A Review Paper: Forming Behavior Analysis and Failure Modes of Tailor made Blanks (1993-2017)

Manoj M.Joshi[#1], R.S.Hingole[*2]
[#1] *Mech Engg Dept., NBNSSOE, Pune*
Research scholar,RSCOE,Pune
manoj.joshi@sinhgad.edu
[*2] Principal, Dr.D.Y.Patil Educational Federation,,Varale ,Pune
hingolerrahul@gmail.com

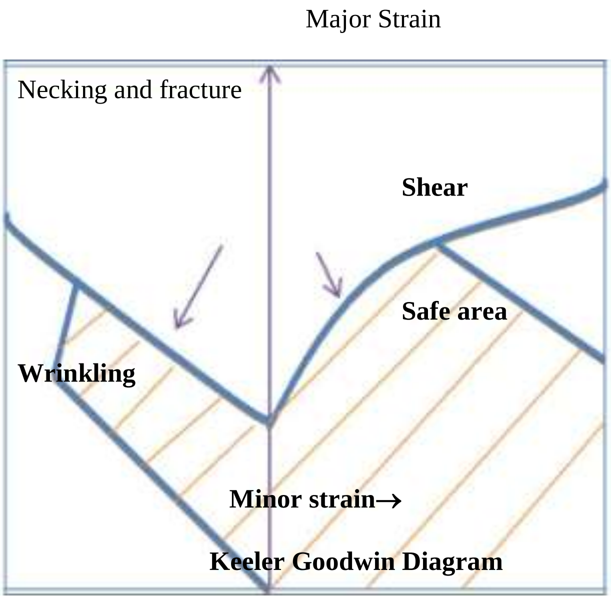
Abstract

Objective: Reduction in vehicle weight, cost, increase in mileage, eco friendly techniques are continuously employed in Automobile industries.TWB (Tailor welded blanks) help in meeting this requirement. Two different constituent sheets of the tailor-made blank are welded or adhesively bonded. Today it is challenging for automobile, aircraft industries to successfully stamp tailor welded blanks (TWBs) with ease into various desired three dimensional shapes by distributing the plastic strain uniformly over the arbitrary rigid tool surface without wrinkling and splitting. Hence, there is immense research interest in automotive, aircraft industries in evaluating the forming behavior of tailor welded blanks (TWBs) both experimentally and numerically, and comparing these results with that of monolithic parent metals..A review is taken here to study the failure mode analysis of Tailor welded blanks using process parameters and TWB parameters.

Method: A literature search was conducted using the keywords tailor welded blanks, formability analysis of tailor made blanks, tailor weld blank parameters.

Approximately 40 articles were analyzed by their titles, abstracts and conclusions. About 10 articles were selected as they were found to be highly interesting for data abstraction and presenting this review.

Result: Researchers have tried to reveal formability of Tailor welded blanks in order to see that TWB are successfully stamped. It is found that there is a need to unleash further weld line movement, spring back effect to know the behavior properly. Further, focus of research in Tailor made blanks is moved to Aluminium alloys from steel as use of High strength, low weight, cost effective Aluminium alloys is more in Aircraft industries. Also friction stir welding is very effective here to join the different blanks as it offers less welding defects and higher strength and formability due to lower welding temperatures.



Keeler Goodwin Diagram

Forming Limit diagram: Forming limit diagram is an effective way of optimizing sheet metal forming.

♦A grid of circles is etched on the surface of a sheet metal. Sheet metal is subjected to deformation. Usually the sheet is deformed by stretching it over a dome shaped die. Strips of different widths can be taken for the test, in order to induce uniaxial or biaxial stress state. The circles deform into elliptic shapes. The strain along two principal directions can be expressed as the percentage change in length of the major and minor axes. The strains as measured near necks or fracture are the strains for failure.

♦A plot of the major strain versus minor strain is shown in Keeler-Goodwin forming limit diagram which gives the limiting strains corresponding to safe deformations.

FLD: A plot of the combinations of major and minor strains which lead to fracture.. Slope of the right hand side curve (necking curve) is found to decrease with increasing values of the strain hardening exponent,n.Variations in sheet thickness, composition, grain size all reduce the slope of the neck curve. Sheet thickness also has effect on FLD. Higher sheet thickness increases the FLD.

Rule of Mixtures (ROM), Failure modes, Material models and average stress in the material of the weld:

Tensile properties measurement: Uniform strain condition assumption fails in case of TMB as material is heterogeneous.

Rule of mixtures method can be applied for longitudinal (Standard ASTM E 8 test specimen).Assumption: longitudinal strains are uniform across the welded specimen.

$P=\sigma_1 A_1 +\sigma_2 A_2 +\sigma_w A_w$ -(1)

Knowing strength and strain-hardening coefficients of the base metals,

$\sigma_w = [P-K_1\varepsilon^{n1}A_1-K_2\varepsilon^{n2}A_2]/ A_w$ where ε is the uniform longitudinal strain.

Primary failure modes in forming of TWB in deep drawing

1) Tearing and 2) Wrinkling

Strain hardening models used with FEM technique.

Holloman's power law is most simple and often used.

$$\sigma=K\varepsilon_p^{\,n} – (3)$$

Very good approximation of the actual stress strain curve is obtained by using Holloman's power law.

A modification of this model is given by **Ludwik's law** which is expressed as:

$$\sigma=\sigma_y+K\varepsilon_p^{\,n} -(4)$$

Ludwick's law has included yield stress here. Both equations are widely used in modeling of metal forming processes including modeling of tailor welded blanks

Voce law: An exponential law gives the description of the strain hardening of both weld and base metals

$$\sigma = A - B \exp(-C\,\varepsilon_p)\ (5)$$

Conclusion: Researchers have considered following TWB parameters for the forming analysis (1) Thickness ratio, (2) yield strength ratio, (3) Weld orientation, (4) Weld location or offset (5) Weld width.

Important deep drawing behaviors predicted were 1) Maximum weld line movement 2) Draw depth 3) Maximum punch force.

Keywords: Tailor welded blanks, formability analysis of ***tailor made blanks***, ***tailor weld blank parameters.***

K. Veera Babu et al [1] had developed an expert system for predicting the deep drawing behavior of tailor welded blanks made up of steel and Aluminium alloys which were used as base materials. An expert system was established to predict the tensile behavior of tailor welded blanks with the following parameters (1) thickness ratio, (2) yield strength ratio, (3) weld orientation, (4) weld location or Offset, (5) weld yield strength and (6) weld width and it was observed that there was unpredictable weld line movement in the case of Aluminium alloys used for TWB, other output parameters were found to be predictable. Necking is observed in case of weaker base materials parallel to the weld region.

N. Bhanodaya Kiran Babu et al [2] made investigations on the effect of differential heat treatment on the formability of Aluminium tailor welded blanks. Dissimilar welded blanks were made from heat treated and non heat treated Aluminium alloys.

Poor formability was shown by AA6061, AA2014 aluminium alloys which was revealed after LDH test. Then AA2014 was solution treated and heat treatment was carried out on it which had shown that there was uniform elongation along weld line with hardly any weld line movement.

Mahmoud Abbasi et al[3]made investigations on effect of weld zone and geometric discontinuity on formability reduction of TWB.Monolithic blanks of IF-steel with two different thickness levels 0.8mm and 1.2 mm were used.CO_2 laser welding was used.ASTM E8 standards were used. Tiny weld regions with non uniformity enhance the non-homogeneity of strain and as a result limiting strains were obtained at lower dome height values.

Tobias Gnibl et al [4] studied formability of Al-Cu friction stir welded tailored blanks conditioned in a PWHT prior to forming and increase in forming temperature gives softening effect and better formability characteristics.

Wangtu Huo etal [5] had studied the warm formability and post-forming microstructure property of high-strength AA 7075-T6 Al alloy. Warm formability of 7075 T6 is improved with increasing temperature up to 200 °C and decreases afterwards, depending on both fracture and uniform strain of the sheet at elevated temperatures.

M. S. Lee et al [6] had explored effect of process parameters on epoxy flow behavior and formability of CR340/CFRP composites in the deep drawing process. Here, hybrid composite material was fabricated by stacking carbon fiber–reinforced plastic (CFRP).On CR340 plates, resulting in greater specific strength and stiffness than other stacked composites fabricated by laminating method. Deep drawing tests were conducted for this hybrid composite material with various process parameters. The experimental results showed that with low blank holding force, the forming depth of the CR340/CFRP composites was higher. In the case of the CR340/CFRP composite material, accurate thickness measurement was difficult because there was epoxy leakage and hardening in the die round area.

Bhanodaya Kiran Babu NADIKUDI et al[7] did the formability analysis of dissimilar tailor welded blanks welded with different tool pin profiles. Rolled plates of aluminum alloys AA6061-T6 and AA2014-T6 were used as base materials. Frictions stir welding was carried out on AA6061 and AA2014 aluminum alloys using different tool pin profiles. The effect of tool pin profiles on the mechanical properties and formability of welded blanks were investigated with the help of tensile test and LDH test. The welded blanks made with square pin profiled tool result in better mechanical properties and formability as compared to blanks made with other pin profiled tools. The pulsating action of the square pin tool in the weld zone produces fine grains, leading to an improvement in properties in the weld zone. The weld zone microstructure of welded blank made with a square pin tool reveals fine equiaxed grains and uniformly distributed grains. A better tailor welded blank can be made with aluminium alloys by using square pin profiled tool.

J. Rojek et al [8] did experimentation to find out mechanical properties of the weld zone in tailor-welded blanks. Tailor welded blanks were obtained by joining steel sheets (1000mmx150 mm) of the grade DC04 and of the thickness 1.0 mm in the weld zone in tailor-welded blanks. Different methods, including metallographic observations, uniaxial tension tests, micro hardness measurements, indentation tests and numerical simulation of laser welding were carried out for determination of mechanical and geometrical characteristics of the weld zone in tailor welded blanks. The stress–strain curves obtained with different methods show certain differences although the level of stresses is similar. The tensile test can be considered as the most trustworthy method to determine stress–strain curve as the curve is a direct result of the test. The methodology consisting in using the specimens with weld along the loading direction gives a stress–strain curve for a material in a weld. Comparison of the results obtained using standard and small specimens indicates that both sizes give similar results as the yield stress and hardening of the material in a weld zone are concerned, therefore standard specimens can be used for testing.

Yanli Song et al[9] had tried to find out influences of thickness ratio of base sheets on formability of tailor welded blanks. Erichsen cupping tests were conducted on a number of DP600 steel tailor welded blanks experimentally and FE analysis software ABAQUS 6.10 was used for validation. Crack onset sites of tailor welded blanks during the Erichsen cupping tests were analysed. The quantitative relationships between the forming performances and the base thickness ratio were established for tailor welded blanks made from base sheet of identical strength. Based on these relationships, the IE values of tailor welded blanks made from base sheets of identical strength but different thickness can be evaluated and the forming forces, however, may not be accurately estimated in some cases, assuming that the IE values of the tailor welded blanks made from base sheets of identical strength and thickness are known and the two different types of tailor welded blanks undergo a similar stamping process. The fact that the experimental results basically agree to the fitted curves.

H.Wang et al [10] studied Multiple-iteration spring back compensation of tailor welded blanks during stamping forming process. HSS (High speed steel) TWB The left side is a rectangular blank with a thickness of 1.6 mm, and the right side is an isosceles trapezoidal blank with a thickness of 1.2 mm. 1.Tensile tests show that the mechanical properties of the thin and thick materials are highly similar. The weld seam decreases the maximum elongation and yield strength of the TWBs. The tensile strength of the TWBs is larger than those of base materials 2. The fracture of the base materials involves a typical ductile fracture, whereas that of the welded blank includes ductile and cleavage fractures 3. The simulation of the entire forming processes is used to analyze the forming process of the TWBs. Experimental results indicate that the simulation results agree with the experimental results. Thus, the simulation can provide guidance to actual production.4. The maximum value of spring back is 3.04 mm without spring back compensation. When the multiple-iteration spring back compensation and the simulation of the entire forming processes are implemented for the third time, the formed part after spring back satisfies the allowable tolerance.5. Inspection results show that 24 of the 32measuring points can satisfy geometrical tolerances. Thus, the qualified rate of production can reach 75% by using multiple-iteration spring back compensation at the first time of die tryout. Therefore, the number of compensation and tryout time can be decreased by using the proposed method.

CONCLUSION

Two different constituent sheets of the tailor-made blank are welded or adhesively bonded to form a Tailor welded blank (TWB). A part having non uniform loading conditions can have one blank with two sections having two different thicknesses or materials such that the stronger or thicker sheet is used at load carrying areas and the thinner or weaker material at less loaded places. As these tailor welded blanks are widely used in automobile, aircraft, ship building industries it is a matter of great research interest of studying the formability characteristics and mechanical properties of these tailor welded blanks.

After studying and scrutinizing 40 research papers, it was found that there is a sizable work which needs to be done on finding out formability characteristics, mechanical properties of TWB made up of High strength Aluminium alloys (AA 5083,AA 6082) using design of experiments and FEA and compare the results with base Aluminium alloys by varying process parameters of Friction stir welding like spindle speed, cutter feed rate, depth of penetration etc. Friction stir welding (FSW) has got certain specific advantages over fusion welding. These merits are A) Better strength and formability due to lower welding temperatures B) Weld defects are very less.High strength Aluminium alloys most commonly used and easily available in the market can be used as they are light in weight and have high strength.

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