. b.

Fig. 4. Microstructure images of SZ and HAZ (a) 1500 rpm (b) 2000 rpm





a. b.

Fig. 5. Microstructure images of Weld Zone (a) 1500 rpm (b) 2000 rpm

4. Conclusion

It can be proven that Friction Stir Welding can be performed in Carbon Steel St 37 under parameters: tranverse speed at 40 mm/min and variances of high rotational speed at 2000 rpm and 1500 rpm. FSW with 2000 rpm tool rotation give higher tensile strength than FSW at 1500 rpm rotation. Stir Zones of FSW products have greater value of hardness than base metal.

References

1. T. M. Wayne & Nicholas, E. D., Friction stir welding for the transportation industries, **18**, 269-273 (1997)
2. R. Seerangan, V. Balasubramanian, S. Malarvizhi, A.G. Rao, Def.. Tech., **11**, 308-317 (2015)
3. A.P. Reynolds, W. Tang, T.G. Herold, H. Prask, Scripta Mater, **48**, 1289-1294 (2003)

4. J.C. Lippold, D.J. Kotecki, Welding metallurgy and weldability of stainless steels, (2005)
5. S.H.C. Park, Y.S. Sato, H. Kokawa, K. Okamoto, S. Hirano, M. Inagaki, Sci Tech. Weld. Joint., **10** (2005)
6. S.Y. Tarasov, V.E. Rubtsov, E.A. Kolubaev, Wear, **318**, 130-134 (2014)
7. Z. Khan, Z. A. Khan, A. N. Siddiquee, Mater. To. Proceedings **2**, 1450-1457 (2015)
8. V. L. Manugula, K. V. Rajulapati, G. Madhusudhan Reddy, R. Mythili, K. Bhanu Sankara Rao, Met. & Mater. Transc. A., **48**, 3702-3720 (2017)
9. R. Ramesh, I. Dinaharan , Ravi Kumar , E.T. Akinlabi, Mater. Sci. & Eng, **A687**, (2017)
10. A.Pradeep, S. Muthukumaran, Mater & Des., **5**, 25-35 (2013)
11. Y. Liu, D. Dong, L. Wang, X. Chu, P. Wang, M. Jin, Mater & Des., **A627**, 296-305 (2015)
12. L.N. Brewer , M.S. Bennett , B.W. Baker , E.A. Payzant , L.M. Sochalski-Kolbus. Mater. Sci. & Eng., **A647**, 313-321 (2015)
13. A. M. El-Batahgy, T. Miura, R. Ueji, H. Fujii, Mater. Sci. & Eng.,**A651**, 904–913 (2016)
14. J. Rodriguez , A.J. Ramirez, Mater Character, **110**, 126-135 (2015)
15. R. Singh, A Hand Book on Friction Stir Welding, (2012)
16. M. Jafarzadegan , A.H. Feng, A. Abdollah-zadeh, T. Saeid , J. Shen, H. Assadi, Mater. Charact., **74**, 23-41 (2012)

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