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Heat Generation and Machining Accuracy According to Material for Ultra-Precision Machining

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차량 경량화를 위한 이종소재 접합 연구

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ABSTRACT

Currently the automobile market is developing eco-friendly vehicles in order to cope with fuel efficiency regulations. Many studies have been conducted to improve travel performance and fuel economy of the environment-friendly vehicles, and vehicle manufacturers study how to manufacture light-weight vehicles for improving fuel economy for both existing vehicles and environment-friendly vehicles. Exemplary light-weight vehicle technologies include optimal design of vehicle body structure which is a light-weight vehicle method by changing component shapes or layout to optimize the vehicle body structureand the new process technology for using new light-weight and very strong materials Various studies.

Key Words : Multi-material Bonding(이종접합), Light Weight(경량화), FEA(유한요소해석)

1. Introduction

Currently, the automotive industry is researching and developing environment-friendly vehicles to cope with intensifying regulations for fuel economy and exhaust gases. Many studies are being conducted to improve driving performance and fuel economy, and carmakers are researching lightweight vehicles to improve the fuel economy of both conventional and environment-friendly vehicles. There are various lightweight technologies, including the optimal design of the body structure, which optimizes the body structure of vehicles by changing the shape or layout of parts, and new process technology that uses lightweight, high-strength materials rather than conventional materials. This study investigates the dissimilar material bonding of ultra-high-tensile-strength steel and aluminum for lightweight vehicles.

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2. Dissimilar Material Bonding

2.1 Materials and Methods of Dissimilar Material Bonding

Various dissimilar material bonding methods are being considered, such as aluminum bonding. Among them, the automotive industry is applying self-piercing riveting (SPR) and blind-rivet bonding, which are mechanical bonding methods, for dissimilar material bonding. They are also applying adhesives to complement the peel-off load, which is insufficient in rivet bonding, and static load, which lasts for a long time.

For analysis of the dissimilar material bonding field, adhesive bonding can be implemented using ANSYS DYNA, which is a universal finite element program, and SPR bonding can be analyzed using ANSYS DYNA and Deform2D[1-13].

For dissimilar material bonding in this study, SPR, blind-rivet bonding, and a hybrid bonding method that combines adhesive bonding and riveting are applied, as shown in Fig. 1; the materials are listed in Table 1.

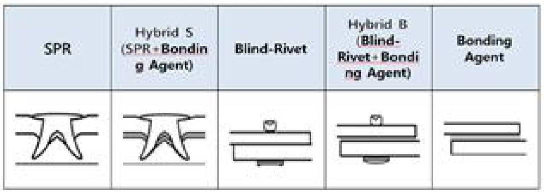


Fig. 1 Sections by mechanical bonding

Table 1 Bonding materials

No	Metal material
1	SABC1470 (1.4t) + AI5083 (2t)
2	SGARC780 (1.4t) + AI5083 (2t)
3	SGACEN (1.2t) + AI5083 (2t) * Existing product

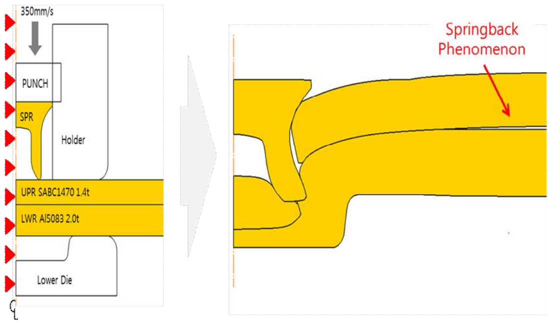


Fig. 2 Springback Phenomenon by SPR bonding

2.2 Analysis of Dissimilar Material Bonding

The materials used in this study for the analysis of dissimilar material bonding were hot-stamping materials, which encounter difficulties in mechanical bonding and require condition selection through bonding analysis. As shown in Fig. 2, SPR and blind riveting were analyzed using finite element analysis. The SPR analysis results show that although bonding was possible, the interlock formation, which affects the bonding strength, was not good. Additionally, a gap between the materials was generated due to the elastic recovery around the bonding part resulting from the plastic change of hot stamping, which is an ultra-high-strength material, thus decreasing the bonding strength. In the case of the blind-rivet method, there was no effect on material strength because bonding is carried out after hole processing, and the strength was compared through analytical simulation using ANSYS, as shown in Fig. 3.

In the results of the mechanical bonding analysis, the bonding method using blind riveting and a bonding agent simultaneously showed the highest strength.

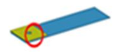
Joining method	Blind-rivet	Bonding Agent	Blind-rivet +Bonding Agent
Modelling			
Interpreted			
Maximum Strength	2.74 KN	9.88 KN	12.81 KN

Fig. 3 Bonding test analysis modeling and result

3. Jig Design and Fabrication of Specimens for Dissimilar Material Bonding

To produce identical specimens because the bonding strength varies depending on the overlapping area, a clamp was applied to prevent material movement during bonding, as shown in Fig. 4. The specimens were designed and fabricated to allow 100×30mm overlaps in accordance with KS B0851.

Pre-Hole was applied for blind riveting and Ashland Pliogrip5760B for adhesive bonding. The SPR was bonded using the SPR equipment of Atlas Copco Korea. Fig. 5 shows the fabricated specimen. Three types of specimens, that is, ultra-high-tensile-strength steel+aluminum (SABC1479+Al5083), high-tension steel+aluminum (SGARC780+Al5083), and galvanized steel+aluminum (SGACEN+Al5083), were fabricated by the bonding methods (SPR, hybrid SPR, blind riveting, hybrid blind riveting, and adhesive bonding).

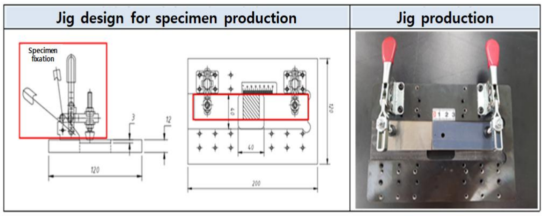


Fig. 4 Mechanical bonding Jigs for specimen production

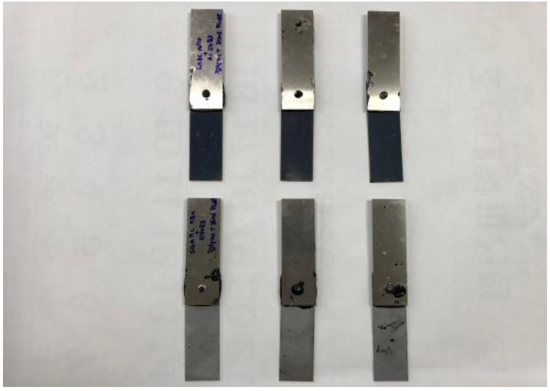


Fig. 5 Multi-material bonding specimens

4. Dissimilar Material Bonding Strength Test

4.1 Materials and Methods of Dissimilar Material Bonding

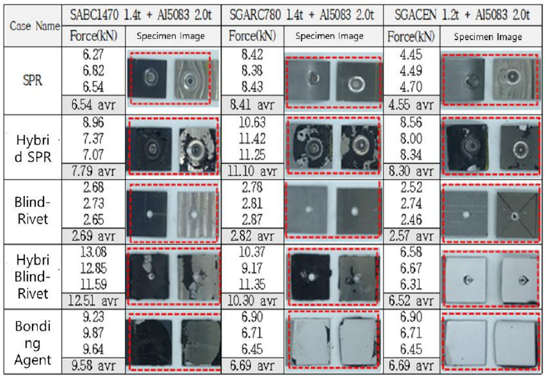
A shear tension test was carried out to measure the bonding strength at the testing speed of 2 mm/min. According to the test results, which are shown in Fig. 6, in the SABC1470+Al5083 combination, the hybrid blind method (blind rivet + bonding agent) showed the highest strength at 12.51 KN. The reason that hybrid SPR bonding had lower strength than the other method is that, although SPR bonding was performed, it was difficult to secure strength due to the spring-back phenomenon of the top plate and the incomplete interlock inside it. Therefore, the hybrid blind bonding method appears to be the best bonding method for SABC1470. Fig. 7 shows the bonding strength of each case, and Table 2 summarizes the bonding strengths.

In a comparison of the correlation between the experiment and analysis results of SPR, similar patterns were observed and the possibility of bonding was confirmed. However, it was impossible to apply this to the car body due to the bending of the base metal.

A comparison of the blind-rivet strength between the analysis and experiment revealed similar fracture shapes. The strength error was 2.13% at maximum, thus confirming the reliability of blind joint analysis.

4.2 Salt-Water Spray Test and Durability Analysis of Dissimilar Material Bonding

Ultra-high-tension steel+aluminum bonding requires a review of corrosion because of galvanic corrosion from the potential difference



Case Name	SABC1470 1.4t + Al5083 2.0t		SGARC780 1.4t + Al5083 2.0t		SGACEN 1.2t + Al5083 2.0t	
	Force(kN)	Specimen Image	Force(kN)	Specimen Image	Force(kN)	Specimen Image
SPR	6.27 6.82 6.54 6.54 avr		8.42 8.38 8.43 8.41 avr		4.45 4.49 4.70 4.55 avr	
Hybrid SPR	8.96 7.37 7.07 7.79 avr		10.63 11.42 11.25 11.10 avr		8.56 8.00 8.34 8.30 avr	
Blind-Rivet	2.68 2.73 2.65 2.69 avr		2.78 2.81 2.87 2.82 avr		2.52 2.74 2.46 2.57 avr	
Hybri Blind-Rivet	13.08 12.85 11.59 12.51 avr		10.37 9.17 11.35 10.30 avr		6.58 6.67 6.31 6.52 avr	
Bonding Agent	9.23 9.87 9.64 9.58 avr		6.90 6.71 6.45 6.69 avr		6.90 6.71 6.45 6.69 avr	

Fig. 6 SPR measured bonding strength for SPR bonding methods

Table 2 Joint strength per case

Case Name	SABC1470	SGARC780	SGACEN
Hybrid S	7790 N	11100 N	8300 N
Hybrid B	12510 N	10300 N	6520 N

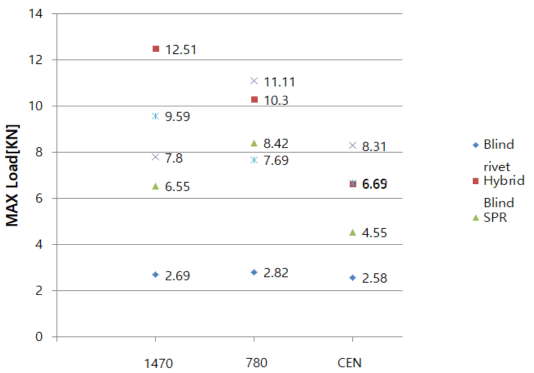


Fig. 7 Comparison of bonding strength for each case

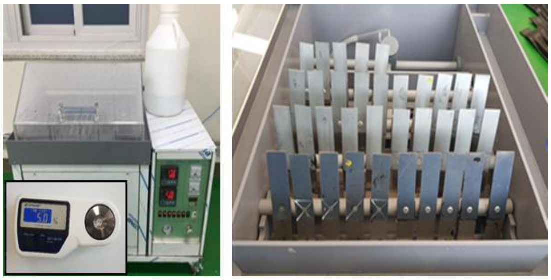


Fig. 8 Salt spray test

between metals. Thus, a corrosion test was conducted with salt-water spray.

The salt-water spray test of dissimilar material bonding was carried out in accordance with the KS D 9502 standard. A 5% salt-water solution was sprayed for 48 hours at 0.1MPa pressure and then dried for 30 min, before a shear tensile test was conducted. Fig. 8 shows the salt-water spray test and specimen setting.

When the appearance was compared between prior to and after the salt-water spray test for 48 hours, the corrosion reaction was the largest in SGACEN, followed by SGARC780 and SABC1470. SABC1470 did not meet the durability requirement because the bonding was

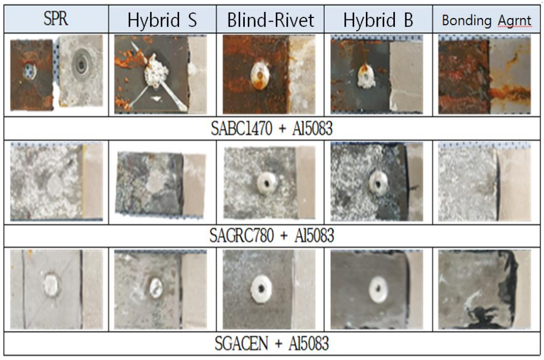


Fig. 9 Salt spray test result

Fig. 10 SABC1470 salt spray test result

Table 3 Strength Change after Salt Water Spray test

	SPR	Hybrid S	Blind-Rivet	Hybrid B	Bonding
Before the test(N)	6540	7790	2690	12510	9580
After the test(N)	0	7644	2672	12078	10839
burglar(%)	0	98	99	97	113
SABC1470 1.4t + Al5083 2t					
Before the test(N)	8410	11100	2820	10300	6690
After the test(N)	8512	9777	2732	9989	6789
burglar(%)	101	88	97	97	101
SGARC780 1.4t + Al5083 2t					
Before the test(N)	4550	8300	2570	6520	6690
After the test(N)	4902	8151	2685	6495	7056
burglar(%)	108	98	104	100	105
SGACEN 1.2t + Al5083 2t					

separated due to rivet corrosion during the salt-water spray test in a specimen bonded with SPR alone. SGARC 780 shows a 12% strength reduction rate when SPR and adhesive bonding were used together. It was confirmed that hybrid B showed an insignificant corrosion effect.

Fig. 9 shows the salt-water test results, and the SPR separation phenomenon is shown in Fig. 10. Table 3 outlines the strength changes after the salt-water spray test for each bonding method.

5. Results and Discussion

This study investigated ultra-high-tensile-strength steel and aluminum dissimilar material bonding for a lightweight car body and verified the possibility of applying this bonding method to the car body by testing the strength of different bonding methods.

1. According to the results of the dissimilar material bonding analysis and tests, in the ultra-high-tensile-strength steel and aluminum bonding, the hybrid B bonding method using blind riveting and adhesive bonding showed the highest bonding strength. The analysis and test showed similar fracture shapes, and the maximum strength error was 2.13%, thus verifying the reliability of the blind bonding analysis.

2. According to the results of the salt-water spray test and strength analysis for dissimilar material bonding, the hybrid B bonding method showed greater strength and durability than SPR.

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