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EFFECT OF TOOL SHAPE GEOMETRY AND ROTATION SPEED IN FRICTION STIR WELDING OF 2024-T3

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ABSTRACT :

The aim of this papers is studied effect of tool pin geometry and welding parameters (rotation speed and welding speed) on the mechanical properties and microstructure of 2024-T3 welded by FSW. Three different tool pin geometry (tapered cylindrical threaded pin TCT, straight cylindrical threaded pin SCT and triangular threaded pin TT) with variable rotation speed (710, 900 and 1120) RPM and constant welding speed (26) mm/min. results showed quality of the weld and the mechanical properties (ultimate tensile strength, yield strength and elongation) effect with different pin geometry and welding parameters. TCT tools gives maximum tensile strength as compared with SCT and TT equals to (410MPa) and joint efficiency (85.25%) of base metals at rotation speed (900RPM) and welding speed (26mm/min). The microstructure of the weld nugget is fine and equaixed in all the tools compared with base metal and grain size increased with increased rotation speed because increase heat input.

Keywords: Friction stir welding, 2024-T3 Aluminum alloy, Rotation speed, Welding speed, Tool geometry.

تأثير الشكل الهندسي للأداة والسرعة الدورانية في لحام الخلط الاحتكاكي لسبيكة الالمنيوم 2024 – T3

جاسم محمد سلمان   قبس خالد ناجي

الخلاصة :

يهدف هذا البحث الى دراسة تأثير شكل الاداة الهندسي ومحددات اللحام (السرعة الدورانية والخطية) على الخواص الميكانيكية لسبيكة الالمنيوم لحمت بلحام الخلط الاحتكاكي WSF تم اعتماد ثلاث ادوات مخروط اسطواني مسننTCT و اسطواني مسنن TCS ومثلث مسنن TT مع تنوع السرعة الدورانيه (710,900,1120 دورة/ دقيقة) والسرعة الخطية ثابتة (26ملم/ دقيقة) . اثبتت النتائج ان كفائه اللحام والخواص الميكانيكية (الاجهاد الاقصى ، اجهاد الخضوع و الاستطالة) تتاثر مع تغير راس الاداة والسرعة الدورانيه . تعطي أعظم اجهاد شد يساوي (410.5×10^{6}باسكال) وكفائة اللحام 85.25% مقارنة مع المعدن الاساس عند السرعة الدورانية (900دورة/دقيقة) والسرعة الخطية (26ملم/دقيقة) . بنية منطقة اللحام ناعمه ومتساوية في جميع الادوات مقارنة مع معدن الاساس ويزداد حجم البلورات مع زيادة السرعة الدورانية بسبب زيادة الحرارة الداخلية .

1.INTRODUCTION :

The solid state welding produced to joint two pieces of metals or nonmetals and alloys called Friction stir welding (FSW) [P. Suinivasulu *et al*, 2015]. FSW have more advantage lead to reduce problems accrue when use fusion welding such as , no defect found during joint, no cover gas or flux used ,improve compared the base metals and can be welded dissimilar metals [M.K.Besharati, 2014]. Aluminum Alloys have weak ability to fusion welding ,especially 2024 AA because more amount heat input during fusion lead to increase grain growth and weak the mechanical properties (tensile strength and hardness) [W. J. Ali *et al*, 2013]. The choice of aluminum alloy for this work the result of the use of these alloys in the process of forming sheet metal which used in airplane and specially in the body and wing airplane and 2024 AA used in the bottom surface Wing airplane[P.Carlone *et al*, 2013]. The autogenously process has been started by welding Institute (TWI) in December 1991 and initially used for joining the alloy difficult by to weld by other methods [A. Suresh *etal*, 2013]. The welded materials in FSW, by rotation tools (shoulder) through the joining point plates and friction lead to development heat which causes plasticized materials and grain refinerment by means of dynamic recrystalization and this heat causes the latter soften without reaching the melting point and allows traversing of the tool along the weld line[A. M. Takhakh, 2012] as shown in Figure 1[A. M. Takhakh].

Tool material and geometry is important factors in FSW. So that, quality friction stir weld requires the proper tool material selection for the desired application [Akos M. *etal*, 2013]. The flow of plasticised material in the work piece is affected by the tool geometry as well as the linear and rotational motion of the tool. Important factors are shoulder diameter, shoulder surface angle, pin geometry including its shape and size, and the nature of tool surfaces [R.S.Mishra *et al*, 2007] Different welding zone in FSW compared with fusion methods result heat and mechanical work divided this into four different zones: Parent metal (PM), Heat affected zone (HAZ), Thermo-mechanical affected TMEZ and NZ[V. Sa, G. Mahendranb, *et al* , 2014].

2. EXPERIMENTAL WORK :

Can be divided experimental work in to two parts manufactory tools and selection materials.

2.1 Selection the materials :

The base materials used in this study is AA 2024 aluminum alloy with thickness of 8.4 mm. the mechanical and chemical properties in **Table 1and 2**. Two plate butt welded by Friction stir welding process by using Universal milling machine (AJAX) is not prepared directly machine so that is using required fixture system as shown in **Fig. 2**.

2.2 Manufacture tools :

The work is studied three different tools (pin) such as tapered cylindrical threaded pin (TCT), straight cylindrical threaded pin (SCT) and triangular threaded pin (TT), as shown in Figure 3. also the shoulder was concaved in all the tools and the angle between the edge of shoulder and the pin was 10°. The tools is made X13 the and chemical composition and details parameters of FSW in **Table. 3 and 4** .

2.3 prepared specimens .

Start to prepared the samples after welding to the microstructure and tensile test by cutting samples perpendicular the welding direction. the microstructure used Keller's reagent (1 ml HF, 1.5ml HCl ,2.5 ml HNO3 and 95 ml H2O). The specimen tensile test according to the ASTM B 557M-02a sub size as shown in **fig. 4**.

3. RESULTS AND DISCUSSION :

3.1 Microstructure test.

The microstructure is characterized microstructurally by four distinct zones, SZ along the weld center line , TMEZ on both sides of NZ, HAZ which is surrounding the TMEZ, and BM. The microstructure of BM as shown in **Fig. 5** represents elongated grain containing random distribution of secand phase particles. in **Fig. 6 (a, b and c)** the microstructure of nugget zone with different tools (TCT, SCT and TT) fine and equiaxed grains in all the tools because more heat input can improve the flow of the plastic material plastic deformation result dynamically recrystallized grains. The small grain SZ in all the tools compared base metal addition found of screw thread pin in all the tools beneficial to accelerate the flow of the plastic material also the precipitate distribution, size of the precipitate is finer and the density of precipitate distributions is higher. and plastic deformation result dynamically recrystallized grains addition found of screw thread pin in all the tools beneficial to accelerate the flow of the plastic material also the precipitate distribution, size of the precipitate is finer and the density of precipitate distributions is higher [Yan-hau, *et al*, 2005]]. In **Fig. 7 (a, b and c),** the microstructure NZ is at three tools with change rotation and welding speed. Grain size increases with increasing rotation speed and decreases welding speed because increased heat input by friction results increasing growth of grain size.

3.2 Tensile test .

The result that is changed in the tool geometry had an imposing effect on tensile test. The maximum tensile strength by TCT tool equals (410.5Mpa) at joint efficiency equal (85.24%) of base metal compared with SCT and TT tools at rotation speed (900RPM) and welding speed (26mm/min) in **Fig. 8** because TCT tools produced good material stirring quality and mixing during welding. The SCT and TT tools pin profile produced insufficient mixing because pins are incapable of deforming appropriate metal during rotation leading to low tensile strength. By the changing of pin, there is a significant difference in the heat input through friction and material deformation. and further increase yield strength and elongation in **Fig. 9 and 10** by increase rotation speed at (900RPM) in all the tools same effect but still lower of base metals because of increasing the temperature leading to dislocation and growth of the precipitates but the continues increased rotation speed lead to decrease the tensile strength at (1120RPM) because excess heat input results coarsening grain and reduction in dislocation density of the strengthening precipitates during the thermal cycle of FSW The reasons for lower tensile strength of welds found presence of defect surface and subsurface during welding, such as tunnel defects. The crack occurred in the middle of the weld is relative to the void defection of the weld and the crack is just on the upside of the voids. Void defect is a very serious defection, which affects the tensile properties greatly, and decreases the tensile strength sharply.

4. CONCLUSIONS :

Effect of tool pin and rotation and welding speed on microstructure, tensile properties of AA2024 were investigated and the following results were obtained:

1. The effect of tool pin profile and welding parameters on the appearance of the weld is presented.

2. It is found that the joint fabricated using tapered cylindrical threaded pin (TCT) profiled tool exhibits super tensile strength equal to (410MPa) and efficiency (85.24%) of base metals as compared to straight cylindrical threaded pin (SCT) and triangular threaded pin (TT).

3. The ultimate tensile strength, yield strength and elongation increased with increased rotation speed and decreased welding speed (710 - 900) RPM but continuous increased rotation speed lead decreased tensile strength at the (1120RPM) in all the tool.

4. Effect of welding speed opposed the effect of rotation speed in the mechanical properties .

5. An increase of grain size in the NZ with increasing rotation speed and decrease welding speed. Also, increasing rotation speed resulted finer and homogenous distributions of particles in the SZ.

Table 1 : Mechanical properties of the 2024-T3[Sanjeev N. K *et al*, 2014].

Yield strength (Mpa)	Ultimate Tensile Strength (Mpa)	Elongation(%)
370	481	18

Table 2: Chemical composition (weight %) of 2024-T_3 aluminum alloys.

Elements (%)	Nominal (%)	Measured
Cu	3.8-4.9	4.85
Mg	1.2-1.8	1.36
Mn	0.3-0.9	0.6
Si	≤ 0.5	0.8
Ti	≤ 1.5	0.035
Cr	≤ 0.1	0.008
Fe	≤ 0.5	0.23
Zn	0.25	0.075
Ni	0.15	0.008
Al	Bal.	Bal.

Table 3: Chemical composition (weight %) of FSW tool .

C	Cr	Mn	Si	Fe
2-2.3	11.5-13	0.3-0.35	0.34-0.4	Rem

Table 4 : Details and parameters of FSW . Tool 1

Weld characteristic	Weld detail
Weld type	Butt
Material welded	AA 2024-T3
Material thickness	8 mm
Shoulder diameters	20 mm
Pin length	7.6 mm
Pin shape	SCT, TCT and TT
Rotation speed	(710, 900 ,1120) RPM
welding speed	(26) mm/min

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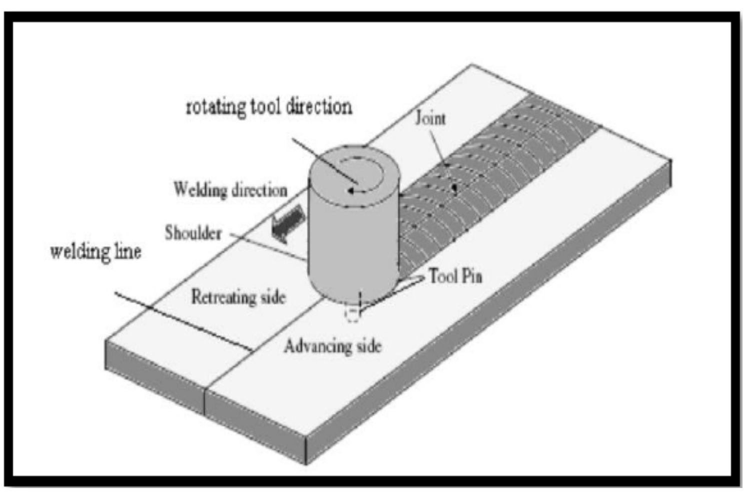

Figure 1: Schematic of friction stir welding process [7].

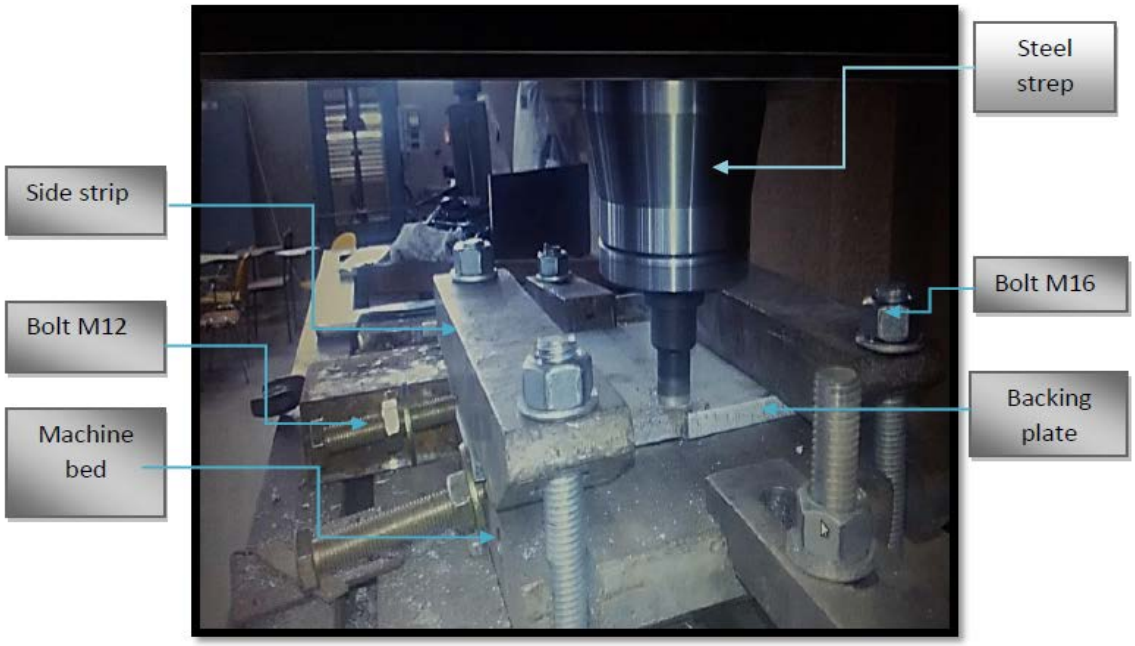

Figure 2 : Fixtures system.

Figure 3: Friction stir welding tools

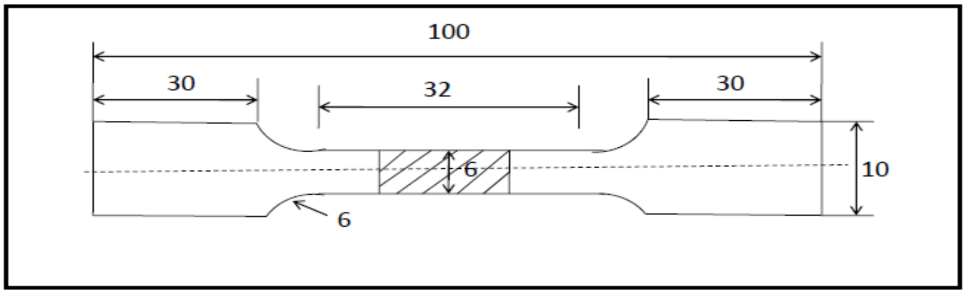

Figure 4: ASTM sub size sample for tensile test.

Figure 5 : Microstructure of base metals(50X) .

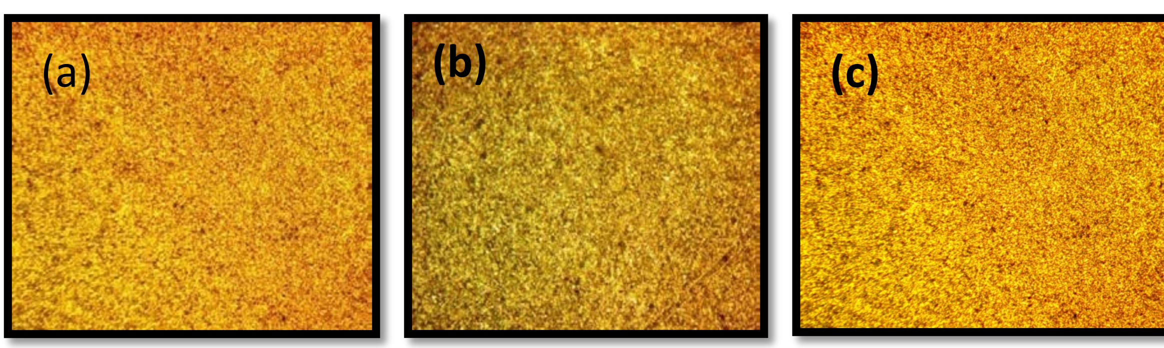

Figure 6: Image microstructure with different tools at 50X
(a) TCT tools, (b) TCT tools and (c) SCT tools.

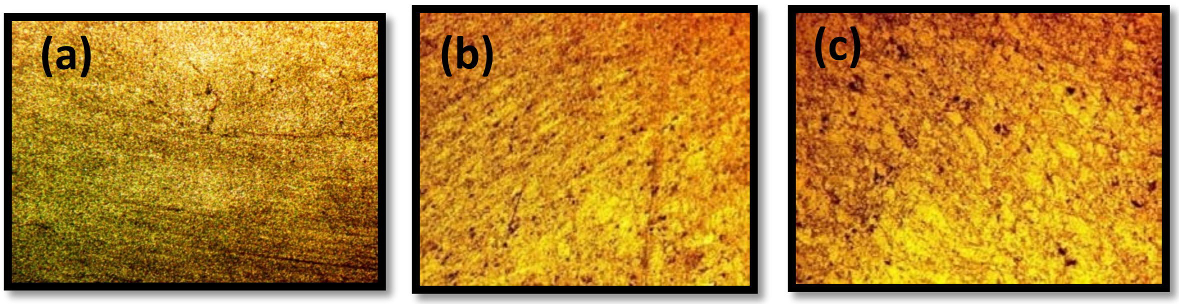

Figure 7: Image microstructure with different rotation speed at 50X **(a)** 710 RPM - 26 mm/min in TCT tools, **(b)** 900 RPM - 26 mm/min in TCT tools, **(c)** 1120 RPM - 26 mm/min.

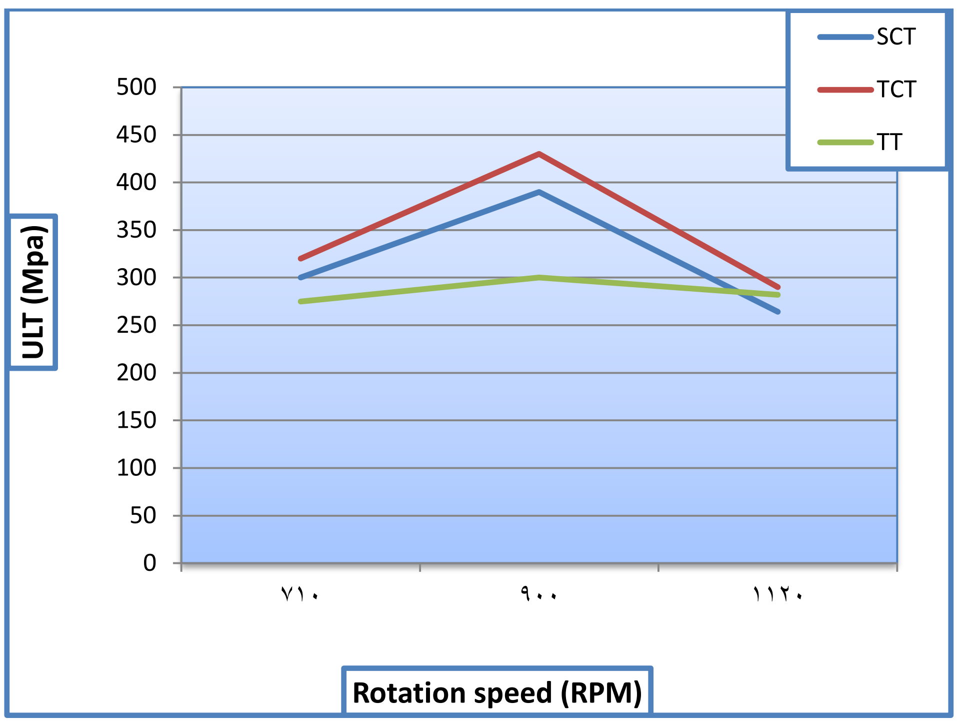

Figure 8: Effect of tool pin profile and rotation speed to the Ultimate tensile strength at constant welding speed .

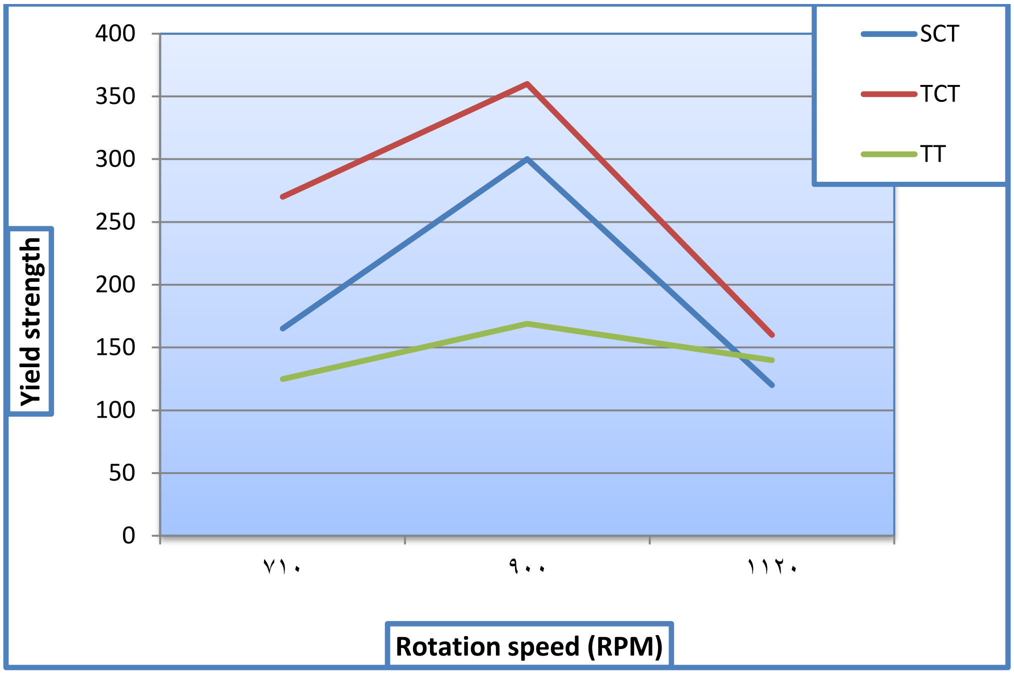

Figure 9: Effect of tool pin profile and rotation speed to the yield strength at constant welding speed .

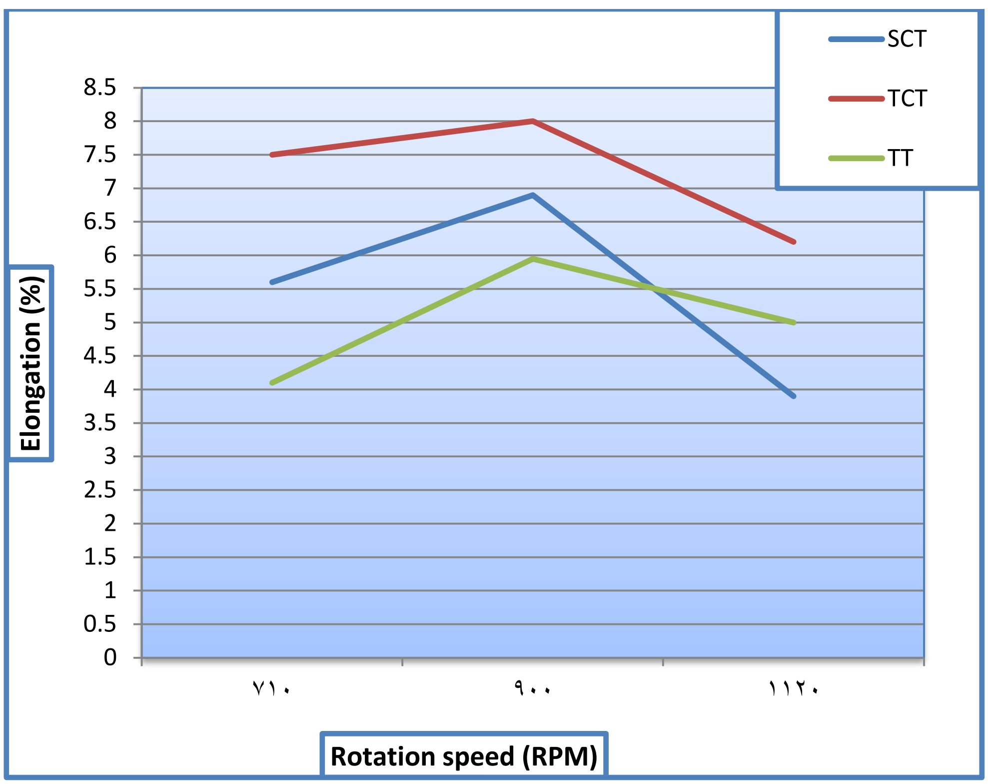

Figure 10 : Effect of tool pin profile and rotation speed on the elongation at constant welding speed .

REFERENCES :

Ákos Meilinger and Imre Török “ The Importance Of Friction Stir Welding Tool ” University of Miskolc, Department of Mechanical Technology , Production Processes and Systems, vol. 6, No. 1, p: 25-34, (2013).

A.Suresh Babu and C.Devanathan “ An Overview of Friction Stir Welding ” IJRMET ,Vol. 3, p: 2249-5770, (2013) .

Ayad M. Takhakh Asmaa M. Abdullah “ The Optimization Conditions of Friction Stir Welding (FSW) for Different Rotational and Weld speeds ” NUCEJ, Vol.15 , No.2, p:187 – 196 , (2012) .

M. Kazem Besharati Givi “ Advances in Friction Stir Welding and Processing ” Mechanical Engineering, University of Tehran (2014).

N. sunil.B, Anudeep.B and Tirupathi.K “ Experimental study on the effect of welding speed and tool pin profiles on AA2014-T6 friction stir welded butt joints ” International Journal of Engineering Research and General Science ,Vol. 3, Issue 1, ISSN 2091-2730, (2015) .

P.Srinivasulu, Dr.G. Krishna Mohan Rao and MSN Gupta “ Experimental Investigation Of Mechanical Properties Of Friction Stir Welded AA 6082 Aluminum Alloy Butt Joints ” International Journal of Science, Vol.4, No .1, P: 2394-1537 , March (2015).

P. Carlone and Gaetano S. Palazzo “ Influence of Process Parameters on Microstructure and Mechanical Properties in AA2024-T3 Friction Stir Welding ” Metallogr. Microstruct. Anal. Vol.2,P: 213–222, (2013) .

Rajiv S. Mishra and Murray W. Mahoney “ Friction Stir Welding and processing ” ASM International, Materials Park, (2007) .

Sanjeev NK, Vinayak Malik and H.Suresh Hebbar “Verification Of Johnson-Cook Material Model Constants Of AA2024-T3 For Use In Finite Element Simulation Of Friction Stir Welding And Its Utilization In Severe Plastic Deformation Process Modelling” IJRET, Vol.3, Issue 6, P: 2321-7308, (2014).

Venugopal Sa, G. Mahendranb, E.Ravikumarc and M. Sivashanmugamd “ Impact of M2-Hss Tool Pin Profile in Fsw Welded Joints On Mechanical Properties Of Aa7075-T6 Aluminium Alloy ” Journal of Engineering Research and Applications , Vol. 4, Issue 5, p:77-81, (2014) .

W. Jalal Ali and Qays Hazim Ismael “ Effect of Friction Stir Welding Parameters on the imp- act Energy of the Weldments of Poorly Weldable Aluminum Alloys by Fusion Welding ” Dept. of Mechan ical Engineering/ College of Engineering / Mosul University Vol.21, No. 6, (2013).

Yan-hua Zhao, San-bao Lin and Lin Wu, Fu-xing Qu “ The influence of pin geometry on bonding and mechanical properties in friction stir weld 2014 Al alloy ” Materials Letters, Vol. 59 , p: 2948 – 2952, (2005).