TAILOR WELDED BLANKS (TUB$_S$) FOR A SHEET METAL INDUSTRY AN OVERVIEW

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Abstract **- S**heet metal stamping technology has a ultimate challenge to meet expectations primarily such as, low cost, low weight & high quality of a stamped panels in past years, due to its dynamic competitive & nature. To achieve these goals, many improvements are accepted till date and many going on. Tailor welded blank (TWB) is one of such improvement which have really proved to be a promising to get all primary goals of the stamping industry very effectively. In sheet metal forming operation, the blank is typically supplied in a single piece, usually cut from a larger sheet and has uniform thickness. Especially, car body panels were usually made up of several smaller components. Each component is formed individually and subsequently welded together to create the desired body panel. This approach incorporates high tooling, long lead time, laborious efforts & certainly high material costs. Moreover, this approach also contributes to the dimensional inaccuracy in the assembly process.

Therefore, it is attractive to form the body panels in a single stamping by using Tailored Blanks, to incorporate various advantages in single sheet. The first use of Tailor welded blank in a history is somewhat unclear. From earlier researches, it is known that Honda (1967) had used TWBs first in automotive for body side rig, but was too costly due to non-developed welding techniques at that time. This all scenario is drastically improved over a decades & a modern TWBs with highly developed welding techniques supported by precise numerical methods available which are reviewed in this paper. This review paper focused to gather all recent developments & research work in the area of TWBs in manufacturing industries.

Keywords – Tailor welded blank, formability, numerical analysis, simulation.

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1. INTRODUCTION

Sheet metal stamping is one of the main manufacturing processes which is widely used to create majority structural components for modern automobiles due to its merits such as the high production rates, low manufacturing costs and maximum material utilization which again in turn reduces cost of material scrap. To produce such improvements using more advanced materials, which are more expensive, is not always the solution as the material cost can be approximately 70% of the final part cost in sheet metal forming applications. Performance parameters such as structural rigidity in operation & passenger safety in any mis-happening are critical requirements for both customer satisfaction and government regulations in any country across the globe.

Typically, to create e.g. a structural member for an automobile chassis, several sheet metal stampings are formed separately and then welded together to produce the component. This allows the sheet metals to be varied so that the material properties and characteristics are located in the areas of the structural member where required. For example, for a door inner component, stronger material is required near the hinge to support the weight of the door when the door is opened. However, the material near the door handle can be lighter weight for mass reductions and so less force is required to close the door. As opposed to forming multiple components and subsequently welding these stampings together to create the structural member, flat sheet metal blanks can be welded together prior to the forming process. Thus, only one forming operation line is required to fabricate the component. This is referred to as a TWB, as the designer able to tailor the location of the material properties within the final structural member where desired. These material differences can be with respect to the grade/strength of the material, the thickness of the sheet metal, or the coating, e.g., galvanized versus un-galvanized.[5]

For weight and cost reduction, the technology of TWBs is a promising technology for both automotive and aerospace sectors. In this literature review, a comprehensive overview of the TWBs is given with the emphasis on the mechanics of forming of TWBs. In manufacturing of TWBs, a structural part or product is made up by joining several metal sheets of possibly different thicknesses, materials, and surface coatings. The point is that the joining (welding) is performed prior to the forming. The possibility of having different sheets of different thickness, strength, and material properties enable the designer to distribute the material optimally. Optimal distribution of the material, indeed, means lighter structures, higher strengths, and joining before forming results in lower production costs.[1]

2. LITRATURE SURVEY

The tailored blank is a well-established steel semi product enabling optimized car body engineering. The cost-performance balance of a tailored blank is the decisive criterion for its application in a car body. The cost of a tailored blank is directly related to the productivity of the welding machine[14].

Literature review has been categorized based on parameters which decides the successful execution & the quality of the part. These utmost important parameters are:

1. Welding techniques for TWBs.
2. Finite Element Simulation & Numerical analysis.
3. Formability analysis
4. Defects & Failures modes.

2.1 Welding Techniques for TWBs:

The welding is used for joining of material in TWBs prior to forming. Primarily, there four processes which are used in TWBs production. 1- Laser beam welding 2- Friction stir welding 3- Plasma arc welding 4- Mash seam resistance welding. LBW & MSRW are extensively used techniques & Friction stir welding (FSW) is a new solid-state joining process invented at The Welding Institute 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[18]. There are several different laser welding systems available. CO2 and Nd:YAG lasers are already in use in industry. Low power Nd:YAG lasers are used in the electronics industry. Rapid improvements in technology mean that diode lasers of sufficiently high power and power density to produce good deep penetration welds are now available. Sound welds without major defects and full penetration can be produced via laser welding. High performance of welding products can find in the laser weld metal sheet as a result of tensile testing[6] . Laser welding can produce weld beads having high aspect ratio (penetration/width) due to the high-energy density. The Nd:YAG laser produces the finer weld microstructure, whereas TIG with Ar gas shielding produces the coarser microstructure. This is due to the different energy density and hence different cooling rates. The fine weld microstructure led to increased micro hardness values[3]. An experiment performed on the welding operation GTIG & Arc Weld for Stainless Steel and Mild Steel having same thicknesses and different thicknesses, and carrying the Tensile Strength, Shear Strength tests over UTM and Impact Strength over Charpy's Impact Test. It is found that , ultimate strength of a specimen is perpendicular to the direction of the application of load (having different thicknesses) which is welded by ARC welding is more than the specimen welded by TIG welding and concluded that the ARC welding is more preferred for welding specimens of different thicknesses[22].The viability of using the double-sided arc welding (DSAW) process, comprised of a plasma arc welding torch above and gas tungsten arc welding torch below the joint, to produce autogenous square welds between 1.0 and 1.5 mm thick AA5182-O aluminum sheets for applications such as tailor welded blanks (TWB) has been studied. Unlike Nd:YAG laser welding, there is no loss of Mg, weld metal strength, or hardness in the AA5182-O aluminum DSA welds. The significant potential advantages of the DSAW process with respect to the welding of aluminum tailor welded blanks may make DSAW the process of choice for such applications[10]. The fixed-optics laser-welding machine with continuous material feeding is by far the most productive solution and offers the highest flexibility for the manufacturing of various blank types and batch sizes. The moving-optics 2-dimensional laser-welding machine allows manufacturing of complex blanks. This machine type offers the highest flexibility in terms of product spectrum and is also suitable for prototyping[14]. The elongation of welded joints under perpendicular tension becomes lower than that of the base metal because the deformation is restrained by the increased hardness of welds. When the weld heat input is high and thus the heat-affected zone is softened, strain concentrates in the softened zone, and the elongation significantly decreases. The strength of welded joints under parallel tension becomes higher than that of the base metal, but the elongation thereof becomes lower because the weld is harder than the base metal. The elongation of weld joints is estimated systematically by the sum of weld metal hardness and base metal hardness. The fatigue strength of welded joints is lower than that of base metal regardless of equal thickness or differential thickness welded joint. Also, as the thickness ratio increases for the differential thickness joints, the fatigue strength becomes low[17]. Using welding tool with spiral path on the pole , because of improving tool and work piece connection and preventing tool vibration, produced a TWB with high strength and formability. Increasing of tool rotation speed cause enhancement of heat resulted from friction between tool and sheet and improved penetration, strength of weld and increased major strain of Erichsen test[19]. Deformation behavior of laser-welded tube blank of TA15Ti-alloy at elevated temperature was investigated by both hot tensile tests and HPGF. The hot tensile tests were carried out on four different specimens at 800◦C with an initial strain rate of 1.0×10^{-2} s^{-1} and HPGF experiment was performed at 800◦C with a constant pressure of 9.5MPa[11].

TWB is influenced by loading direction, mechanical prop of base material, thick ratio of welding sheets rolling direction & welding parameters like weld speed, angle etc[15]

2.2 Finite Element Simulation & Numerical analysis with an experiment:

This step is inevitable and performs a key role in TWB effective use. Higher the use of soft techniques for prediction. Its performance saves a lot of money & efforts which would need otherwise to prove same part by trial & error. The Finite Element Method may contribute to the prediction of Tailored Blank behavior and its manufacturability.

In an experiment related to TWBs, made by TIG, the sheets of M.S. and SS304 used for TIG were cut in to different dimensions with thickness of 1, 1. 5, and 2.0 mm. for same thickness combination of blank to observe failure pattern of Tailor Welded Blank with materials used are M. S. and SS304. Then he made specimen & performed test on tensometer of 2T capacity. After that numerical calculations are performed followed by simulation. Results of all 3 process which shows good agreement among all 3 process results[8]. A Performed test on 5 types of specimen set of 2 diff material viz. DP 600 & H340LAD+Z (both single) with 3 specimens having weld line location difference. He found that 1- The tensile strength of TWBs stands between two base material strengths. 2-The plastic formability of TWBs was worse to base material. For the formability mainly affected by the weaker blank, so the formability depends on the weaker one's property. 3- In the tensile test process, the deformation of weld line was tiny; for this reason, the TWBs joint model was simplified as rigid is acceptable. 4-The location of weld line has great influence on the TWBs' formability[21]. Material SS304 is used for an experiment which is widely used in fabrication of chemical process equipments. Experiments were carried out in laboratory of the institute on Tensometer (K I P L - PC2000) Of 2 T capacity at a speed of 1.5 mm/min. Deformed tailor-welded tensile specimens of both base metals, longitudinal TWB and transverse TWB. It also shows that the failure occurs on the thinner part of the tailor-welded tensile specimens. Also, values of K and n are derived. These experimental values are validated using analytical model & found good agreement between both. Also, it is concluded that approximate equation of true stress and true strain not gives exact behavior of TWB as these parameters are found on the bases of thin section or weak section. However, it is quite useful to predict the overall behavior of TWB for given base material. In the present derivation, only two blanks are considered but it is possible to derive similar equitation for multiple blanks. It can be extended for multiple numbers of TWBs[18].

2.3 Formability analysis:

To apply high quality Tailored Blank products in the automotive industry, it is important to understand the formability behavior of Tailored Blanks during deep drawing. The failure types for Tailored Blanks, the influence of the weld process and weld location on the formability and the weld line motion must be investigated. Prediction of the weld line movement is therefore very important to predict the press formability (strain state, failure) of a Tailored Blank. The Finite Element Method may contribute to the prediction of Tailored Blank behavior and its manufacturability. It consists 3 steps – a. Weld Modelling b. Sheet Modelling c. Tool Modelling.

a. Weld Modelling: There are two strategies to model Tailored Blanks in a finite element program. The first strategy is to model the weld accurately. In this situation, the weld type is taken into account, i.e. the dimensions and the shape of the weld, and also the volume fractions of martensite in the weld and the HAZ are taken into account. This approach requires a fine element mesh in the weld area. The second strategy is to neglect the weld type, only the place of the weld is taken into account. In this last approach, the weld and HAZ are modelled with one row of (coarse) elements, or are simply neglected which holds that in the last option the originated martensite is not taken into account[18].

b. Sheet Modelling: The blanks are modelled with three-node triangular plane stress elements. Three different element types are available to simulate the deep drawing of Tailored Blanks, i.e. membrane elements, which account for membrane stresses only, Kirchhoff elements, which account for bending stresses as well and Mindlin elements, which also account for shear stresses. Considering the geometry of the simulated products, the bending stresses and the shear stresses are expected to be inferior to the membrane stresses. Hence it will be sufficient to use membrane elements[18].

c. Tool Modelling: Since deep drawing of Tailored Blanks differs from deep drawing of uniform blanks, the tools must be adapted to this process, especially when base materials with a different thickness are being joined. The necessary adaptations are summarized below for each deep drawing tool, assuming different thickness of the base materials[18]. It is concluded that the weld line motion is significantly influenced by the occurring strain state, especially when the material is stretched perpendicular to the weld, due to strain localization in the thinner (weaker) base material. A minimization of weld displacement can be achieved by placing the weld in a region with low strains perpendicular to the weld line or to choose the load bearing capacities of the applied base materials equal. The elastic plastic material behavior is preferred to the rigid plastic material behavior, since in the elastic plastic model the strains are not overestimated in low strained areas. More accurate description of the blankholder force is needed to accurately simulate Tailored Blanks. The Finite Element Method can be used to predict the stress state, strain state and weld line motion during deep drawing, in case an elastic plastic material model is used and that the blankholder force is described accurately[23]. An experiment to compare B pillar part forming both by single & tailor welded blank is conducted. The former blank was of steel HCT600 & TWB was combination of HCT600 & HCT980X. Simulation of TWB drawing in FLD dia shows a safe strain for which there are no cracks or nucleus to cracks. When comparing true values of logarithmic strain in critical areas of the part drawn from TWB to strain values in FLD – dia, obtained technological safety given by the area of limit deformations. After that a crash test is conducted & obtained values of reaction forces in different time intervals which confirmed that reaction force offered by TWB is better than a single blank[3]. In a forming behavior of the TWBs made of friction stir welding (FSW) process under two different welding speeds 90 and 100 mm/min. The forming simulations were conducted using the LDH test. From simulation results, it has noted that FSW sheets have more formability than the base material. FSW sheet fabricated at 90 mm/min welding speed has noted better formability than 100 mm/min welding speed FSW sheet. It is also noted that by increasing the welding speed of the FSW sheets, formability is decreased[2]. It analyzed formability of cold rolled sheets of thick range from 0.5 to 1.0 mm made using laser butt, though there are no significant diff in TWBs & those of base metals. TWB formability was analyzed by swift test in terms of LDH, FLD & MMS. The results showed that TWB of diff dimensions & radii of cut-off yields diff major-minor strain values of FLD & Diff LDHs. It also confirmed that all TWBs have lower formability than its base metal. Diff thick ratios was studied & concluded that higher the thick ratio, lower the FLC. FLD founds same for similar thick combination but different when thick ratio is same but has diff thick combination. We can get higher formability for smaller thick combo diff bet^{n} 2 parts. There was found an inv. prop relationship betn thick ratio & mms. TWB of thick ratio which would close to 1, were found to have closer min mms to those of base metals. Also, a microstructural analysis shown a large diff of grain size at HAZ for a higher thick ratio TWB[7]. When worked on HAZ using FEM & results are shared to determine optimum heating arrangement for joining the different aluminum thickness. The results shows that different combination of material thickness requires different heating zones to balance melting area of the TWB process. Increasing the thickness of the material is increases the use of heat flux. TWB combination of 3 mm & 1 mm sheet has needed lowest weld flux & has comparatively balanced weld heat area distribution[15]. In a novel concept of lightweight construction for deep drawing tools to improve the forming behavior of tailored blanks using tailored dies made of two different materials. These investigations on the forming of tailored blanks with tailored tools reveal the possibility of improving the forming behavior of tailored blanks by applying the novel method of using hybrid and steel dies at the same time for different material strengths. The experiments show a lot of positive effects such as the reduction of weld-line movement the homogenization of strain and thickness during the forming process, and the weight reduction of tools for press shops. Due to the increase of contact area because of deformation of the polymer tools, the material flow of the softer material was hindered successfully[24]. It has investigated sheet-bulk metal forming method used to produce TWBs. The investigations have shown that sheet-bulk metal forming is applicable to produce rotationally symmetric tailored blanks. Using upsetting tools, a pre-distribution of material can be achieved in the exterior area of a circular sheet blank. Thereby tailored blanks are well prepared for further forming operations like deep drawing or extrusion to manufacture components similar to synchronizer rings. Due to the high process forces, the elastic tool deformation and friction conditions are issues to be considered in further investigations. The elastic tool deformation reaches a maximum in the counterpunch center. Therefore, the surface may have a convex shape to reach a planar area under load. This approach is already known from strip rolling technology, where tools are bossed to compensate elastic deformation. The tribological condition respectively friction shear stress between tool and blank has to be decreased enhancing the process. A sufficient lubricant distribution effects lower upsetting forces and provides high quality components[13]. A Circular draw bead forming and the drawing characteristics of CO2 laser welded SPC1 blanks are investigated by experiment and numerical analysis. During the drawing process, the drawing forces and the strain distributions are investigated. Numerical results predicted deformation characteristics well in comparison that are in good agreement with the results of experiments. It is concluded that the strains and restraining forces during the forming and the drawing processes show different patterns according to the combination of welded blanks[9]. The bending test results showed fairly good repeatability and the springback values of TWB specimens lie in between the values of parent materials except in a few cases. Predicted simulation results with incorporation of weld zone showed a good agreement with the experimental results as compared to the simulation results without incorporation of the weld zone[27]. A forming criterion for tailor welded blank is presented based on the analytical model in this research. This criterion suggests LSR and LTR for forming limit of TWB. When thickness ratio or strength ratio in tailor welded blank is greater than LTR or LSR, formability will be limited and necking will happen sooner. The influence of thickness ratio on the formability of TWB has been investigated by experimental tests and FE simulations, but strength ratio has just been studied by simulation. All the simulation and experiment results indicate that by the increase of thickness ratio and strength ratio, the formability will decrease and weld line movement will increase. The obtained results of the present study indicate that fracture happens in the thinner side of TWB and near to the weld line. Simulation results have a good agreement with experimental results as well[20].

2.4 Defects & Failures modes:

The results obtained by numerical simulation regarding springback phenomenon of a part manufactured from tailor welded blanks. It is concluded that 1. the modification of sheet thickness leads to important variations of springback parameters: 2. increasing of the sheet thickness results in reduction of the springback effect, the final geometry of the formed part is closer to the ideal part shape; 3. variation of the springback phenomenon proportional with sheet thickness is observed for both areas of the part; 4- the part area made by E220 present a springback intensity higher that the part area made from FEPO steel[4]. The two-step methodology FEA and orthogonal experiment method to study the effect on thinning used. It deduced from the experiments that the impact of the seven process parameters on the thinning rate from strong to weak are punch radius, draw tonnage, blank holder force, die radius, contact friction, draw bead height, binder stroke. The thinning rate effectively planned through FEA simulation optimization and orthogonal experiment, and the quality forming parts can be produced without obvious defects[26]. A laser welding technique is studied and found that in welding, number of defects have been observed, but can often be controlled by a suitable choice of welding speed. Weld surface topography is affected by the presence of several weld defects: Pores in the weld pool, Cratering, undercutting, slumping, humping, cracking, blow-holes all of which adversely affect weld quality[6].

3. Conclusion:

We reviewed the multiple parameters which decides the successful execution & the quality of the TWB part made. The various welding techniques along with laser welding & FSW which is a new solid-state joining process invented are reviewed. The Finite Element Method may contribute to the prediction of Tailored Blank behavior and its manufacturability. Simulation is a key for successful TWB manufacturing in which the planar strain distribution approximates the experimental results. Simulation uses FEM software for development of draw & continues changes in development for various defects such as wrinkle, crack, spring back iteration in

CAE software. Formability analysis has utmost importance in deciding the functional viability of tailor welded blank. It is s quite easy formability analysis in case of single material forming as compared with TWBs because of weld line shift, spring-back & wrinkles which are the most challenging defects in this case, which if predicted using effective numerical analysis, a tailor welded blank can be proved to be a knack for an automotive sheet metal industry. We can observe TWBs as one of the critical concept in sheet metal. Though various researchers contributed good work in this field, further study requires in the simulation and analysis to understand effective ways which could be helpful to enhance TWBs utilization in sheet metal industries.

Nomenclature and Abbreviations:

AA5182-O	An aluminium alloy material
Ar	Argon gas
CO_2	Carbon-di-Oxide gas
FLC	Forming limit curve
FLD	Forming limit diagram
FSW	Friction stir welding
GTIG	Gas tungsten insert gas welding
HAZ	Heat affected zone
HPGF	High pressure gas forming
HSS	High speed steel
K	Strength co efficient of given Blank N-mm
LBW	Laser beam welding
LDH	Limiting dome height
LSR	Limit strength ratio
LTR	Limit thickness ratio
MSRW	Mash seam resistance welding
MMS	Minimum major strain
n	Strain hardening exponent of given blank
Nd: YAG	Neodymium doped yttrium aluminium garnet
TWBs	Tailor welded blanks

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