part basis to verify this. For parts that exceed the 0.1% limit, alternative solutions will have to be found.

RoHS

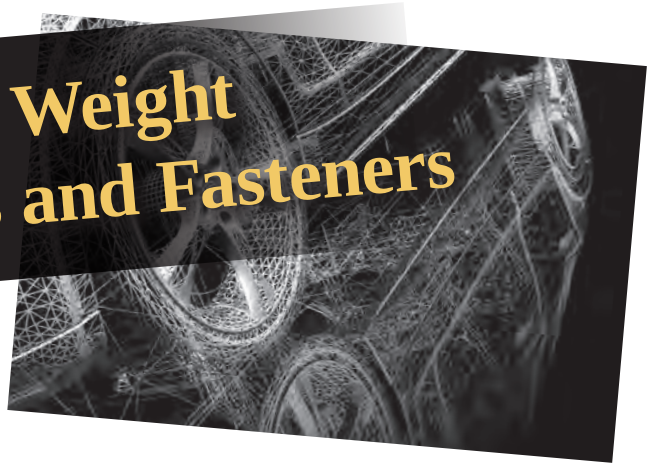
About the same time that REACH was being passed, the first requirements of RoHS or the Restriction of Hazardous Substances Directive were taking effect. This is another European Union Directive. It is actually short for "Directive on the restriction and use of certain hazardous substances in electrical and electronic equipment". One of this directives primary intentions is to help meet targets for recycling and recovery of electronic waste.

Although it is commonly believed to be a restriction solely on lead solder, RoHS actually restricts ten different substances, including lead, cadmium, and hexavalent chromium. Of the ten, these three are the substances that may be present in fasteners. Unlike REACH which sets limits on the total weight of the object, RoHS makes the restriction on each "homogenous material" in the product. This means, for example, an electric circuit board comprised of multiple components, must be broken down and assessed for each homogenous part. This can get complicated because many components can be further broken down into smaller parts. The directive states that the limits apply to the smallest single substance that can be, theoretically, mechanically separated. For fasteners, that likely means that the base fastener and surface finish (plating or coating) need to be considered separately. This effectively means that the surface finishes must not contain cadmium or hexavalent chromium, or be made from common, lead-containing screw machine material.

Conclusion

It is clear that today's society demands that industry be "solid citizens" and wise stewards over the environment. It is no longer acceptable to callously disregard the health and well-being of employees and consumers alike or to wantonly disabuse the environment in which we all live. Although these six developments in the fastener industry are noble and positive advancements, they come with challenges. Many of the products and processes used today have been defined with years of experience and know-how and cannot be easily replaced. Our challenge as an industry, therefore, is to rise to these challenges and find new, innovative ways to make exceptional products that are not at the expense of our health or the environment.

The Impact of Automobile Weight Reduction on Components and Fasteners



by Feny Chen, industrial analyst of MIRDC

The Trend of Automobile Weight Reduction

To discuss this topic, please look at **Fig. 1** to see how this trend has developed. One reason was that the price hike of oil before 2009 prompted many countries to reduce their dependence on oil imported from other countries. Another reason was the rising awareness of environmental protection and health, resulting in the reduction of emissions from power plants, industries and motor vehicles. To internal combustion engine vehicles, weight reduction plays a very important role on energy saving and emission reduction; according to relevant studies, If the weight of an automobile is reduced by 10%, its fuel efficiency may be increased by 6 to 8%; in addition, the reduction of every 100 Kg of weight would lead to the reduction of carbon dioxide emission by 3g per Km. Therefore, weight reduction has become a trend that automakers are forced to follow.

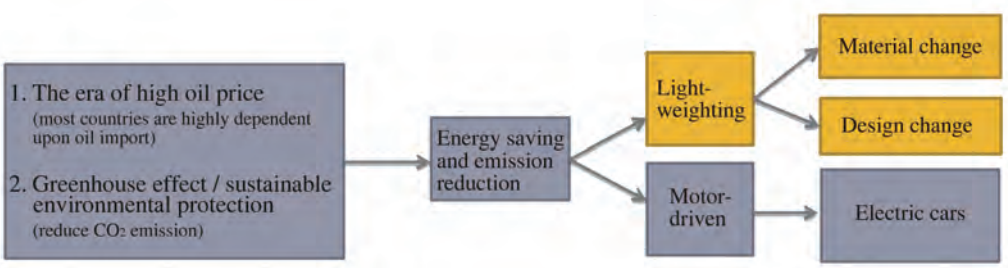


Fig. 1: How This Trend Has Developed
Data source: drawn by the MII of MIRDC (March of 2016)

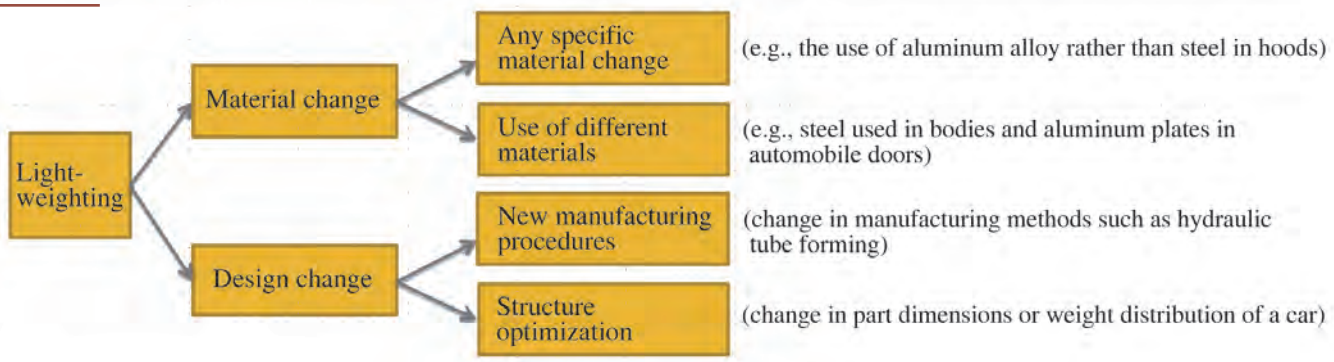


Fig. 2: Directions in Which Automobile Weight Reduction is Heading *Data source: drawn by the MII of MIRDC (March of 2016)*

The Directions of This Trend

With regard to automobile weight reduction, not only the frame but also accessories should be taken into consideration. For example, a car without ABS and anti-collision system must have a weight reduction design that is different from a car with these systems. In 1990s, Department of Energy of the US led an inter-ministerial cooperation plan to jointly develop a new generation of cars; participants of the plan included academic institutions and two big automakers – GM and Ford. This plan marked the start of the trend of automobile weight reduction; in the plan, Uncle Sam invested 200 million dollars in the research of the weight reduction of body structure and power system. As of now, automakers continue to put effort in automobile weight reduction according to the newest material technologies.

In this article, I try to generalize the main aspects and directions in terms of automobile weight reduction from the directions in which the research and development of global automakers are heading. The directions may be classified into two categories: change in material and change in design. The category of material change includes the change of a single material and the combination of different types of materials. The category of design change includes new manufacturing methods and optimized structural designs. Please see **Fig. 2**.

As of now, most automobiles' bodies are made of steel plates and lighter parts only comprising 30% of their weight. In terms of material changes, high-strength steel and aluminum alloy have exhibited a fast development; other materials that have been developed include porcelain, plastic, fiberglass and carbon fiber. According to McKinsey's studies, lighter materials and parts used in an automobile will reach 70% in 2030 and high-strength steel (plate), aluminum alloys and resin will dominate these materials. We will elaborate them in the following paragraphs.

(1) High Tensile Steel Plates

Thanks to the automobile weight reduction (so as to be more gas efficient) and to ensure safety, big effort has been put in the development of AHSS (advanced high strength steel) in the past few decades. Thanks to the regulations on safety and fuel efficiency, AHSS has been widely used on automobiles' body structure. According to the FSV (future steel vehicle) concept brought forth by the IISI (International Iron & Steel Institute) in 2011, with 97% of AHSS (with more than 50% of it having greater than 1000 MPa of tensile strength, a FSV would be 39% lighter than a conventional vehicle with 80% of mild steel; in addition, such FSV would have the highest anti-collision safety rating. Several years ago, Nissan's Fairlady Z (the 6th generation), equipped with additional side airbag and bounce safety hood, had its weight increasing to 1,580 Kg from 1,480 Kg; to lose some weight, its body lost 10 Kg: the use of high tensile steel plates (with 590 to 780 MPa) jumped from 35% to 53% (4% of them was of high tensile steel plates of 980Mpa). Recently, Nissan announced it would

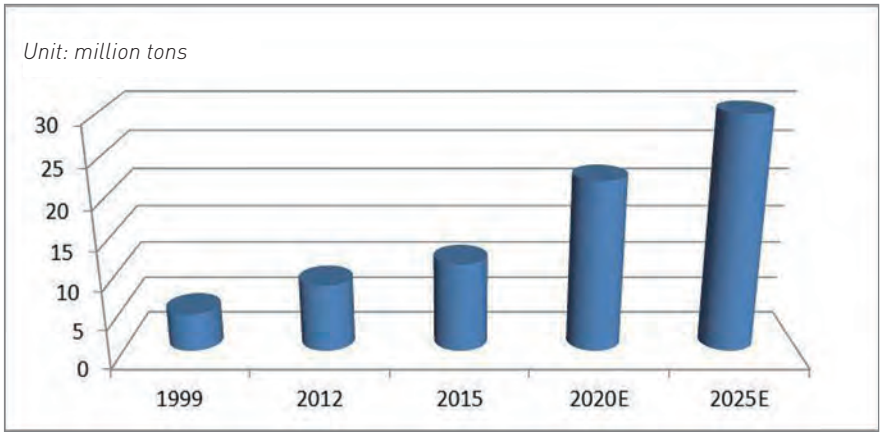


Fig. 3: The Global Increasing Pattern of the Use of Aluminum Alloys on Automobiles
Data source: Ducker Worldwide; drawn by the MII of MIRDC (March of 2016)

use more AHSS to make its new automobiles lighter without compromising safety. As of now, Infiniti Q50 is the first model that uses AHSS. All of Nissan's 2017 models will be made of AHSS so as to reduce their weights by 15% without compromising the rigidity of their body structure.

(2) Aluminum Alloys

Aluminum alloys have been used most in reducing automobiles' weights. Please see **Fig. 3** for the global increasing pattern of the use of aluminum alloys on automobiles thanks to the special characteristics of aluminum alloys – lighter, reusable and easy to form. Actually, frames made of aluminum alloy are 30 to 40% lighter than frames made of steel; an engine made of aluminum alloy is 30% lighter than an engine made of steel; a radiator made of aluminum alloy would be 20 to 40% lighter than a radiator made of copper; a rim made of aluminum alloy is 30% lighter. Therefore, as of the present time, aluminum alloys would be ideal materials that may be used to achieve automobile weight reduction.

Alcoa of the US used aluminum alloys to fabricate a bus in 2011, resulting in a weight reduction of 12% and an increase of fuel efficiency by 6%. Throughout the service life of this bus, a reduction of 50 tons of carbon footprint may be achieved. According to the IKA, the study done by University of Aachen indicated: the weight of a passenger car weighing 1,229 Kg may be reduced by 74% to 444 Kg if all steel parts are completely replaced by aluminum alloys. But the downside is: aluminum's density is about one third of steel's density and aluminum's modulus of elasticity is also about one third of steel's; this means a steel component's weight would become one third if it is replaced by aluminum alloy and its structural rigidity would become one third in this case. In other words, if the same rigidity is aimed at, no weight reduction may be achieved because three times of aluminum in weight must be used. This is the reason that aluminum alloys are usually used for components that do not require high rigidity, such as hood, rooftop, trunk, brake caliper and rim, but not used for chassis and body. If we want to use them in chassis and body, some obstacles need to be overcome first.

For the time being, types of automobiles with a body structure made of 100% aluminum alloys are predominantly sedans (such as Audi A8L 3.0TSI). Sedans with a price tag less than NT$ 4 million rarely have aluminum alloy body structure. There are several reasons for this: aluminum alloys are more expensive; aluminum alloys require high level of technology to process and fabricate; their production line has to be separate from the production line of steel-made automobiles; their design and fabrication are more complicated; equipment used for their fabrication is more expensive. Therefore, their production cost remains higher and for the present stage, they are used only for flagship sedan models and sports cars.

(3) Resin Materials

Carbon fiber is a new fibrous material that contains more than 95% of carbon and has high strength and high modulus of elasticity. Compared with steel, it is 10 times stronger, but its weight is one tenth of steel's. It is sintered with a resin to be used as a composite material, which is often used to fabricate fuselages. According to the test results of a Japanese material factory, if such composite material is used on automobile, its fuel efficiency will be increased by 40% because of its weight reduction, resulting in a substantial reduction of carbon dioxide emission. Therefore, the composite material is regarded as a great new environmental material. Lexus LFA made by Toyota Group was first marketed in Japan in December of 2010 and 65% of its body structure was made by CFRP (carbon-fiber-reinforced polymer), resulting in a weight reduction of about 100 Kg; however, its price tag was quite high – 38.5 million yens. Carbon fiber's price remains quite high for the present stage and hence it is not widely used; however, with its special physical characteristics – stronger than steel and lighter than aluminum, its potential in future application remains great.

Weight Reduction of Parts and Components

If no weight reduction is done, the weights of chassis, interior, power system and components may total 308 Kg. This figure comprises 20.56% of the average weight of an ordinary automobile – 1,500 Kg. Because an automobile includes 1,000's of components, it may lose a lot of weight if each component loses a little weight.

For the present stage, there are several types of materials that may be used to achieve weight reduction of components: carbon fiber, lighter alloys (aluminum alloys, magnesium alloys and titanium alloys), engineering plastics, composite materials and high strength steel. Of course, weight reduction of either body structure or parts should not compromise safety and performance. As previously described, weight reduction may be achieved by change in material or design. As of now, components of automobiles are still predominantly made of steel, but the use of aluminum alloys, magnesium alloys, plastic and composite materials on components continue to grow and the use of cast iron and low-strength steel on components

exhibit a gradual decline. Physical characteristics of various types of materials have affected their use in different types of components. Lighter materials will exhibit a closer integration with components, product design and fabrication technology. We will elaborate on this topic in the following via two categories -- larger parts (such as transmission system) and smaller parts (such as fasteners).

(1) Weight Reduction of Larger Parts – Using Transmission System as an Example

The heaviest system of an automobile is its engine. Components of an engine, such as cylinders, pistons and crankshafts are made of high-strength metals that can withstand high temperatures because they have to withstand tremendous amounts of pressures and high temperatures caused by 1,000's of small explosions per minute under a controlled condition. To ensure engine's durability, a conventional engine is quite heavy. Moreover, to pass the motion from an engine to four wheels, an integrated design of transmission box, cylinders and other parts would be needed. Therefore, undoubtedly, these parts are the heavier parts of an automobile. In an electric car of the future, motion may be directly passed onto each wheel; in such case, these heavier transmission-related parts, which need to be maintained periodically, may be eliminated. As of now, Venturi-Venturi, which is an independent French sports car company, has been pouring effort in the development and application of such futuristic electric car.

(2) Weight Reduction of Smaller Parts – Using Fasteners as an Example

Studies have indicated that weight reduction of smaller parts is not significant in terms of weight reduction of automobiles. In fact, this topic should be considered by two perspectives: (a) If the body structure and components remain to be made of the same steel materials (b) If the body structure is made of different, lighter materials in the future.

From the first perspective, an automobile uses about 3,000 fasteners and their total weight comprises about 4.5% of the automobile's weight. The average weight of a fastener is between 22.5 to 27 g; therefore, if each fastener can be 1g less, the weight of the whole automobile would be 2 Kg lighter. Therefore, automakers would choose to reduce such 2 Kg via better designs of components and body structure. For example, Phillips Screw Company of the US has shortened the lengths of head portions of their fasteners and the round, recess heads have been replaced by hexagonal heads to make them more effective. Please see **Fig. 4**.

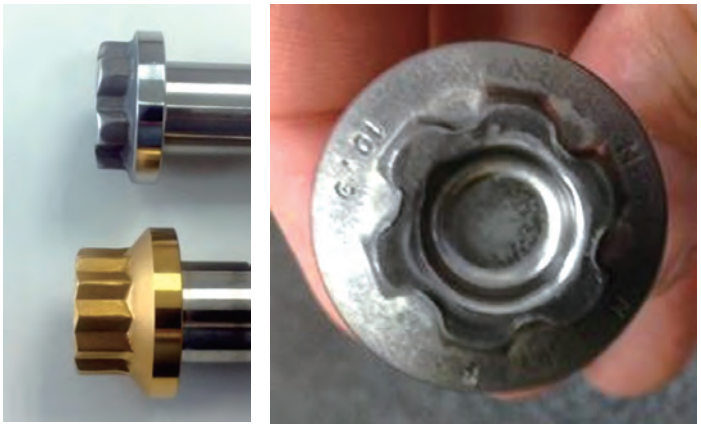


Fig. 4: Phillips Screw Company of the US Has Changed the Design of Its Fasteners

Data source: Ducker Worldwide; drawn by the MII of MIRDC (March of 2016)

From the second perspective, if the body structure is made of different, lighter materials in the future, change in shape or design may not suffice; in such case, the switch to lighter material may become necessary. The purpose of fasteners is to fasten components and body structure together so as to ensure safety; in other words, fasteners should have an optimal strength and do not need to be overly strong. If components and body structure are predominantly made of aluminum alloys and CFRP in the future, whether carbon steel and steel alloy will remain suitable materials to be used to fabricate fasteners would be something to ponder about.

In the past few decades, spot welding was used to connect one piece of metal to another and each automobile had 2,000 to 5,000 joints that needed to be welded. Spot welding is inexpensive: Each joint costs about US$ 0.05; welding is relatively fast: Each joint takes less than one second to do; in addition, welding may be automated easily; furthermore, no additional material is needed in welding. However, spot welding can not be used for pieces made of composite material. Not too long ago, a CFRP factory pointed out: When CFRP is widely used in the future, spot welding will not be used and the amount of fasteners used in an automobile will be greatly decreased.

Conclusion

In light of the above, automobile weight reduction has become a global trend and the competition of different types of materials has become fierce. Though at the present stage, structure-related parts are predominantly made of steel, more opportunities and challenges will pose for the fastener industry of Taiwan as technology advances and new regulations are enforced. How to lay out our business plan and strategy for the future within the confine of the present technologies would be something worth pondering. ■