Research Article

Study on Stress Depending on HSS Panel Joint Method in Automobiles

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***Abstract*— A vehicle to which a body panel reinforced by repairing an automobile body is applied must be welded or joined by a method suitable for the panel material so as to prevent corrosion of the panel and ensure rigidity of the body structure. As a result of studying the stress by the joining method of HSS and UHSS panels, it was confirmed that the welding method was performed in parallel and the joining method was superior to the simple joining method from the tensile stress strength. In addition, spot welding and post-bonding rivets were used as an efficient joining method that can minimize the deformation of the material properties of the vehicle body panel, prevent corrosion, and maximally maintain the rigidity of the vehicle body structure..**

***Index Terms*— Bonding method; joint method; welding method; welding**

I. INTRODUCTION

Reducing vehicle weight is imperative to lower emissions and improve the mileage. With the downsizing of automobile engines and the implementation of policies to increase hybrid and electric vehicles, the use of aluminium, plastic, and carbon fibre materials is increasing, but the materials have lower price competitiveness than steel. The development of the steel industry has allowed for increasing the steel strength by adding hard tissues to soft tissues in order to secure high strength, enhance the safety, and reduce the weight of the vehicle body structure to contribute to the increase of the energy consumption efficiency and to reduce the CO2 emissions. As a result, new steel materials, such as high-quality high strength steel (HSS) and ultra-high strength steel (UHSS), are applied to an increasing number of vehicles.

In contrast to the joining method applied to the conventional vehicles made of mild steel, the reinforced vehicle body panels should be joined or welded during repair works by a method suitable for the panel material to prevent the corrosion of the panels and secure the structural strength of the vehicles in order to protect the passengers in the event of an accident and ensure long-time use of the vehicle structure. However, the application of abnormal joining methods often leads to secondary damage in an accident, causing social losses.

In the present study, a stress test was performed with the joining methods employed for vehicle repair to find an efficient joining method that can better secure the strength

II. METHODS AND APPARATUSES

A. Specimen Preparation

The specimens used in the present study were HSS (SGAFC1180Y 1.2t) that is applied to actual automobile panels. As shown in Figure 1, the HSS panel was cut into a size of 100mm×30mm to prepare the specimens. The UHSS (1470×1.2t, 1.5GPa) specimens were prepared by disassembling a portion of the hot-stamped center pillar and cut to a size of 100mm×30mm by using a shearing machine, as shown in Figure.

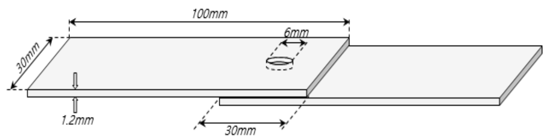

Figure 1. Welding specimen (L (100mm) × W (30m) × T (1.2mm))

B. 2.2 Methods

The vehicle panel specimens were joined by applying seven different methods (bond joining; CO2 welding; CO2 welding and bond joining; spot welding; spot welding and bond joining; and rivet joining; rivet joining and bond joining), and the average values were obtained by performing the tensile test five times for each method.

The HSS and UHSS specimens were subject to bond joining, [1][2] plug joining,[3] resistance spot welding, [3-8] and self-piercing rivet joining[9-13]. The bond joining [14,15] was performed by debonding the specimens and applying the original two-component panel adhesive supplied by the H vehicle manufacturer. The plug joining (CO2 joining) was performed, as shown in Figure 1, by making a 6 mm-hole, placing the specimen over the hole, and welding with the T3 multi-functional MIG/MAG welding system (380 V, (Figure 2)) under the welding conditions shown in Table 1. The spot welding was performed by overlapping the specimen and applying the inverter spot welding W-510 system (A company, 380V, Figure 3) to the two materials under the welding conditions shown in Table 2. The self-piercing rivet joining was performed by using the system manufactured by B Company (Figure 4). The joining was performed by the seven methods shown in Table 3.

TABLE 1 PLUG WELDING CONDITIONS

Voltage	21.5V
Current	150A
Weld time	2.5sec

TABLE 2 SPOT WELDING CONDITIONS

Weld current	9.1 kA 1.5V
Welding force	3.5 kN
Welding time	0.19sec

TABLE 3 TYPE OF METHOD TO WELD THE SPECIMEN

Method		Description
1		Bonding
2		CO_2
3		CO_2 and Bonding
4		Spot welding
5		Spot welding and Bonding
6		Rivet
7		Rivet and Bonding

Figure 2. T3 GYS Auto welding system

Figure 3. Auto W-510 spot welding system

Figure 4. Bodyliner Selfpiercing rivet gun

C. Experimental Apparatus

The tensile and shear strength test in the present study was performed by mounting the prepared specimen on the testing system (SHIMAZU, Figure 5) having a capacity of 25,000N to test the maximum tensile and shear strength while elongating the specimen at a rate of 3mm/min.

Figure 5. Tensile shear strength test machine

III. RESULTS AND DISCUSSION

The experimental results showed that the methods combined with bond joining provided good tensile test results in both the HSS and UHSS panels. While the length of the HSS specimens that were subject to bond joining and then welding was increased and the width was decreased in the tensile test, the length and width of the UHSS specimens remained unchanged. The thermal deformation was severe in the CO_2 joining around the welding surface. A slight thermal deformation was found in the spot welding around the spot welding area, but the rivet joining showed no thermal deformation. The thermal deformation around the joining may lead to long-term change of the tissues or materials, causing early corrosion of the panels.

A. Analysis of Stress Depending on HSS Joining Method

When the HSS specimens were joined by using the rivet only; the stress was lowest, as the rivet tended to detach from the rivet hole, which was enlarged during the tensile test. The magnitude of the stress was highest in the order of spot welding, CO_2 welding, and bond joining. The bond joining, the bond joining followed by rivet joining, and the bond joining followed by spot welding showed excellent joining performance with a similar Lobe diagram up to the tensile distance of about 3.5 mm, as shown in Figure 7. Figure 8 shows the fractured shapes after the tensile test.

The CO_2 welding also showed an excellent stress curve in the joining of HSS panels. However, in the joining method combining the CO_2 plug welding and the bond joining, the high temperature generated by the welding caused a distinctive thermal deformation around the welding surface, as shown in Figure 9, and a fracture was caused by the elongation around the welding surface. On the other hand, the joining performed by using the spot resistance welding system showed a lower stress than the CO_2 welding, but the thermal deformation around the welding surface was less severe, as shown in Figure 9.

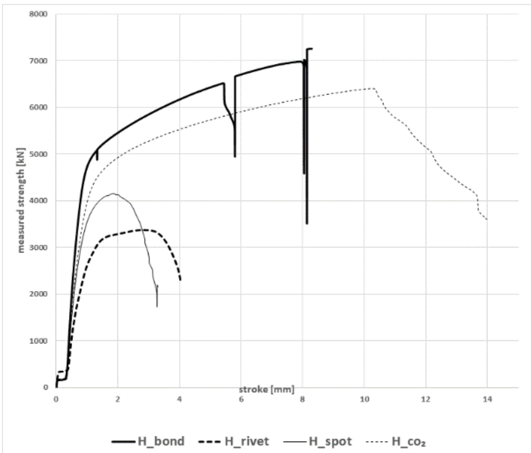

Figure 6. Stress by the joining method of HSS

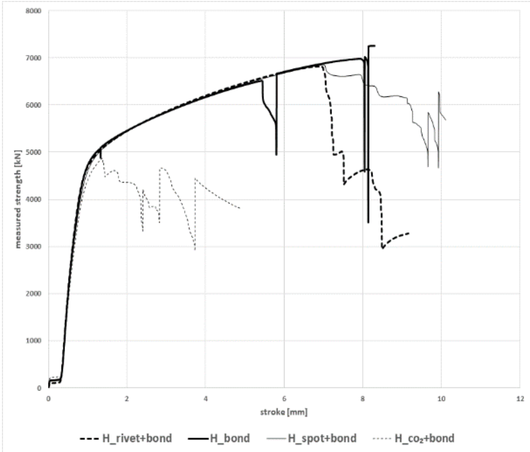

Figure 7. Stress by the joining bonding method of HSS

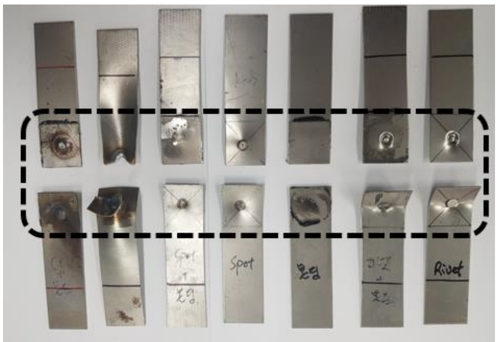

Figure 8. HSS tensile stress strength fracture

Figure 9. Thermal deformation of welded part

B. *Analysis of Stress Depending on UHSS Joining Method*

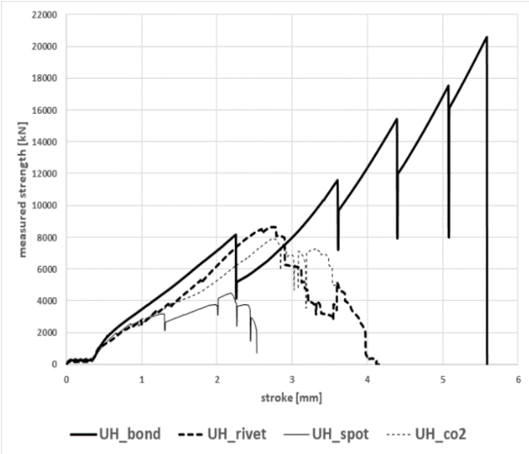

Figure 10. Stress by the joining method of UHSS

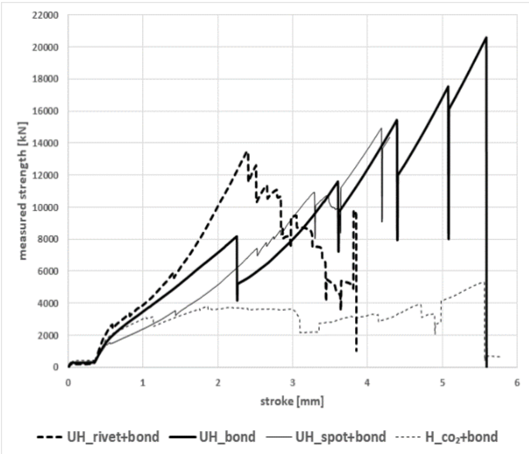

Figure 11. Stress by the joining bonding method of UHSS

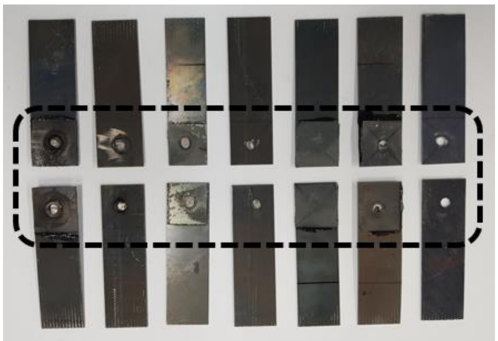

Figure 12. UHSS tensile stress strength fracture

When the stress of the USS specimens was tested by applying a single joining method, the bond joining showed the best performance, as shown in Figure 10, and a similar tendency was found in the rivet joining, spot welding and CO_2 welding up to the tensile length of 1 mm. The strength was high in the order of the rivet joining, CO_2 welding and spot welding.

When the rivet joining, spot welding and CO_2 welding were each combined with the bond joining, the tensile strength was high in the order of the bond joining followed by the spot welding and the bond joining followed by rivet joining, as shown in Figure 11. Figure 12 shows the fractured shapes after the tensile test.

Among the joining methods combined with the bond joining, the best strength up to the tensile length of about 2.5 mm was found in the method combined with the rivet joining. In the CO_2 welding, despite the uniform adhesion in an area of 3cm×3cm, the heat melted the adhesive, and thus the tensile strength after a tensile length of 1 mm was the lowest.

With respect to the maximum tensile strength, the simple bond joining was found to be the best method. While the tensile-shear curve showed a steep increase until a fracture in the rivet joining and the spot welding, the curve slowly increased with elongation until a fracture in the CO_2 welding.

C. Analysis of Stress Variation in Bond Joining

In the bond joining, the tensile strength of the UHSS specimens was about three times higher than that of the HSS specimens, as shown in Figure 13 [16]. Figure 14 shows the fractured shapes in the bond joining, and the specimens were not deformed in the tensile test.

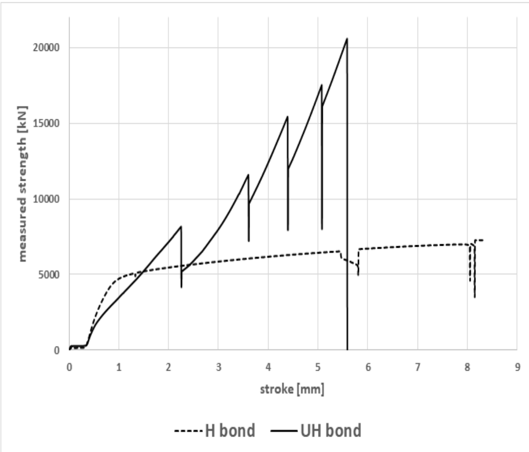

Figure 13. Stress by the joining bonding method of HSS and UHSS

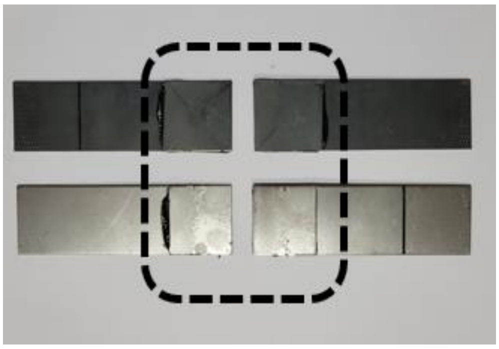

Figure 14. Tensile stress strength fracture of joining bond

D. *Analysis of Stress Variation in CO_2 Welding*

In both the joining of HSS panels and the joining of UHSS panels, the tensile strength was higher with the simple CO_2 welding than the CO_2 welding combined with the bond joining, as indicated by the results of the tensile test shown in Figure 15 [17]. This may be because the high temperature and the inert gas involved in the plug welding decreased the performance of the bond joining. The high temperature caused by the heating during the welding might have melted the adhesive, which disturbed the CO_2 welding or lower the performance. The same was found in the joining of UHSS panels. Therefore, it seems to be better in the welding based on the inter CO_2 gas not to accompany the bond joining.

The HSS specimens underwent deformation and tearing in the tensile test, as shown in Figure 16, while the UHSS specimens were not deformed.

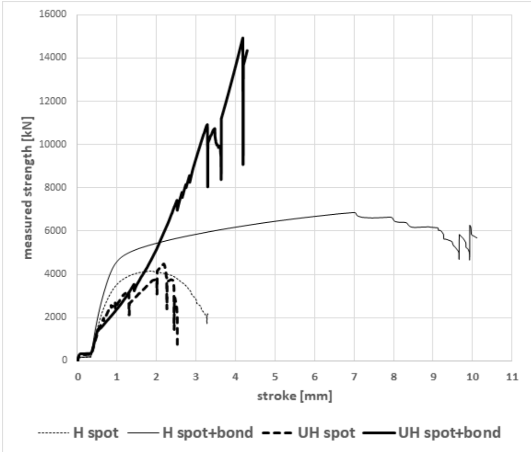

Figure 17. Stress by the joining spot method of HSS and UHSS

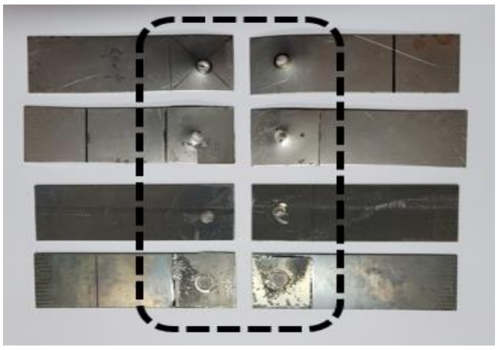

Figure18. Tensile stress strength fracture of joining bond

E. Analysis of Stress Variation in Rivet Joining

In the joining between UHSS panels, the bond joining followed by the rivet joining showed the highest performance, as shown in Figure 19. The tensile strength in the combined method of the bond joining and the rivet joining was higher in the joining of the UHSS panels than in the joining of the HSS panels. The HSS specimens showed a slow increase in the tensile strength curve, while the UHSS specimens showed a steep increase.

As shown in Figure 20, since the HSS specimens are relatively soft, the rivet joining part was elongated, and the rivet dropped out. On the contrary, the rivet of the UHSS specimens was simply fractured without a change in the material.

Since the HSS is relatively soft, the rivet was detached as the rivet joint was elongated during the tensile test. On the contrary, the UHSS showed no change in the material until the rivet fractured.

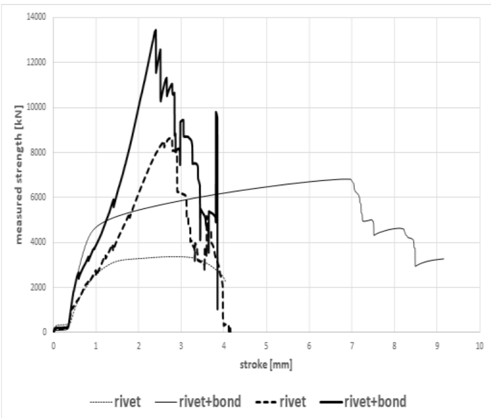

Figure 19. Stress by the joining rivet method of HSS and UHSS

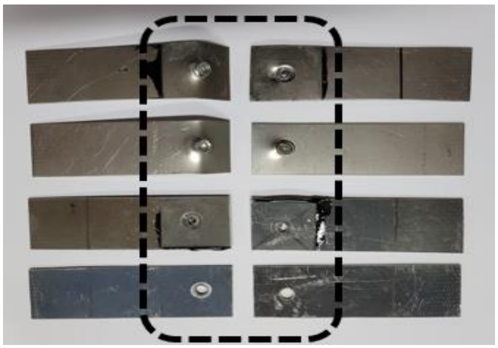

Figure 20. Stress by the joining rivet method of HSS and UHSS

IV. Conclusions

The present study was conducted to investigate the stress depending on the joining method for the joining between HSS panels and between UHSS panels. Regardless of the joining method, the tensile strength was higher in the UHSS specimens and in the HSS specimens. The tensile strength of each material was higher in the method combined with the bond joining than the single methods. The methods that are capable of minimizing the deformation of the original materials and the change of the properties, maintaining the strength, preventing corrosion to avoid deformation for a long time and maintaining the joining performance were found to be the spot welding method and the rivet joining method followed by bond joining, which can minimize the thermal deformation.

With the diversification of the panels for vehicle bodies, in addition to the methods of joining heterogeneous materials, dissimilar joining should be studied further in order to apply a joining method suitable for each panel material in the repair of vehicles.

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