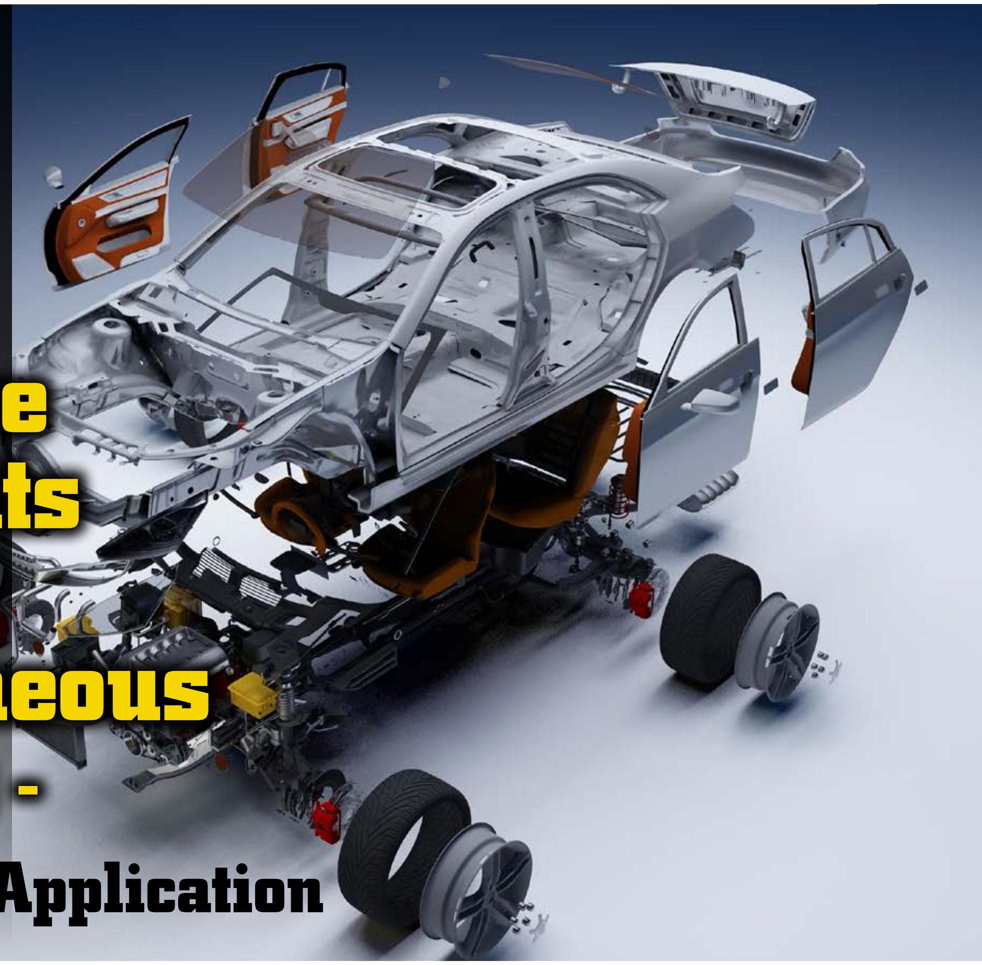
異質材料汽車零組件接合技術與應用



Bonding Automotive Components Made of Heterogeneous Materials - Technology & Application

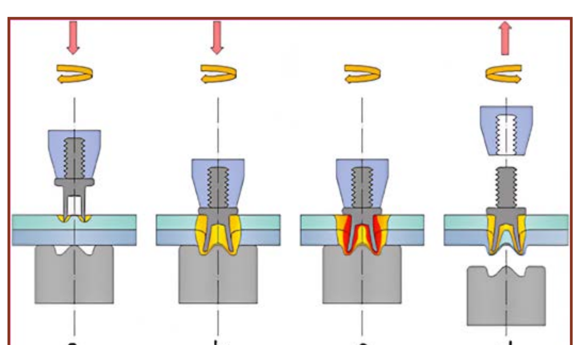
In automotive production, there are readily visible components like those for mounting car seats. There are also many components using mechanical fasteners (screws, bolts, etc.) in invisible areas to fasten carpets, interior/exterior decorations as well as metal plates (welding or riveting). It is easy to assemble with fasteners, but they add weight to the vehicle. Component bonding comes with many options and variations. Below I will briefly explain the methods for bonding various automotive components made of heterogeneous materials.

Automotive Components Bonding Technology & Application

(1) Self-piercing Riveting

Aluminum alloy has a wider use in the automotive industry, increasing the use of aluminum bonding with aluminum or steel. Spot welding is not the best choice in most cases, because aluminum is highly oxidizable. The high temperature in spot welding is more likely to form a thin coat of oxidized aluminum that gets in the way of metal bonding. Self-piercing riveting is the alternative option which we can consider to use on connecting aluminum alloy as well as other different materials.

Self-piercing riveting can connect aluminum, steel, plastic, carbon fiber reinforced composites and various materials. The whole process doesn't require pre-drilling. The whole fastening process with self-piercing rivets doesn't require heating. This method can be used to connect the same or different materials on body in white, such as steel-to-steel or aluminum-to-steel bonding. Self-piercing riveting is a room temperature bonding method for connecting two or more metal plates. The custom-made rivet pierces through the top plate without going through the bottom plate, and spans out its hollow structure to form a secure riveting spot. **Figure 1** shows the self-piercing riveting of thin plates. Through external force, the rivet pierce through the first-layer and middle-layer materials and flows and extends within the bottom material, thereby forming an interlocking and permanent plastic-deformed riveting process. The bonding creates a flat surface on one side and a protruding cylindrical shape on the other.



Source: Manufacturing Science, July 2022

Fig. 1. Self-piercing Riveting with Thin Plates

Self-piercing riveting relative to other bonding methods have the following features:

(1) It can connect two or more layers of plates of different materials, widths and strengths. It is the best method to connect different lightweight materials.

(2) It doesn't deform from heat and can be used to connect coated or electroplated plates without undermining the coating.

(3) Compared to conventional riveting, it is highly efficient, requires less equipment investment, consumes less energy and therefore the cost is lower.

(4) It is safe and environmentally friendly, and doesn't generate heat, fume, spark, dust and scrap.

(5) Stable riveting quality; high repeatability; allowing for visual check of riveting spot quality.

(6) Able to couple with bonding.

Self-piercing riveting is actually used on Audi's TT and A8 models. **Fig. 2** shows self-piercing riveting on the TT model. This method is gradually spreading among European carmakers. It is gaining attention in North America where local carmakers have more opportunities to use aluminum alloy and other lightweight materials that can't be connected with conventional spot welding. There was less than 1% of aluminum alloy composition in car body before 2015. Spot welding remains to be the most common bonding method for body in white. However, lightweighting is gaining more and more attention and self-piercing riveting can connect aluminum alloy, steel plates, plastic, carbon fiber reinforced composites and various material combinations. The whole process does require pre-drilling. Lightweight manufacturing is worthy of attention.

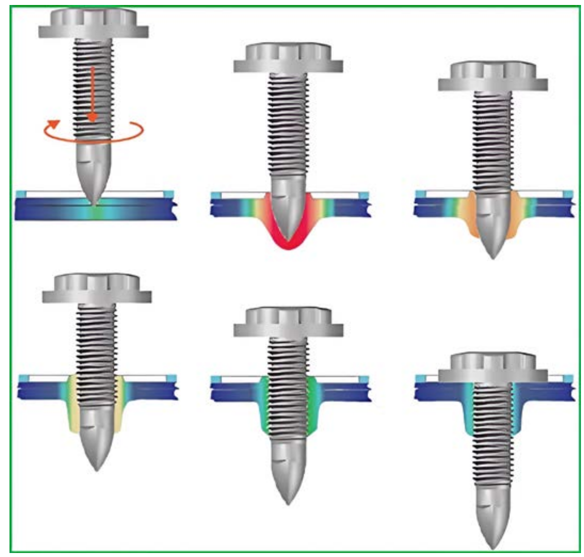
Source: invetr.com(2022/05)

Fig. 2. Self-piercing Riveting on the Audi TT Model

(2) Flow Drill Screw

Thread forming tapping screws evolves directly from self-tapping screws. The use of thread forming tapping screws requires pre-drilling and then driving the screws into the holes to create female threads via a strong force. The material originally on the female threads will be squeezed to the male threads. This is the mechanism of thread forming tapping screws and it can only be used on thin and deformable materials. Later comes the invention of thread cutting tapping screw with one or more slots at the tip of the screw. The screw utilizes its tip and threads when it drives into the pre-drilled hole and creates female threads in a way similar to a thread tap. It can be used to connect thick plates, and harder or fragile materials that are not easy to form.

Flow drill screw is a room temperature forming method that utilizes high-speed spinning to heat up and deform plates, tap and then deform the plates, as shown in Figure 3. Its advantage is being applicable to single-sided bonding to make bonding thin plates and small holes possible. It is mostly used on riveting components on car body plates (such as structural parts with little bonding space) that doesn't work well. It can be used to connect automotive components. The restriction on flow drill screws is that the bonding spot needs higher rigidity. The screw is detachable and can potentially loosen off and lead to insufficient strength when the car body is in service for a long term. **Figure 4** shows flow drill screws in use with Ford F-150.



Source: lightweighting world, May 2022

Fig. 3. Flow Drill Screw

Source: www.assemblymag.com (May 2022)

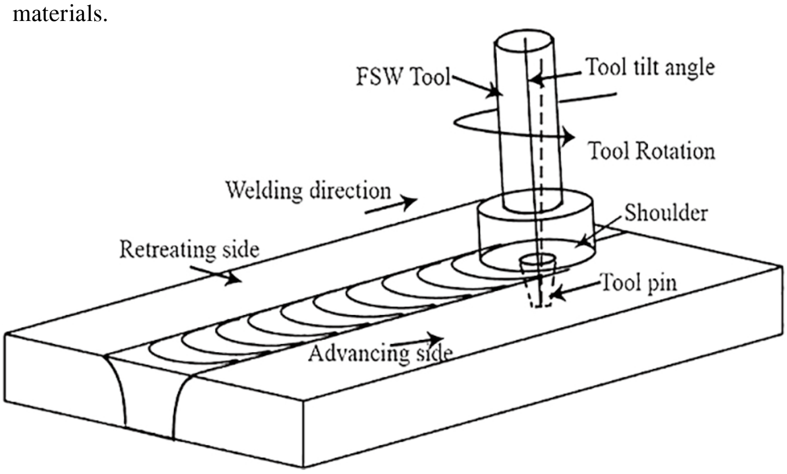
Fig.4. Flow Drill Screws in & Use with Ford F-150

(3) Friction Stir Welding

Friction stir can be divided into two types of manufacturing processes. The first one is friction stir welding which concentrates on metal bonding, and the second one is friction stir processing focusing on grain refining materials or adding fine grains. Metal alloys or metal-based composite materials usually are either very hot or contain high energy to heat up the welded area to the melting point. Next is to add or not add filler metals and the molten substances spread to both sides of the spot that has to be fastened. The two sides will connect into one after the molten area cools down and solidifies.

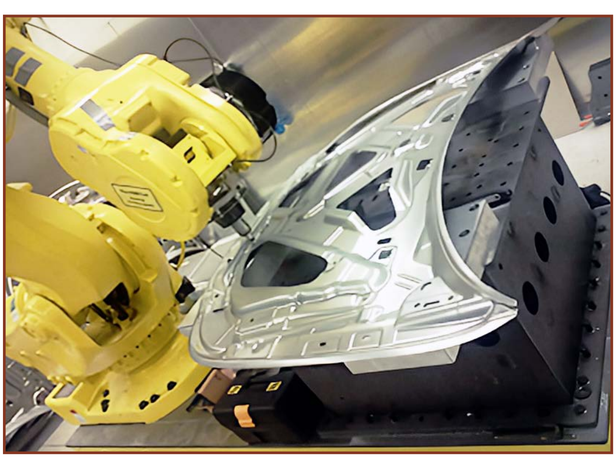
Friction stir is a new manufacturing method and a new welding method developed by The Welding Institute in UK. Unlike conventional welding, friction stir welding is a solid state bonding that brings flawless high quality bonding and creates better mechanical properties compared to average fusion welding. Therefore, friction stir is used on aluminum alloys such as 7075 and 2024 that would have been hard to connect using conventional welding. In recent years, friction stir has been widely applied to the bonding of other light metals and their alloys. Friction stir utilizes mechanical spinning and friction to generate heat. The stirring head is made of a hard material. It reaches in two workpieces that has to be bonded and spins hard to create friction. When the material softens (the plastic transforms), the head moves slowly and continues spinning. Lastly, the head is taken out and the bonding is complete. **Figure 5** illustrates friction stir.

Friction stir best suits the bonding, surface modification, precipitation hardening type material bonding, and dissimilar materials bonding of average or superplasticity light alloys and their composites. It also suites low-melting alloys such as aluminum alloy, magnesium alloy and their automotive components or composites. **Figure 6** shows an example of friction stir applied to the bonding of car body plates made of different materials.



Source: lightweighting world, May 2022

Fig. 5. Friction Stir



Source: bioage.typepad.com, May 2022

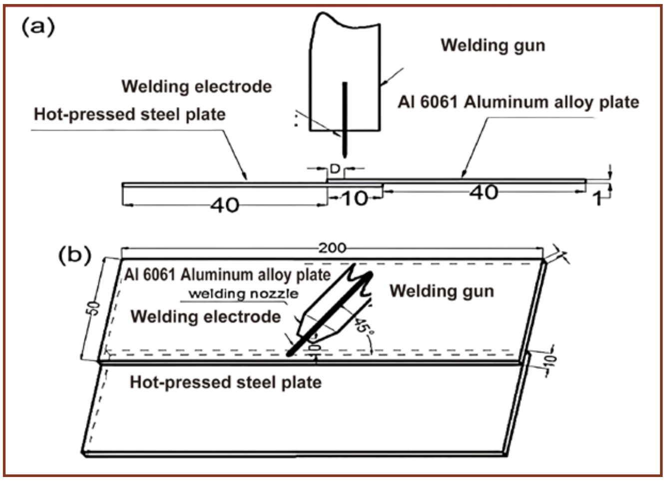
Fig. 6. Friction Stir Applied to the Bonding of Car Body Plates Made of Different Materials

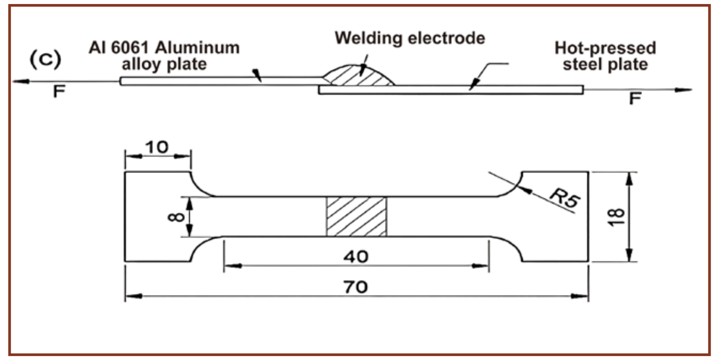
(4) Cold Metal Transfer

There has been tremendous progress in the automotive industry in recent years. More and more technologies are applied in automotive manufacturing. Fusion welding is indispensable in automotive manufacturing. Car body plates are thin. They have a high standard for the quality of appearance and they weld fast. Therefore, the conventional metal inert-gas welding and metal active-gas welding have limited applications in the automotive industry. The new cold metal transfer technology can properly solve the difficulty in welding the automotive thin plates. The name which contains the word “Cold” derives from the fact that the heat input is much less than gas metal arc welding. Cold metal transfer is a type of arc welding mainly used with thin plates, steel and aluminum-mixing welding, and other tasks that aren’t easy to solve with metal inert-gas welding and gas metal arc welding.

CMT (Cold Metal Transfer) monitors the globule state of welding wire to accurately feed the welding wire. When the globule short-circuits the molten pool, the short circuit signal is sent to the digital processor and the welding machine stops outputting electric currents, while the welding wire feeder withdraws the wire to separate it from the globule and let the globule transfer by itself. This is when the welding machine enters the “cold” state. After the globule separates with the welding wire, the signal is sent again to the digital processor and the feeder continues to feed. The welding machine re-outputs the electric currents and the machine enters the “hot” state. The CMT wire feeding system comprises two feeding mechanisms that work in tandem to intermittently feed the wire in the process. The subsequent wire feeding system feeds the wire to the pool at a fixed speed, and the preceding wire feeding system feeds the wire at a fixed rate according to the instructions by the digital processor. The digital processor collects signals and accurately analyzes the movement of the globule to achieve accurate wire feeding and electric current output control. The cyclic “hot - cold - hot - cold” states of the globule in the CMT globule transfer process clearly reduces spattering and the input of welding heat.

Cold metal transfer is a brand-new type of metal inert-gas welding and metal active-gas welding. Compared with conventional counterparts, cold metal transfer has extremely low heat input and can weld plates as thin as 0.3 mm. It can also bond high strength steel plates with aluminum alloys. It has been applied to bonding Tesla’s EV thin plates. This bonding technology can gain accurate control, and has a fixed short-circuit transfer cycle that is not subject to random parameters. Cold metal transfer has literally zero electric currents and can effectively reduce splattering to give fine welding quality. **Figure 7** illustrates cold metal transfer. Its mechanism is to weld one side of the aluminum alloy material (such as 6061 series) and bond with the steel material on the other side. The base material doesn’t melt and there is little deformation.





Source: Manufacturing Science, July 2022

Fig. 7. Cold Metal Transfer

Opportunities for Taiwanese Automotive Component Companies

The use of heterogeneous and composite materials is increasing every year in response to automotive lightweighting. Taiwanese companies are good at low volume, diverse, flexible and high quality manufacturing, so they are suited to increase application of bonding heterogeneous materials such as aluminum alloy with steel materials (plates), composites (carbon fiber) with metal, setting a different price for lightweight automotive components to lift product value-adds. Topics on saving energy and reducing carbon emission are gaining public awareness. The use of non-ferrous metals, plastic/rubber materials, composite materials and lightweight alloys is increasing every year. It is better for Taiwanese companies to develop advanced manufacturing (e.g., laser welding instead of glue bonding car light covers and light seats) to reduce material consumption and improve component strength. Taiwanese companies mostly start with automotive components when they tap into the leading automakers' supply chain. They should target vehicle functions, or modularized bonded components to avoid over-designing materials, simplify material application, enhance properties that make for component sharing, effectively reduce the number of components used and of cost, and improve profits. ◻

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