International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Observation of Different Experimental Parameters Effect using Friction Stir Welding Through Simulation of Tailor Welded Blanks

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Abstract**:** ***In the present scenario, the industries of automobile are focusing in decrease in the weight of the automotive body by using which we can increase the efficiency of fuel orally. Many researchers are working keeping this as motto, many joining techniques and engineering materials are used to decrease the decrease in weight for increasing the fuel efficiency. By synchronizing this, there is a technique called tailor welded blanks (TWB) is recommended highly by many automobile industries and researchers have been chosen this technology. In the current work, the motto is the behavior of forming in the TWBs using the process of friction stir welding (FSW) in two welding speeds (90 mm/min and 100 mm/min). The simulations of forming were conducted using the test called limiting dome height (LDH). Eight strain paths were considered for the simulation with maximum size of 200×200 mm to minimum size of 25×200 mm. The base metal Forming limit diagrams, the sheets of FSW are plotted and compared. From the results of simulation, it has noted that base material has lesser formability than FSW sheets. At 100 mm/min welding speed, FSW sheet fabricated and has noted increasing the formability than the welding speed of FSW sheet at 90 mm/min.***

Index Terms**:** ***FSW sheets, Forming limit diagram, speed of welding.***

I. INTRODUCTION

The new joining process in solid-state called Friction stir welding (FSW) has been developed at The Institute of Welding in 1991. Now a day's FSW process took the lead to join the non-ferrous materials in addition to advanced high strength ferrous material. This process involves many process parameters, especially tool related and welding parameters plays a vital role during the joining [1],[2](Mishra and Maa (2005) and Nandan et al. (2007)). There were many studies carried out on the process parameters effect on joint formation, mechanical properties compared to base metals, microstructure analysis over different zones, formability of FSW sheets etc, on the different materials.

A few formability studies based on numerical and experimental analysis were carried out on the sheet of FSW made of aluminum alloys and concluded that FSW sheets are having better formability than base metal. For example, Lee et al. (2009) estimated the results of formability of Tailor weleded blank FSW, via experiments and simulation of numerical. In that work, they took blanks of FSW made of, 5083-H18, 6111-T4, 5083-O, AZ31 magnesium alloy sheet materials and dual-phase steel (DP590). The increased ductility in the weld aid the results of AA5083-O, AA5083-H18, and AZ31 Tailor welded blank sheets. Similar work (Chung et al. (2010) and Kim et al. (2010)) was accomplished to look into the performance of formability for four automotive sheets, viz.,5083-H18, 6111-T4, 5083-O, DP590 and 5083-O steel sheets, each having one or two varying thicknesses. Kim et al. (2010) studied the formability performance in FSW aluminum alloy 6111-T4 sheet with 1.5 mm thickness with respect to material directional combination. They compared the material direction combinations in three different types.

Recently Janaki Ramulu et al. (2013 b) carried out an initial investigation on the effect of tool rotation speed and welding speed on the formability of Friction Stir Welding sheets made of AA 6061. Based on the experimental data the current work aimed the speed of welding effect on the formability of Friction Stir Welding sheets and compared with base material formability. The two levels of the speeds of welding (90 mm/min and 100mm/min) experimental data have considered at which better weld properties are seen from Ramulu and Ganesh (2013) research work.

II. METHODOLOGY

A. Base material and friction stir welded blanks mechanical properties

For the present work, AA6061 aluminum alloy base material and FSW fabricated at two different welding speeds was considered. The base material mechanical properties and FSW blanks were shown in the Table.1. All the properties were taken from the available literature (Ramulu et al. (2013 a, b, c) and Ramulu and Ganesh (2013)).

B. Modeling of limit dome height test simulation

In a test of Limit Dome Height (LDH), the sheet was deformed by a hemispherical punch with diameter of 101.6mm inside a die opening diameter of 105.7mm. Simulations were performed for eight strain paths with sheet dimensions of 200x200, 175x200, 150x200, 125x200, 100x200, 75x200, 50x200 and 25x200mm.

Manuscript published on 30 September 2019
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The required tools for Limit Dome Height test are die, punch, blank holder, draw bead and blank generated in a CAD package Solid Works and meshed in PAM STAMP 2G using Delta Mesh facility. The base material contains elements of quadrilateral shell in Belytschko–Tsay formulation

Table. 1 AA 6061 Base material and friction stir welded (FSW) blanks mechanical properties

Blank	FSW parameters	Yield Strength (σ) (MPa)	N	K (MPa)	R0	R45	R90
Base Material	--	0.271	0.1	0.42	0.79	0.95	0.851
FSW 1	TRS: 1400 rpm Welding Speed: 90 mm/min Plunge depth: 1.9 mm Shoulder Diameter: 18 mm	0.182	0.3	0.535	1	1	1
FSW 2	TRS:1400 rpm Welding Speed: 100 mm/min Plunge depth: 1.9 mm Shoulder Diameter: 18 mm	0.184	0.28	0.535	1	1	1

with five through-thickness points of integration. Hill's and Holloman's strain hardening law 1948 isotropic hardening yield criterion used as the plasticity model. Throughout the simulation the same size of mesh 1mm was used. It was found that necking criterion is sensitive to size of mesh and limit strain is optimum to the mesh size of 1–5mm is based on the thickness gradient. Throughout the study the constant coefficient of friction μ taken as 0.2. The force of Blank holder (100kN) was taken in such a way that neither the blank tears nor draws in near draw beads during the prediction of forming.

A. Failure criterion and Forming limit diagram (FLD) construction

The obtained displacement at failure can be from the gradient of thickness – based necking criterion. The necking in the sheet metal occurs when the gradient of thickness (ratio of thickness of nearest elements or circles) falls below 0.92. Here the ratio of thickness is equals or less than 0.92 are taken as necked elements (Ramulu and Ganesh (2011)).

Major limit strain and minor limit strain were evaluated from the deformed sheets using TGNC during simulation for each steel grade sheets. According to the TGNC the ratios of the two meshing elements thickness is calculated and major strain and minor strain were considered where thickness ratio 0.92 or lesser has obtained. For constructing FLD, on y-axis major strain values and on x-axis minor strain values were taken. FLD was plotted by joining these limit strain co-ordinates. This procedure was followed for all the materials.

III. RESULTS AND DISCUSSION

A. Forming limit diagrams (FLD)

A FLD is used in forming of sheet metal for estimating the sheet metal forming behavior. The diagram seeks to give a graphical description of material failure tests, such as a limit dome test. In FLD, there are two important zones called as drawing side and stretching side. In this work three FLD are constructed from the LDH simulation test results.

B. Base material FLD

Fig.1 shows the forming limit diagram of the base material. It is observed that FLC is slight decreased towards the in-plane stretching from the drawing side whereas it increased towards stretching side. The minimum major strain is noted at plane strain i.e. 100x200 mm strain path as 0.0653 mm and maximum major strain is at biaxial stretching i.e. 200x200 mm as 0.315 mm. in whole formability of the base material is increased in the stretching zone as compared to the drawing zone.

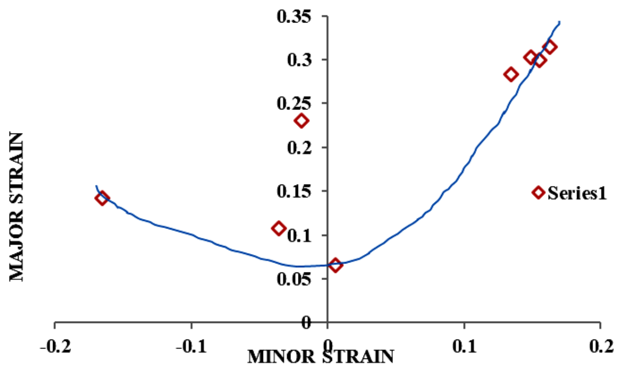


Figure 1 Forming limit diagram of AA 6061 base metal

C. FSW blanks FLD

Fig.2 & 3 shows the FLD's of the Friction Stir welded sheets made of AA 6061. Fig.2 is made the speed of welding at 90 mm/min whereas 100 mm/min is of Fig. 3.

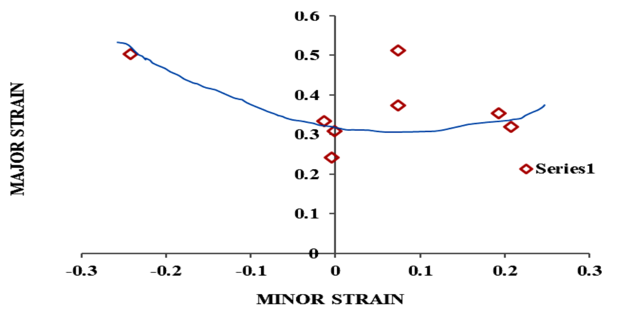


Figure 2 Forming limit diagram of FSW blanks fabricated at 90 mm/min welding speed; 1400 tool rotational speed; 1.9 mm plunge depth using 18 mm shoulder diameter

It is clear that drawing side and stretching FLC is almost similar in Fig. 2 and minimum is reported at the plane strain zone as 0.26 mm and maximum at 0.511 mm at biaxial stretching.Whereas in the other FSW condition, it is seen that drawing zone to stretching zone forming was come down as shown in Fig.3.
maximum major strain is noted as 0.64 mm for 25x200 mm strain path and minimum is at plane stain zone as 0.299 mm.

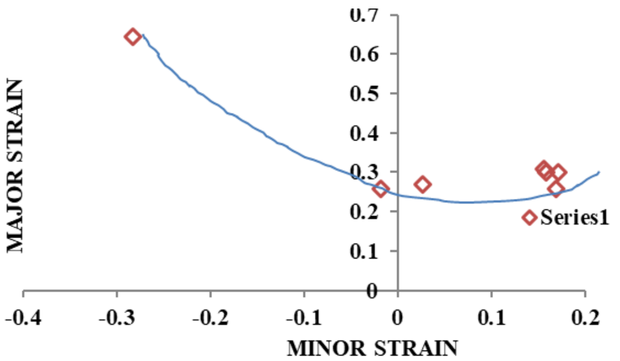
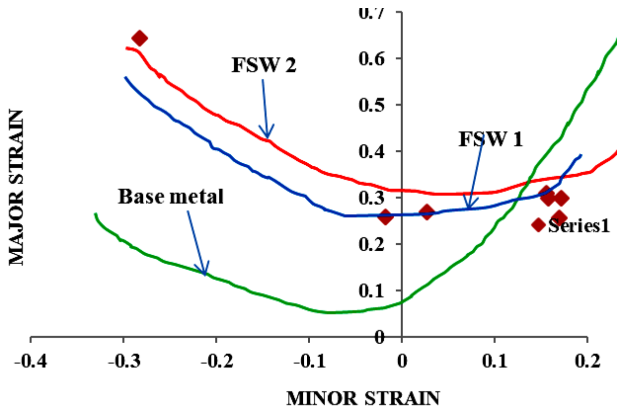


Figure 3 Forming limit diagram of FSW blanks fabricated at 100 mm/min welding speed; 1400 tool



rotational speed; 1.9 mm plunge depth using 18 mm shoulder diameter

Figure 4 Comparison of three FLCs

D. FLD's comparison

The comparison among the three FLC's is made in the Fig.4. It is clear that formability of base is showing the less formability than FSW sheets forming. FSW1 is showing better formability in stretching side whereas FSW2 is better in the drawing side. The overall formability is for FSW1 than other two FLC's. it indicates that by increasing the speed of welding for FSW joints, the formability will come down.

IV. CONCLUSIONS

From the current numerical simulations, the conclusions are drawn in the following way.

- From the forming limit diagram of the base material, formability is increased when strain path width is increased. The same observation is noticed in other FSW sheets also.
- The overall formability of base material is less compared to the FSW sheets.
- The formability of FSW sheet is better at 90 mm/min than the FSW sheet at 100 mm/min
- By increasing the welding speed of the FSW sheets, formability is decreased.

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