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AN INVESTIGATION INTO THE EFFECT OF MATERIALS ON JOINING FOR AUTOMOTIVE PANEL USING TAILOR WELDED BLANKS

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Abstract

A laser welded blank for use in applications calling for tailor welded blank (TWB) in vehicle panel assemblies. A promising approach to reduce manufacturing costs, decrease vehicle weight, and improve the quality of automotive body components is through the use of tailor-welded blanks. This term refers to blanks where multiple sheets of material are welded together to create a single blank prior to the forming process. The welding process creates formability concerns in a traditional forming process due to material property changes in the weld and in the heat-affected zone adjacent to the weld. Malaysian automotive manufacturers are still lack of this advancement. Hence, this project endeavors to build a platform for the industries by pioneering researches in this area. This paper presents to investigate the weld properties of high strength steel laser weld for joining the automotive panel. Laser weld and different types of steel are considered in this study. Experiment was carried out to determine the properties of materials after welding, forming and drawing process of TWB. It is observed from the acquired results that the potential TWB gives the best material combination. It can be seen that cross sectional area and steel grade are the most significant subjected to the tensile loading.

Keywords: TWB; automotive panel; laser welding; high strength steel

1. Introduction

The automotive industry is an extremely competitive global market that is continuously challenged to improve its products and operations. Customers demand high performance cars at minimal cost, which often conflict with the ever constricting government environmental regulations. These requirements force automakers to come up with innovative solutions to reduce manufacturing costs, improve product performance, and reduce vehicle weight. Recently, the automobile industries have tried to develop various types of cars with high quality and low cost to meet customer's demands. With the increasing demand for stronger, lighter and safer cars, the automotive industry is adopting many new manufacturing methods [1, 13, 14]. One of the most prominent of these uses tailor-welded blanks (TWB) in automotive stampings [4]. With TWBs, welding occurs prior to, rather than after, the stamping process. A typical TWB is laser-welded and comprised of two or more sheets. Each sheet typically has a different thickness, although sheets with different strengths, formabilities and/or coatings are also common. The trend toward TWBs is driven principally by industry's move towards light weighting but also to lowering production costs by reducing the number of forming and materials handling operations [7]. The concept of laser-welded TWB processing raises a number of interesting issues with respect to residual stresses. First, the welding procedure itself produces residual stresses. While weld-induced residual stresses have been well-documented [8–11] the authors are aware of no experimental studies to determine residual stresses in TWBs.

Tailor blanking is an established process used increasingly in automotive body components fabricated using steel sheet [2]. TWBs consist of multiple thicknesses, and sometimes multiple alloys, sheet metals, which are welded together into a single blank of multiple gauges. In automotive applications, these blanks are stamped to produce body panels. Numerous advantages of this process arise from reducing weight, decreasing part count, streamlining the assembly process, and cutting costs significantly by using singular TWBs instead of multiple blanks, which would have to be individually stamped and assembled [3].

Laser-beam welding creates good quality welds with minimum shrinkage and distortion. This type of welds have good strength and generally ductile and free of porosity. The process can be automated and can be used on a variety of materials thickness of up to 25 mm. It is particularly effective in thin workpices. Laser welding techniques nowadays are highly developed resulting very strong weld joints. Significant flexibility in product design, structural stiffness, crash behavior, and formability can be achieved by the growing trend toward welding and forming sheet-metal pieces. Therefore, making it possible to use different materials in one component, weight savings, and cost reduction in materials, scrap, equipment, assembly and labor [15].

The aim of this paper is to investigate the weld properties of high strength steel laser weld for joining the automotive panel. In this study, TWBs made by the laser welding process with different thickness combinations were applied in deep drawing process and their forming behaviour was investigated. Experiment was carried out to determine the properties of materials after welding, forming and drawing process of TWB.

2. Experimental details

After a series of preliminary study, 5 automotive steel panels/sheets with different grades each was chosen as potential specimen. These panels are divided into two thicknesses that were joined according to combinations. Table 1 listed the grades, thicknesses and combination of creating a specimen. Five different thickness steel materials are considered in this study including SPCC, SPHC, SAPH 370, SGACC and SPCEN.

Table 1**:** List of specimen needed for the project

No.	Combinations (0.7t - 1.2t)	Specimen No.
1	SPCC - SPHC	3
2	SPCC - SAPH 370	3
3	SPCC - SGACC	3
4	SPCEN - SPHC	3
5	SPCEN - SAPH 370	3
6	SPCEN - SGACC	3
	Total	18

For specimens' preparation, first the base panels are sheared into thin strips according to dimension that is 60 mm x 10 mm as shown on Fig. 1a. The panels are sheared by using a shearing machine .The sheared specimens are then checked for accepted tolerance. Strips that were not complying with the tolerance range were voided. Fig. 2 shows a sheared base metal of each grade.

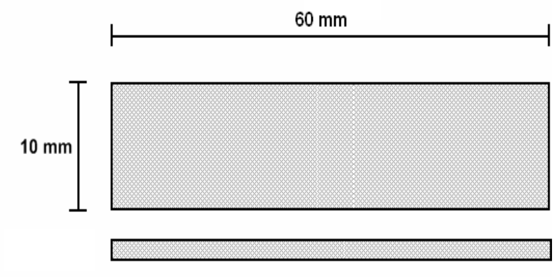

Fig. 1. Dimension for shearing

Fig. 2. NC shearing machine model 6131

The specimen's combinations with two base specimens of different thickness are combined according to Table 1.Then, the specimen's joint with laser welding. A set of constant parameter of laser welding were selected for the combination specimens to gives better results. The laser weld was set for high penetration from top to bottom in one encounter for the finest quality. Table 2 listed the welding parameter for this testing. Fig. 3 shows the laser welding machine used for the project, Fig. 2 shows the combination being laser welded and Fig. 4 shows the specimens that have been welded. After the specimens were prepared, then the testing began.

Table 2. Laser welding parameters

Laser Welding Parameter	Value
Laser Type	Nd: YAG
Power	3.5 kW
Pulse Width	7.5 ms
Frequency Rate	7.5 ms
Speed	Manual
Focal	60 mm -70mm
Filler Metal	Hi Nickel wire 0.3mm
Shield Gas	Argon

Tensile test was used for mechanical properties of each specimen including strength, ductility, toughness, elastic modulus, and strain of the weldment area. The specimen with dimension of 60 mm x 10 mm for base metal (see Fig. 1) and 120 mm x 10 mm for TWBs (see Fig. 3) was snuggly fit the grip teeth. INSTRON Universal Testing Model 3369 tensile test machine was used in executing the test. For every specimen, repetition was done three times.

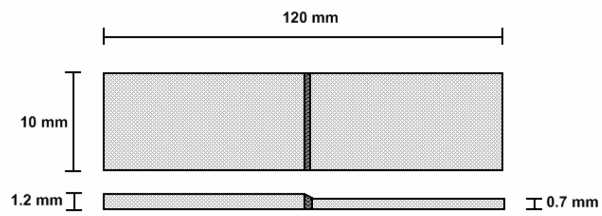

Fig. 3. TWBs tensile specimen dimension

3. Results and Discussion

The purpose of taking tensile test for the base metal is to create a reference data of same sheet metal that were used to the TWB specimens. The obtained data then used as compare to the data obtained from the TWBs. Only certain values are taken from the data for validation purpose. Table 3 listed the material properties of tensile test for different combination of TWBs.

Tensile testing was conducted using INSTRON Universal Testing Model 3369 machine. Consequently, all the specimens have the same characteristic. The TWBs tend to fracture at the thinner strip of 0.7 mm where the area is smallest except one of the SPCEN-SGACC TWB which fractures across the weld line. This proves that the welding fuse the two perfectly creating strong joints as stated in the literature review [1,2,4].

According to Fig. 4, it can be seen that there are two distinct patterns such as SPCCs and SPCENs. The yield strength (YS) of the TWBs of the thinner (0.7 mm) combination sheet of SPCCs give the higher yield strength than SPCENs. The SPCCs have higher yield strength than SPCENs counterpart.

It can be seen from Table 3 and Fig. 4 that the mechanical properties of the TWBs are much lower than the rest of its bases either 0.7 mm or 1.2 mm thicknesses. It is found that the thinner strip 0.7 mm of the TWBs plays a major role in determining the overall mechanical properties mainly for the YS, UTS and strain value than the 1.2 mm thick partner. This means that the smallest cross sectional area of the TWBs is the most affected when subjected to tensile loading. When a high load is given, the smallest cross sectional area generate the highest levels of stress. The SPCEN based TWBs produce the lower YS and UTS than the SPCC based.

Table 3. Materials properties of different combination of TWBs

Exp. No.	TWBs Combinations (0.7t - 1.2t)	Readings	Yield Strength (MPa)	UTS (MPa)	% Strain	E. Modulus (GPa)
1	SPCC - SPHC	1	181.71	310.97	17.55	95.19
		2	210.69	284.91	16.86	93.34
		Ave.	196.20	297.94	17.21	94.27
2	SPCC - SAPH 370	1	181.71	283.03	16.66	97.63
		2	178.80	281.83	17.64	93.62
		Ave.	180.26	282.43	17.15	95.63
3	SPCC - SGACC	1	185.66	288.51	17.29	95.19
		2	182.57	288.51	17.71	93.34
		Ave.	184.12	288.51	17.50	94.27
4	SPCEN - SPHC	1	141.03	265.03	18.76	95.66
		2	134.42	258.17	19.08	101.18
		Ave.	137.73	261.60	18.92	98.42
5	SPCEN - SAPH 370	1	133.49	262.63	17.96	96.39
		2	138.55	262.63	19.28	91.46
		Ave.	136.02	262.63	18.62	93.93
6	SPCEN - SGACC	1	171.52	236.06	7.19	92.01
		2	131.38	260.74	19.10	97.65
		Ave.	151.45	248.40	13.14	94.83

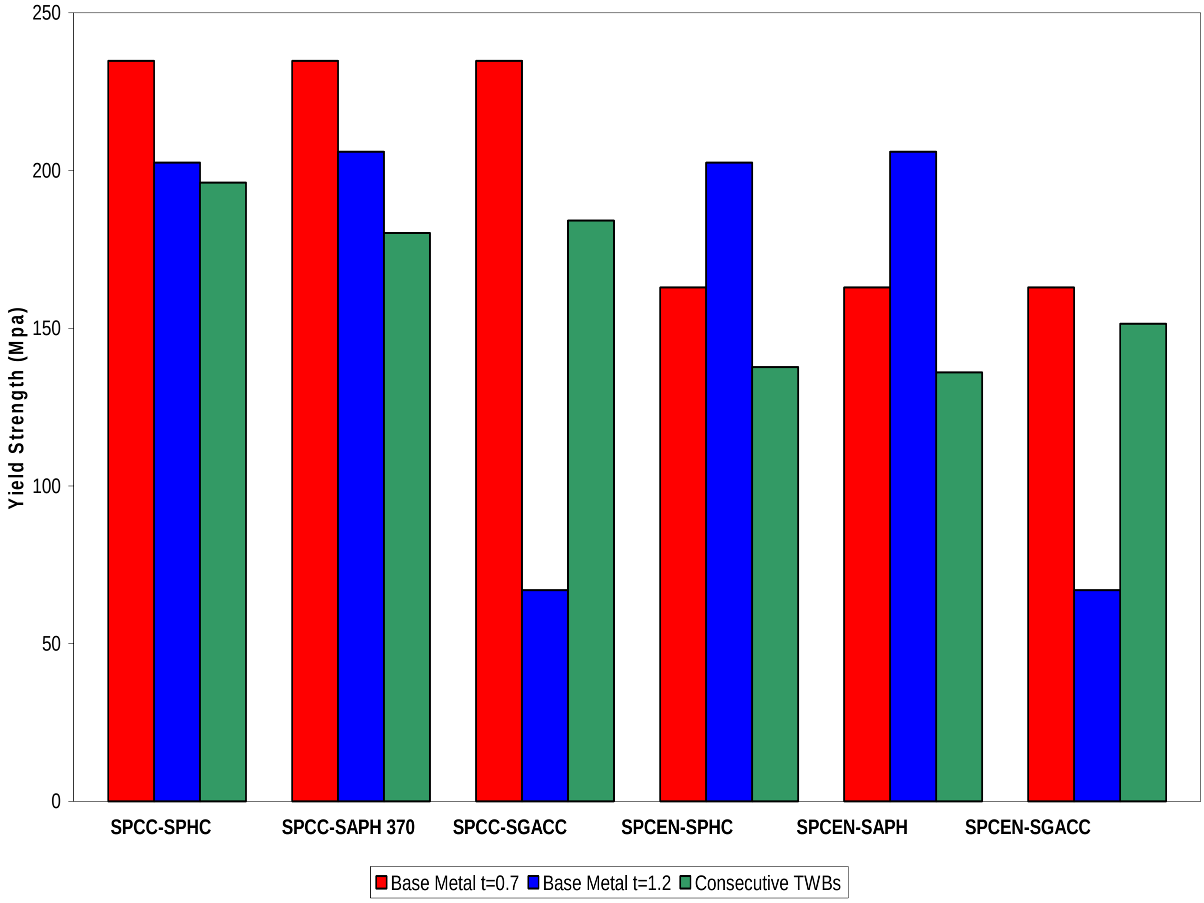

Fig. 4. Comparison of TWBs yield strength with their base metals

The grade of the materials plays an important role in influencing the obtained results. Different grade of steels are produced by altering the chemical composition. The level of strain of the specimen are much affected by the chemical composition itself than the cross sectional area. It is also found that 0.7 mm strip play a major role in determining the overall strain value due to the steel grade. SPCCs are manufactured for drawing quality while SPENs are manufactured for the deep drawing quality. Obviously, SPCENs is best SPCCs in strain value comparison. A more ductile steel grade elongate better than the vice versa grade.

The smaller of the speciment's area and the ductile the grade, bring the base metal prone to overwhelm the TWBs. If the crucial base (SPCCs & SPCENs) of the TWBs were compared, the SPCENs produce the superior quality than SPCCs if those were adapted in automotive manufacturing application including the car door panel. The SPCEN have higher in formability due to its lower YS and higher in drawability due to its higher strain. The candidates to be paired with SPCEN are either SPHC or SAPH 370 due to their high strength use for structural stability.

4. Conclusion

The most significant parameter of TWBs are the cross sectional area and steel grade when subjected to tensile testing. From the acquired results, it can be concluded that the location at the thinner base (0.7 mm) of the TWBs with smallest cross sectional area and type of high ductility steel, SPCC and SPCEN base hold foremost influence of the overall TWBs properties. Comparing the 0.7 mm SPCC with SPCEN, SPCEN have the desirable superior property formability and drawability to be made as the intermediate panel. While SAPH 370 and SPHC base are chosen than SGACC due to the higher strength value that can be made as the hinge panel. When a high load is given, the smallest cross sectional area generate the highest levels of stress. The SPCEN based TWBs produce the lower YS and UTS than the SPCC based. Hence, the proposed TWB combinations would be SPCEN-SPHC and SPCEN- SAPH 370.

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