# Tensile Testing on Formability of Different Gauge Tailor-Welded Blanks

Song Xue*[,1,2], Jie Zhou[2] and Ying-Qiang He[2]

[1]*College of Material Science and Engineering, Chongqing University, Chongqing 400010, China*

[2]*School of Manufacturing, Southwest University of Science and Technology, Sichuan Mianyang 621010, China*

**Abstract:** The formability of tailor welded blanks (TWBs) which combined with different blanks is difference to single material blanks. It has the benefits to improve the forming process by the study on the formability of TWBs. As an effective and practical material property test method, tensile test were applied to study it. Base material and tailor welded blanks test specimens had been designed for tensile testing and the test was carried out. The strength and plastic properties of different TWBs were acquired and the results were discussed. The results of tensile test indicated that the tensile strength of TWBs was between higher strength base material and lower one but formability was lower than any base material. At the same time the weld line location in the TWBs had a significant impact on the formability also.

**Keywords**: Formability, tailor-welded blanks, tensile testing.

## 1. INTRODUCTION

Tailor welded blanks (TWBs) are composed of more than two materials with similar or different strengths or thicknesses joined together to form a single part before the forming operation [1]. In recent years, different gauge TWBs are commonly used in automotive panels manufacturing to satisfy the demand of the automotive industry's developing new cost effective methods to enhance the performance of the vehicle weight reduction and fuel economy [2]. While the character and behavior during the forming process of different gauge TWBs is not alike single thickness (material) sheet behavior. The forming behavior of TWBs is critically influenced by thickness and material combinations of the blanks welded and weld line location etc. Considerable investigations on the behavior of different gauge TWBs have been done in the aspect of stress-strain curve, forming limit strain, dome heigh, deep-draw ability, and weld line movement based on experimental and computer simulation method [3-7]. However, little has been reported on formability investigation of different gauge TWBs by tensile testing [8, 9].

As an effective and practical material property test method, tensile test were applied broadly to evaluate the basic mechanical properties and formability of steel sheet. By the test, the stress-strain relationship of the sheet under static load will be revealed. And a series of basic mechanical properties such as $\sigma_s, \sigma_b, \delta, \phi, n$ and $K$ will be obtained also. These performance properties are the basis to structure and technology design [10, 11].

## 2. TEST METHOD

Electronic universal testing machine (as shown in Fig. **1**) was used to test the TWBs' properties. The test force precision within ±0.5% of indicated value; the test force calibration within grade 1.0; auto data recording mode was adopted to record displacement -load curve in this research and the loading speed of test machine clamp was 5 mm/s.

**Fig. (1).** Electronic universal testing machine.

## 3. TENSILE TEST SPECIMENS DESIGN

The test sheet is the TWBs composed of BaoSteel H340LAD+Z and DP600 with different gauge thickness 1.7 mm/2.4 mm. It is the high strength steel to meet the high performance requirement of auto body. In this test the

*Address correspondence to this author at the School of Manufacturing, Southwest University of Science and Technology, Sichuan Mianyang 621010, China; Tel: +86-816-6089705; Fax: +86-816-6089705;
E-mail: xuesong2004@126.com

specimens' material in thinner side is H340LAD+Z while in thicker side is DP600, the only difference between each is the weld line location. Table **1** displays the chemical components of DP600 and H340LAD+Z and Table **2** listed the material combination of testing specimens.

**Table 1. Chemical Components of DP600 and H340LAD+Z**

| Material | C | Si | Mn | P | S |
|---|---|---|---|---|---|
| DP600 | ≤0.10 | ≤0.05 | ≤2.00 | ≤0.015 | ≤0.01 |
| H340LAD+Z | ≤0.10 | ≤0.05 | ≤1.00 | ≤0.03 | ≤0.025 |

**Table 2. The Material of Tensile Testing Specimens**

| Number | Material | Weld Line Location |
|---|---|---|
| 1 | DP600 | Single material |
| 2 | H340LAD+Z | Single material |
| 3 | TWBs | Located in the center of specimen |
| 4 | TWBs | Located near thicker side offset center 15 mm |
| 5 | TWBs | Located near thinner side offset center 15 mm |

The profile and size of test specimens depends on the dimensions of the sample metal materials, the efficacious length of the specimen should be larger than original gauge length. To study the mechanical properties difference between base metal and TWBs, the test plan had designed two base materials tensile test and the TWBs with three different weld line locations ones. Since there are no international standards for TWBs tensile testing specimen, the specimen profile and size was designed refer to ASTM E8 standard. The marked line was set near to the TWBs' weld line to study the strain condition of weld line zone in the tensile test. The designed profile and size of the base metal and TWBs test specimens shown as Figs. (**2**, **3**).

## 4. RESULTS AND DISCUSSION

### 4.1. Displacement-Load Curve

According to the designed test program the test specimens were tested on electronic universal testing machine. The displacement - load curve is shown as Fig. (**4**). The max tensile force and max break strain of each specimen were listed as Table **3**.

The diagraph and the test data indicated that the max tensile force of thicker base material DP600 is greater than the one of thin base material H340LAD+Z. The max tensile force test indicated that the tensile strength value of TWBs were between the higher strength base material and lower one when the tensile direction was vertical to the weld line.

The max breaking strain value indicated the specimens' plastic behavior. The Table **3** indicated that the breaking strain was different when the weld line located different, the proportion of weaker blank in TWBs was bigger the TWBs' breaking strain was bigger. So the proportion distributed in the TWBs play a decisive effect to breaking strain.

### 4.2. Strength and Plastic Property

The tensile test strength and plastic index of specimens were listed as Table **4**.

### 4.3. Strain Hardening Exponent n and Strength Coefficient K

Strain hardening exponent, n-value, indicates the material harden degree in the process of plastic deformation. While n value is bigger the deformation during the deforming process is more uniform distributed, therefore bigger n-value is benefit to expand deformation zone, decrease the blank partial thinner phenomenon in this way to enhance the deforming performance. So, n value is the key index to evaluate the formability of sheet metal which indicated the capacity of material resistance to continue plastic deformation.

With the power harden material model, true stress can be expressed as a function of n and K, where the strength coefficient K which indicated the strength of the material.

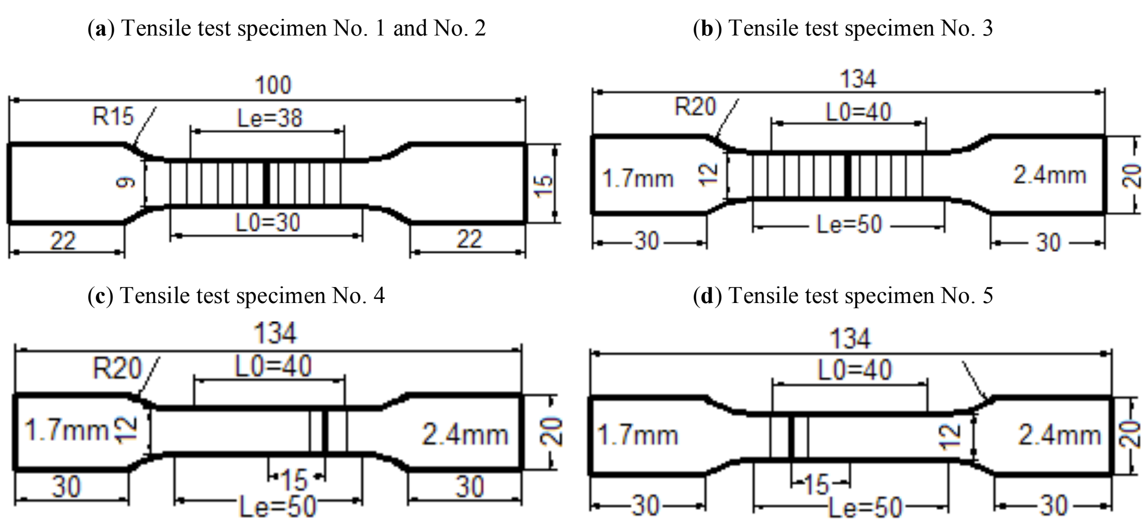


**Fig. (2).** Profile and dimensions of tensile test specimens 67089.

$$\sigma = K\varepsilon^n \quad (1)$$

By the stress-strain relationship model, the n-value and K-value were calculated in this tensile test which listed as Table **5**.

**Table 3. The Max Tensile Force and Max Break Strain of Tensile Testing Specimens**

| Specimen Number | Max Tensile Force (kN) | Max Breaking Strain ($\varepsilon_{max}$) |
|---|---|---|
| 1 | 14.398 | 0.245 |
| 2 | 7.003 | 0.287 |
| 3 | 9.449 | 0.141 |
| 4 | 9.278 | 0.185 |
| 5 | 9.623 | 0.099 |

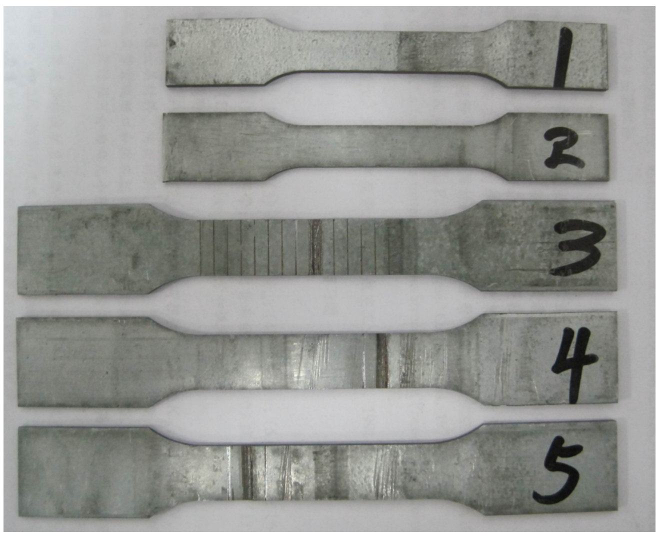


**Fig. (3).** The object profile of tensile testing specimens.

According to the calculated n-value, the strain hardening exponent of specimen 2 reached the max value. It means specimen 2 had the best capacity to resistance to continue plastic deformation. The specimen 5 had the minimum strain hardening exponent value, which means the tensile property of it was the worst. So, the differences in the tensile properties of specimens can be drawing form the comparison of the value of hardening exponent.

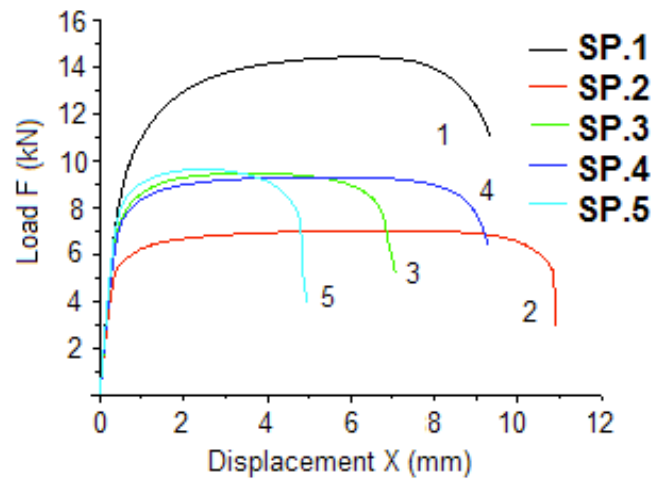


**Fig. (4).** Displacement and load curve of tensile testing specimens.

### 4.4. Results of Testing Specimens

The tested specimens were shown as Fig. (**5**). The tensile specimen cracked at H340LAD+Z side when the weld line vertical to tensile direction. This is because the strength in weld line is higher than in base metal, so the weld line nearly formed rigid joint to TWBs and the deformation degree is direct proportion to the distance to weld line. When the deformation started the weak blank firstly yielded to deform, so the tensile performance of TWBs depends on the lower strength material.

The strength of DP600 is higher than H340LAD+Z, so in

**Table 4. The Strength and Plastic Index of Specimens After Tensile Test**

| Index | Specimen 1 | Specimen 2 | Specimen 3 | Specimen 4 | Specimen 5 |
|---|---|---|---|---|---|
| $\sigma_s$/Mpa | 466 | 369 | 383 | 387 | 405 |
| $\sigma_b$ /Mpa | 666 | 458 | 463 | 455 | 472 |
| $\sigma_s$ /$\sigma_b$ | 0.699 | 0.806 | 0.827 | 0.850 | 0.858 |
| δ(%) | 22.4 | 29.7 | 14.4 | 19.1 | 11.0 |
| ψ(%) | 18.3 | 22.9 | 12.6 | 16.0 | 9.9 |

The results indicated that the formability of TWBs was worse than base materials, the greater proportion of weaker blank the better plastic formability.

**Table 5. The n and K Value for Specimens**

| Index | Specimen 1 | Specimen 2 | Specimen 3 | Specimen 4 | Specimen 5 |
|---|---|---|---|---|---|
| n | 0.151 | 0.158 | 0.069 | 0.100 | 0.047 |
| K | 1031.13 | 717.37 | 597.04 | 632.74 | 571.04 |

a deforming process the deformation speed is not coordinated to the other one, at last it caused the TWBs crack at H340LAD+Z side, while in higher strength side which is DP600 only have little deformation. In this test, the ruling span in H340LAD+Z side elongated relative ratio is 5% and in DP600 is 2.5%. In this sense, the material deforming degree in both side of weld line were not uniform, the deformation in H340LAD+Z side is bigger than it in DP600 side. By comparing the cracked TWBs specimens with different located weld line that the necking cracks occurred on weaker side not in heat affected zone.

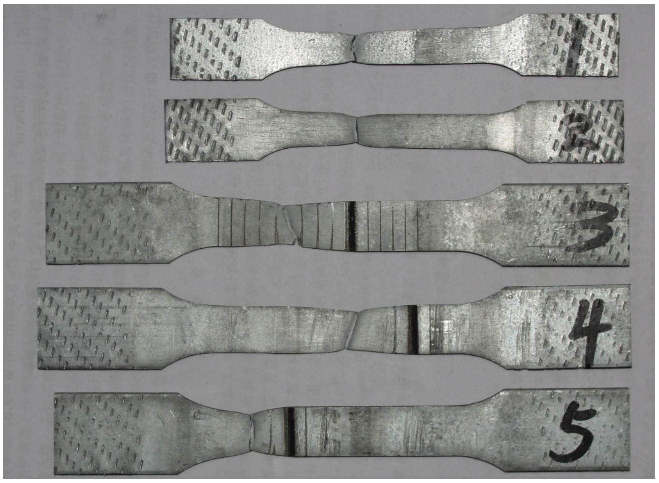


**Fig. (5).** The results of specimens after tensile test.

## 5. CONCLUSION

The following conclusions were drawn from the tensile test on formability of TWBs.

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 depend 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.

## REFERENCES

[1] Gaieda S, Roelandt J-M, Pinard F, Schmit F, Balabane M. Experimental and numerical assessment of Tailor-Welded Blanks formability. J Mater Process Technol 2009; 209: 387-9.

[2] Shi Y, Zhu P, Shen L, Lin Z. Lightweight design of automotive front side rails with TWB concept. Thin Wall Struct 2007; 45: 8-14.

[3] Babua VK, Narayanana RG, Kumar GS. An expert system based on artificial neural network for predicting the tensile behavior of tailor welded blanks. Expert Syst Appl 2009; 36: 10683-13.

[4] Panda SK, Kumara DR, Kumar H, Nath AK. Characterization of tensile properties of tailor welded IF steel sheets and their formability in stretch forming. J Mater Process Technol 2007; 183: 321-32.

[5] Qiu XG, Chen WL. The study on numerical simulation of the laser tailor welded blanks stamping. J Mater Process Technol 2007; 187-188: 128-31.

[6] Lee W, Chung K-H, Kim D, *et al*. Experimental and numerical study on formability of friction stir welded TWB sheets based on hemispherical dome stretch tests. Int J Plasticity 2009; 25: 1626-29.

[7] Jianping L, Dongji S, Qiaosheng H, *et al*. Development of research in tailor welded blanks used in auto industry. Automob Technol 2007; 8: 1-5.

[8] Abbas ZA, Jos S, Rinze B. Finite element modeling and failure prediction of friction stir welded blanks. Mater Des 2009; 30: 1423-12.

[9] Srinivas NB, Janaki RP, Ganesh NR. Application of a few necking criteria in predicting the forming limit of unwelded and tailor-welded blanks. J Strain Anal Eng Des 2010; 45: 79-18.

[10] Panda SK, Hernandez VB, Kuntz ML, Zhou Y. Formability analysis of diode-laser-welded tailored blanks of advanced high-strength steel sheets. Metall Mater Trans A 2009; 40: 1955-67.

[11] Fratinia L, Buffaa G, Shivpuri R. Improving friction stir welding of blanks of different thicknesses. Mater Sci Eng A 2007; 459: 209-7.

Received: September 28, 2010 Revised: November 26, 2010 Accepted: December 22, 2010