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Bonding Automotive Components Made of Heterogeneous Materials - Trends & Types

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Lightweighting of Automotive Components

There are around 1.68 billion units of cars in the world. Cars consume a great deal of fossil energy. They not only require strength and a long service life, but also have to be up to par in terms of performance, appearance, safety, price, environmental protection, and energy saving. Out of all the constituents of a car, steel accounts for 80%, aluminum alloy for 3%, and rubber/plastic/resin for 4%. Since the oil crisis, carmakers have had increased attention to lightweight materials and have been using them to cope with net zero carbon emission. Governments across countries including EU, the U.S., China and Japan have stipulated to reduce vehicle carbon emission to decrease environmental impact. EU set the bar at 130 grams of carbon emission per kilometer drive in 2015. In 2021 it was 40% less than 2007's par which was below 95 grams per kilometer. The U.S. requires that passenger cars' emission per kilometer should be lower than 2021's standard by 2024.

Compared with 20 years ago, cars are 20% to 26% lighter. On average, the use of the following automotive materials have decreased: steel (down by 15%), cast iron (29%), copper (13%), glass (13%); the automotive materials with increased use are: aluminum alloy (31%), magnesium alloy (100%), powder metallurgy (20%), rubber and plastic (29%). The need to reuse, reduce and recycle automotive components increases their recyclability and reusability. Lightweight materials have higher recyclability and advantages. The increased proportion of lightweight materials used on cars could start the innovation of next-generation automotive components. Every 10% of weight taken away from a car can improve fuel efficiency by 6% to 8%. 1% of weight reduction can bring down oil consumption by 0.7%. 100kg less weight can save 0.3 to 0.6 liter of fuel per 100 kilometers.

Automotive lightweighting can be attained in 3 ways. One of them is replacing materials and using lightweight materials such as light alloy, rubber and plastic, or high tensile steel plates to replace conventional steel plate materials. An example is Honda replacing average carbon steel plates for N-BOX with high tensile steel plates. The new car model is 82 kilograms lighter than models using conventional steel plates. Furthermore, some carmakers increase the use of aluminum alloy or CFRP, or multi-materials. **The second approach is to optimize car structures** by downsizing engines or electric motors, or changing material thickness. **The third approach is to improve the manufacturing process** through manufacturing methods (slim manufacturing) or any fastening methods to achieve automotive lightweighting.

The R&D of electric and new energy vehicles have been relentless, but tasks still remain for industrial development, and these include unresolved problems with charging stations, battery reliability and endurance. These vehicles have not popularized in a short term. The ways to reduce EV's and conventional vehicles' energy consumption are: downsizing engines through turbo compressor, improving engine and electric motor efficiency, reducing drag during driving, improving transmission efficiency, and reducing EV weight. EV weight reduction is particularly easy to implement. Rubber, plastic, lightweight alloy and composite materials will play an important role in automotive components. The use of steel, alloy, rubber and plastic will increase for automotive component fastening. Unlike spot welding, automotive components are mostly fastened with rivets or screws. This is not economical in terms of weight and productivity, and therefore, it brings about the development and application of various fastening technologies.

Types of Automotive Component Bonding

Automotive component bonding refers to bonding materials of different characteristics. It usually comes in 3 types which are metallurgical bonding, mechanical bonding and chemical bonding, as shown in **Table 1**. Each has its own strength and drawback. **Currently, the common one is spot welding,** which is more productive and cost effective, but likely to concentrate stress on components. It is not necessarily the best bonding method now that lightweight alternative materials are introduced and applied. High tensile steel plate bonding, for instance, uses different amount of pressing and spot welding electric current from those of aluminum alloy bonding. Additionally, the melting point of steel plates is different from that of resin materials such as rubber and plastic, and it is also different from connecting metals with non-metals in terms of the conditions of bonding. Even with connecting different materials, it could create intermetallic compounds and affect component strength and durability, so it is critical to develop the technologies for automotive component bonding.

Table 1. Comparison Between Various Bonding Methods

Bonding Methods	Typical Example		Strength	Drawback
Metallurgical Bonding	Metal spot welding	Connect two metal plates with electrode bars for spot welding, while pressing and applying currents.	Productive; Low cost	Prone to stress concentration
Mechanical Bonding	Screw fastening or riveting	Connect components using screws or rivets	Bonding Strength; Appearance	Weight; Cost
Chemical Bonding	Adhesive	Fasten components chemically and/or physically with the use of adhesives	Stiffness; Insulation	Hardening time; Function check

Source: Industrial Technology Research Institute (ITRI), July 2022

Connecting automotive components is no easy task. Its process requires considering bonding strength as well as the decline of bonding strength between materials due to electrocorrosion or thermal expansion coefficient. This might require adding an insulating layer. Additionally, temperatures have different effects on automotive components; and therefore, the expansion and contraction rate and deformation vary, which should be taken into account as appropriate. An example is considering using adhesives after mechanical bonding.

Depending on the materials for lightweight aluminum alloy car body and the locations that use components, the bonding methods for steel, aluminum alloy and carbon fiber reinforced composite are different. **The common automotive component bonding methods include self-piercing riveting, flow drill screw, friction stir welding, cold metal transfer welding, laser welding and metal bonding.**

Demand for Bonding Heterogeneous Materials

Automotive components come in numerous types. Cars are going lightweight to cope with the demand for customizing and mass-producing next-generation and electric vehicles. The use of heterogeneous materials and composite materials increases. Component bonding differs from conventional welding and riveting. Heterogeneous material bonding technologies are being developed and applied. Considering car service life and safety, components need to be endurable through time, and component bonding is moving toward high efficiency and reliability.