A Review of Arc Brazing Process and Its Application in Automotive

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***Abstract*—Brazing is a process for joining metallic materials with the aid of melted fillers like solder, the melting temperature of which is below that of the parent metal. In comparison to welding, it has different connection mechanisms also resulting in a lower energy requirement in soldering with advantages such as reduced damages to the material and lower levels of distortion. Therefore, in this research, we studied the efficiency of the GMA brazing process as compared to the conventional GMA welding. The temperature of parent metal is measured by using thermocouple and thermo-vision cameras. In addition, mechanical properties and weldability, such as tensile, hardness, microstructure is evaluated in lap joint structure. As the results, depending on the steel alloy used, arc brazed joints are as strong as GMA welded joints. Furthermore, corrosion resistance is better than welding in the case of stainless components. In conclusion, arc brazing process will be widely applied to thin sheet metal jointing especially for the automotive industry in the near future.**

***Index Terms*—arc brazing, copper wire, corrosion resistance, zinc coating, CMT, low heat input**

I. Introduction

For several years, the automotive industry has been seeking new processes to replace MIG welding in jointing thin zinc-coated plates and stainless steel. During the past 10 years, special attention was paid to the arc brazing process, which became an optimum solution for the automotive industrial application [1], [2]. The use of zinc-coated plates, instead of the typical non-coated steel plates, resulted from the market demand for increased corrosion resistance. Arc brazing process was found to be the most affordable welding technique to replace arc welding for thin zinc-coated plates due to some clear advantages, namely reduction of the zinc burn-off during brazing and less residual stress and geometrical distortion [3], [4]. Despite the lower melting temperature of the filler alloys, the effects of the electric arc heat input of the arc brazing process, especially on the zinc layer integrity and on the physical – chemical and metallurgical properties of the joint, have been harmful.

The features of an optimum arc brazing procedure are still under debate as the optimization criteria may vary according to each specific applications. In case of conventional arc welding, lower heat input requiring lower values for the intensity of the welding mean current and conducting to the controlled short-circuit transfer mode, with the main disadvantages of less wetting and inappropriate seam shape, may define one type of such approach. Good wetting properties with good looking beads, but controlled pulsed arc obtained for higher values of current and heat input with more vaporized zinc, wider Heat Affected Zones (HAZ), partially destroyed zinc layer and more unacceptable defects may describe another approach. In addition to these practical procedures, several fundamental aspects are presented. Due to its importance but also for practical implications, metal transfer through the electric arc is by far the most relevant in defining the limits of experimental procedures characterized by lower heat inputs. Due to wider use of arc brazing process in various manufacturing processes, this study is aimed at optimizing the arc brazing procedures, with a focus on minimization of the heat input and assuring all the quality indicators of the joint.

Therefore, in this research, we studied the efficiency of the GMA arc brazing process as compared to conventional arc welding. Also, we intend to illustrate various applications for the automotive components through the case study.

II. Characteristics of the Process

A. Arc Brazing Source

Fusion welding methods became the "hot direction" to solve problems for joining dissimilar metals due to their high efficiency. Therefore, a fusion welding method with low heat input and high efficiency may provide an answer to realize the aluminum use in the automotive industry. Short-circuiting metal transfer is a suitable method due to its low input characteristics. However, it poses great problems for the producer with the excessive spatter during the welding process.

A recent development in welding technology is the Cold Metal Transfer (CMT) process which is ideal for

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welding aluminum and dissimilar joint due to no spatter welding process and low thermal input.

The cold metal transfer process is a modified metal inert gas welding process developed by Fronious (Aus.) Company. The principal innovation of this method is that the motions of the welding wires have been integrated into the welding process and into the overall control of the process. Each time a short circuit occurs, the digital process control interrupts the power supply and controls the retraction of the wire, as shown in Fig. 1. The wire retraction motion assists droplet detachment during the short circuit, thus greatly decreasing the heat input during welding. That's why arc brazing process is possible to make a good joint without melting of the parent metal and less deformation.

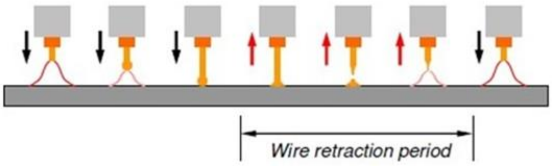


Figure 1. Schematic of the wire retraction at CMT

B. *Comparison of Temperature*

In order to quantitavely compare the conventional welding process and the arc brazing process, we conducted a comparative study using thermocouple and thermo-vision cameras. Two types of wires were used for comparison: first is STS430 Alloy wire, a welding wire used in real situations, and the second is CuAl brazing wire, used during this study.

Material used during study is STS439 2.0t muffler material. Welding and brazing conditions are set so the healthy beads form from observation by naked eyes without complete weld penetration. In other words, the study was carried out by selecting criteria for conditions where results would produce good welding qualities and resulting in similar deposited quantities. Each conditions are set out in Table I.

TABLE I. WELDING AND ARC BRAZING CONDITIONS FOR TEMPERATURE MEASUREMENT

	Welding	Brazing
Wire	STS439 Alloy	CuAl8
Current	134A	121A
Voltage	19.7V	11.4V
Feeding speed	4.4m/min	4.4m/min
Welding speed	0.8m/min	0.8m/min
Shielding gas	Ar-O2 2%	Ar 100%

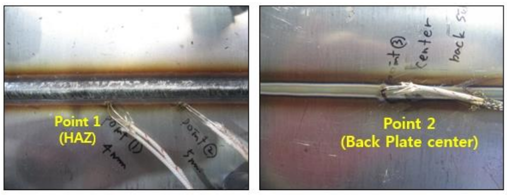


Figure 2. Location of thermocouple attached on HAZ and back plate of center

First, in order to measure temperature using thermocouple, sensor was attached to the center and HAZ of the lower weld line as seen in Fig. 2. K-type thermocouple, able to measure up to 1,200 degrees, was used, and data was collected using DAQ board.

Fig. 3 shows thermo-history curve measured in the center back plate welding. Approximately 15% difference occurred between welding, showing 926 degrees at the highest, and arc brazing, showing 790 degrees at the highest. The above result shows relation to loss of zinc. Evaporation temperature of zinc is around 910 degrees, and in this study, back plate's coating has been burned after welding. However, the loss of the coating is very low for arc brazing, as seen in Fig. 4.

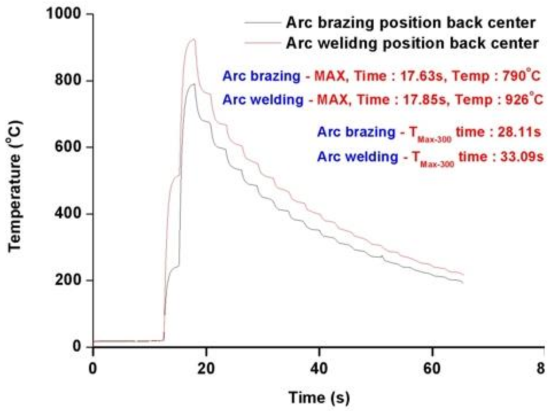


Figure 3. Comparison of thermal measurement results using thermocouple for welding and arc brazing processes of back plate

Figure 4. Comparison of zinc burning phenomenon

Similar results show using thermos-vision camera. Highest temperature at melting point was measured at 1,798 and 1,526 degrees each as seen in Fig. 6. Similar to thermocouple measurement results, approximately 15% difference showed between welding and arc brazing.

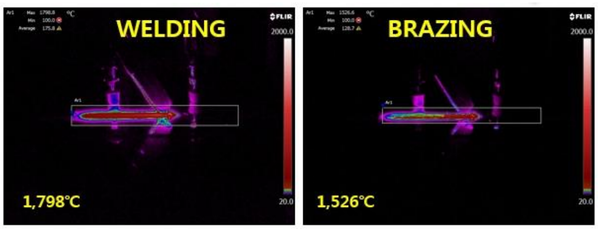


Figure 5. Maximum temperature measured using thermo-vision camera

Under conditions producing similar wire feed rate, arc brazing showed joining at 15% lower heat input as compared to welding, and this will affect the thermal deformation on the final product.

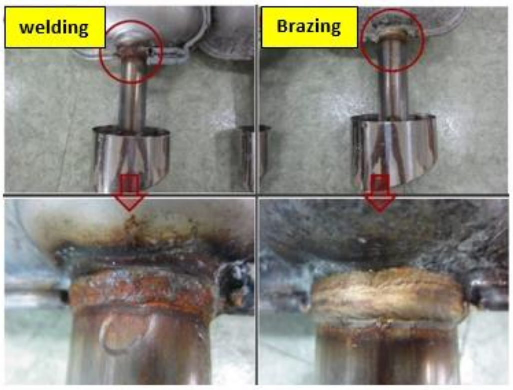


Figure 6. Results from salt spray test using 5% NaCl for 72 hours

C. *Corrosion Resistance*

Exhaust parts require corrosion resistance due to exposure to extreme conditions. As such, we conducted a salt spray test, by exposing 5% NaCl for 72 hours, on mufflers joining using welding and arc brazing methods, as seen in Fig. 6. Unlike welding method, arc brazing method did not show corrosion at the joining. This is due to Cu, contained in filler metal in high quantities has good corrosion resistance qualities. As such, arc brazing process not only minimizes the damage to zinc coating, as shown from section 2.2 results above (Fig. 4), but also has excellent corrosion resistance of filler metal.

D. *Gap Bridging Ability*

Arc brazing process showed an outstanding gap bridging ability. During the arc brazing process only the filler metal dissolved, not the parental metal, and capillary attraction occurred for diffusion jointing by surface tension. To confirm this, we carried out joining after allowing gap between 0 and 2.0 mm under the same heat input conditions, and the results are shown in Fig. 7. The parent metal used was common carbon steel with a thickness of 1.4 mm. The test showed satisfactory appearance and beads formation even at 2.0 mm gap. However, at 2.0 mm gap, fracture of the parent metal occurred during tensile-shear test.

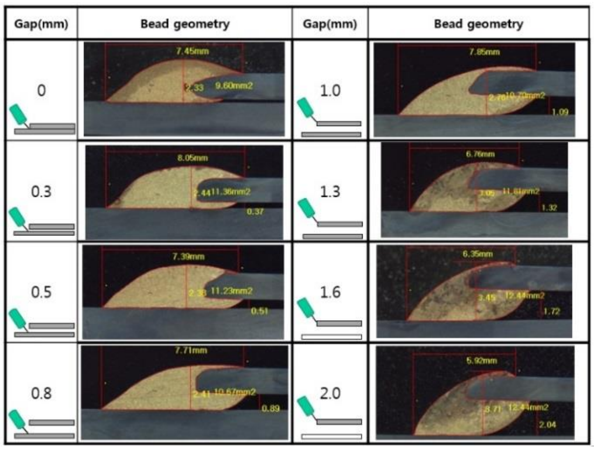


Figure 7. Results from gap brazing test of up to 2.0 mm under same heat input condition

III. Application Results

A. *Muffler Components (Stainless Steel)*

The first application field is the muffler components. Ferrite stainless steel is a typical material, and the conventional MIG/MAG welding process is used in the joining process. In conventional welding process causes problems such as spatter, burned surface, deformation, burn through, etc. as shown in Fig. 8. In addition, only thin metal welding of under 1.0mm in thickness is possible. Currently, the automotive industry trend is building lightweight vehicles. As a result, a new process is needed and arc brazing may be a good solution for the automotive industry. Using arc brazing process to make main muffler assembly will not only improve the weld-ability but also corrosion protection, as shown in Fig. 9. As an example, Fig. 6 shows the results of salt water spray test which compares welding with brazing. Brazing shows better performance than welding process in corrosion resistance.

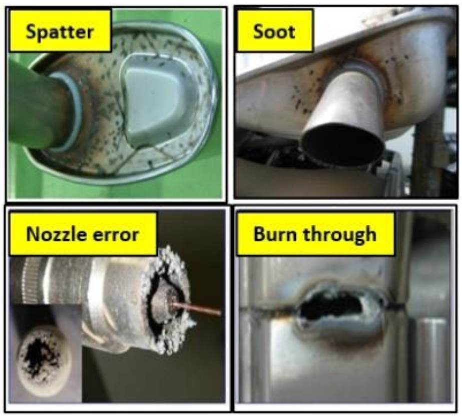


Figure 8. Types of faulty welding results from conventional welding process

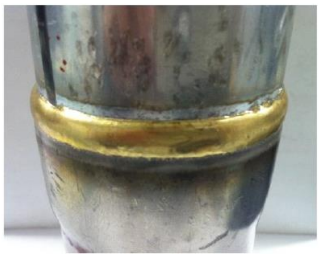


Figure 9. Arc brazing applied joining of muffler part

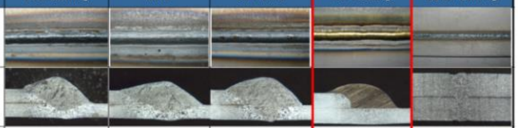
Figure 10. Case study of arc brazing process for internal part of main muffler for minimum welding distortion

Another case is assambly of the inside of a muffler, as shown in Fig. 10. The component has many joining point, and distorsion due to excess heat input leads to problems. Arc brazing process is an optimum solution in this case.

B. Car Body Assembly (Galvanized Steel)

Second application is a bracket welding. It has lap joint design, and an application example is cowl cross member module (CCB). CCB component is located in the front of a dash board, and it supports the front body from environmental deformation. There are 14 sets of brackets on the main body, and its welding point is 59EA, as shown in Fig. 11. CCB components always bring about deformation due to multiple welding points. Therefore, heat input should be restricted to the minimum. In this case, arc brazing process is the best solution. Table II shows the results of steel sheet welding using various processes. Although wire cost is higher than other processes, it has enough merits for application.

TABLE II. RESULTS OF STEEL SHEET WELDING USING VARIOUS PROCESSES

	CO2 welding	MAG	CMT MAG	Arc Brazing	Laser welding
Appearance					
Cross section					
Deposition rate	12.7 mm²	14.8mm²	15.9 mm²	9.1mm²	3.2mm²
Weldmetal Hardness	187	188	195	170	185
Longitudinal distorsion	19.76 mm	24.61 mm	17.41 mm	0	0
Tensile strength	Base metal fracture (348 MPa)	Base metal fracture (348 MPa)	Base metal fracture (348 MPa)	Base metal fracture (348 MPa)	Weld metal fracture (9,270 N)
Heat input energy	3402 J/cm (5.2 m/min)	3564 J/cm (7.2 m/min)	2226 J/cm (6.1 m/min)	1483 J/cm (4.7 m/min)	-
Chearistic	Economical	Ar gas cost	Need CMT utility	Higher wire cost (300% than solid)	Laser system

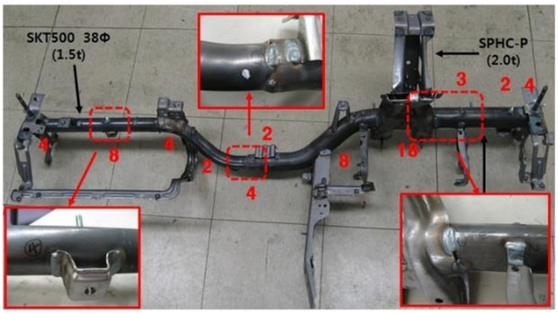


Figure 11. Welding status of cowl cross member parts

C. Dissimilar Metal Joining

New anti-pollution and energy-saving laws impose a reduction in fuel consumption for vehicles from the automotive industry. This reduction may be obtained through various methods: the lightening of vehicles by making car bodies out of aluminum instead of steel; by using high elastic limit steels; or by making some components out of light alloys such as aluminum or magnesium alloys instead of steel [5]. Manufacturing car bodies with steel and aluminum components implies joining of steel to aluminum--the reason for recent studies focusing on the steel to aluminum assembling using new joining methods, with or without steel melting. It is widely known that joining of aluminum alloy and steel is difficult through fusion welding, as aluminum alloy and steel exhibit great differences in their chemical and physical properties, and mass of brittle intermetallic compounds (IMCs) are formed--seriously degrading the mechanical properties of the joints [6]-[8].

Three (GA, GI and CR) types of coated steels was compared in order to establish the relationship between coated type and weld-ability. The results showed that the welding did not become entirely in case of GA and CR steel sheets, but GI steel made by hot-dip galvanizing is generated good joint as shown in Fig. 12. Usually, when joining dissimilar materials using fusion welding, aluminum is melted and steel is wetted by aluminum melt. At this moment, zinc coated layer on the steel surface improved wet-ability with melted aluminum. However, GA steel coated with Fe-Zn alloy did not demonstrate sound joint throughout the entire welding parameter range. Moreover, CR steel without any surface treatment showed the same result as GA steel.

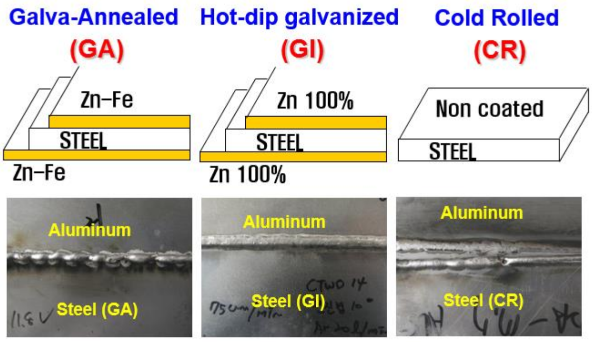


Figure 12. Results of joining steel to aluminum depend on coating types

IV. CONCLUSIONS

We selected the arc brazing process to join steel, stainless and dissimillar materials. Topic mentioned in this paper are summarized as follows.

1) In galvanized components, only a small quantity of zinc coating of the steel sheets evaporate as compared to the MIG welding process. This results in a more stable arc and a pore-free weld.
2) The low heat application in arc brazing not only signifies a lower distortion of the components, but also, it has many advantages such as low coating burn off, possibility of dissimillar joint, easy after joint machining, minimal spatter, etc.
3) Arc brazing process will be widely applied to thin sheet metal jointing, especially for the automotive industry in the near future.

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