Effect of Thickness Ratio on Formability of Tailor Welded Blanks (TWB)

V. Vijay Bhaskar, R. Ganesh Narayanan and K. Narasimhan*

Department of Metallurgical Engineering and Materials Science, IIT Bombay, Powai, Mumbai, India
*Corresponding author: nara@met.iitb.ac.in

Abstract. Tailor welded blanks (TWBs) are made by welding same or different materials having same/different properties into a single blank. They can be tailored to any specific shape and size. The formability of these blanks depend on material and geometric parameters like strength ratio and thickness ratio. This paper studies the effect of thickness ratio on the formability of tailor welded blanks by FE simulation. The formability is assessed by considering the Tensile and Limit Dome Height (LDH) tests. The weld region has been assumed as a line in all the simulations. While modeling tensile test, the ultimate tensile strength and the uniform elongation were monitored. In all LDH simulations, near plane strain condition is considered Uniaxial tensile testing shows that TWB formed will have lower elongation as compared to the base metal and the load bearing capacity will be comparable to that of thinner blank in case of transverse welded TWB. Thickness and thickness strain distribution along the blank show that the effective deforming area in a transversely welded TWB is that of the thinner blank. Both tests indicate that as the thickness ratio increases, the formability of TWB reduces.

INTRODUCTION

A Tailor welded blank consists of two or more sheets that have been welded together prior to forming. TWBs have numerous advantages over conventional processes. They not only reduces the number of parts but also provide reduced weight, improved structural integrity, improved dimensional quality, fewer dies, fewer spot welds, reduced design and development time and lower overall manufacturing costs [1]. Over the years, constant attempts have been made to reduce the weight of the automobile which will ultimately lead to reduction in fuel consumption. It has been found that 1% reduction in vehicle weight can lead to 0.6-1% reduction in fuel consumption [2]. This lead to rise of TWB technology in automobile manufacturing. In this paper, effect of thickness ratio on the formability of TWBs is studied by Finite element analysis. Comparison with the single sheets of base metals will provide a good insight of its effect [3,4].

METHODOLOGY

In order to study the effect of thickness ratio, models for uniaxial tensile testing and LDH testing were prepared. In both the cases, the weld region is assumed to be a line and not as a zone. Thus, no material properties are assigned to the welded area. Though the weld in the actual TWB part used in automobiles are generally angular, as an extreme case, only transverse and longitudinal welds are considered in this paper.

Uniaxial Tensile Testing
For uniaxial tensile testing, a model shown in Fig. 1 is used.

FIGURE 1. Schematic of model used for FE simulations of Uniaxial tensile testing

The two separate half blanks are generated in SOLIDWORKS which are later imported to the FE simulation software OPTRIS and joined to form TWB.
The properties are assigned to each of the blanks separately. The nodes at one end are fixed and the other end are subjected to velocity (10 mm/s). Finer mesh (2mm) is chosen to improve accuracy in results [5].

The parameters which are analysed are % elongation and maximum load. Also, the thickness and thickness strain distribution were monitored at maximum load.

In order to observe the effect of thickness ratio, the thickness ratio is increased from 1 to 1.5. Here, thickness of the thicker blank (1.2 mm) is kept constant and the thickness of the thinner blank is kept as variable because thinner blank is the one where the failure usually occurs in transverse weld. If the thickness of the thicker blank is kept as variable and the thinner blank is kept constant (say as 1.2mm), then not much change is observed in the load-stroke curves for different thickness ratios. In order to study the effect of weld line position, a TWB with thickness ratio 1.5 (1.2mm/0.8 mm) is chosen and the weld line position is varied in 60 mm gauge length as shown in the table below.

**TABLE 1.** Different weld line positions taken in a 60 mm TWB with thickness ratio 1.5 (1.2/0.8)

<table>
<thead>
<tr>
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<th>Thicker blank size (1.2mm)</th>
<th>Thinner blank size (0.8mm)</th>
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<td>6</td>
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* All units are in mm

**FIGURE 2.** Schematic representation of the model used for LDH testing

The blankholder force and punch travel speed are kept around 10 kN and 10mm/s respectively. The friction between the die and the TWB is kept as 0.12. Similar to the uniaxial tensile testing case, here also, the thickness ratio is increased from 1 to 1.5. The parameters which are analysed are maximum pole height and maximum load. Here also, the thickness and thickness strain distribution are monitored when maximum load is attained.

**RESULTS**

**Uniaxial Tensile Testing**

In case of transverse welded TWB, when the thickness ratio is increased from 1 to 1.5, there is a decrease in the load bearing capacity of the TWB. Also, as the thickness ratio increases, there is a reduction in % elongation. Load-Progression curves for different TWBs are shown in Fig 3. As shown in Fig 3, the formability decreases as the thickness ratio is increased.
It is evident from Fig. 3 that TWB thus formed has strength comparable to the thinner sheet at higher thickness ratios. Also, the TWB formed has lesser elongation as compared to base metals. Since in a transverse weld, the thinner blank is the one which will fail easily, the load bearing capacity of the TWB will be determined by that of the thinner blank. The load bearing capacity of the TWB is comparable to that of the thinner (0.8mm base metal) sheet.

In order to support this, when the percentage contribution of the thinner blank to the whole TWB is increased by changing the weld line position towards the thicker blank side. Since the percentage contribution of the thinner blank is increased, one may think that the formability of the TWB will be reduced even more. In a 60 mm gauge length of tensile sample, weld position is varied as shown in Table 1. Load progression curves in all the cases are shown in Fig 4.

As can be seen from Fig 4, with the increase in percentage of the thinner blank from (50-10) TWB to (5-55) TWB, the load bearing capacity decreases and the behaviour becomes similar to that of a single sheet of thickness that of thinner blank (0.8mm). In order to get a better understanding, thickness and thickness strain distribution is monitored along the cross-section of the TWB for different weld positions.(shown in Fig.5)
Figure 5 shows that there is negligible strain in the thicker blank and most of it is concentrated in the thinner blank only. Thus, the effective length in a transverse TWB is the length of the thinner blank. Thinner blank is the one which will decide the properties of the whole TWB. Thicker blank is just providing strength and extending support to the thinner blank. Another important observation which can be made from Fig 4 is that there is a sudden drop in % elongation from 33.86 % (in case of 1.2 mm single sheet) to 6 % (in case of 50-10 TWB). Now, in such a case using a TWB instead of single sheet would cause significant decrease in % elongation. It would be better to use a single sheet instead of a TWB here. Thus, a careful study needs to be done in tailoring TWBs and should not be just driven by the idea of material reduction. It depends extensively on the part geometry. In case of longitudinal welded TWB, when the thickness ratio is varied from 1 to 1.5, load bearing capacity decreases but % elongation remains the same. As the thickness ratio is increased, both the maximum load and the area of crosssection decreases keeping the UTS same for all the cases. In a longitudinal welded TWB, the load is distributed uniformly over the crosssection of the TWB and as thickness ratio increases, the effective crosssection area reduces [6]. Thus, the load bearing capacity decreases with increasing thickness ratio. Figure 6 shows the Load-Progression curves for the same.

**FIGURE 5.** Thickness strain distribution along the blank perpendicular to the weld in TWBs obtained after changing the weld line position

**FIGURE 6.** Load-Progression curves for different thickness ratios in case of longitudinal welded TWB
**LDH Testing**

Similar to the earlier case, here also, as the thickness ratio is increased from 1(1.2mm/1.2mm) to 1.5 (1.2mm/0.8mm), a decrease in the load bearing capacity and pole height is observed. As the thickness ratio increases, the crosssection area decreases, thus the load bearing capacity of the whole TWB decreases. It has been observed that with the increase in thickness ratio, the contribution of the thinner blank to the overall deformation goes on increasing and after say thickness ratio 1.3, it becomes quite dominant and thicker blank becomes just a constraint to the thinner blank. As shown in Fig 7, as the thickness ratio increases, pole height also decreases. This occurs because effectively the deforming volume becomes smaller and smaller as the thickness ratio increases. When the thickness ratio is above 1.3, the load progression curves cluster, i.e., at large thickness ratio, only a small variation in maximum load and pole height are observed. To confirm this, simulations were performed keeping the thinner blank (0.8mm) as constant and varying the thicker blank such that the thickness ratio changes again from 1 to 1.5. The load progression curves in this case nearly match indicating that the contribution of the thicker blank becomes less significant at higher thickness ratios.

In support to the above facts, a similar study, as done in uniaxial testing, was performed on the TWB (203.2mm X 106.2mm) with thickness ratio 1.5 (1.2mm/0.8 mm), by increasing the percentage of thinner blank in the TWB.

Three cases are considered for these simulations: Single sheet of thicker blank, TWB with weld line at center, Single sheet of thinner material. (shown in Fig 8).

Figure 8 shows the comparison of pole height and maximum load of the TWB with that of thinner and thicker base metals. Out of all the cases, when the weld line position is exactly at the center, the pole height and the maximum load are minimum. This happens because the effective guage reduces to that of the thinner blank alone. Strain plots along the crosssection of the blank at maximum load suggested that there is not much of straining in the thicker part. Thus, the thicker blank serves as a clamping part for the thinner blank and the thinner part is the one which contributes to the overall deformation. For each thickness ratio from 1 to 1.5, similar plots were generated and it has been observed that as the thickness ratio increases, the curve shown in Fig 8, rises upwards indicating that the behaviour changes to that of a single sheet made up of thinner base metal.

![Graph showing load progression curves for TWBs with different thickness ratios](image)

**FIGURE 7.** Load progression curves for TWBs with different thickness ratios subjected to LDH testing (TR:Thickness Ratio)
CONCLUSIONS

- As the thickness ratio increases, the formability of the TWB decreases in case of transverse weld.

- In a Transverse welded TWB, the contribution of the thinner blank to the plastic deformation increases as the thickness ratio increases. For higher thickness ratios (greater than 1.3), the thinner blank will dominate the overall deformation behaviour. Under such conditions, the thicker blank nearly appears to act as a rigid body constraint during the deformation of TWB. Thus, the effective deforming area in a transversely welded TWB is essentially that of thinner material at higher thickness ratios.

- The maximum load as well as cup height at maximum load are minimum when the weld line position is at center in a transverse TWB.

- The decision to replace a single sheet blank by TWB should not be driven only by weight reduction consideration but should also consider the impact on the overall formability of TWB.

REFERENCES


