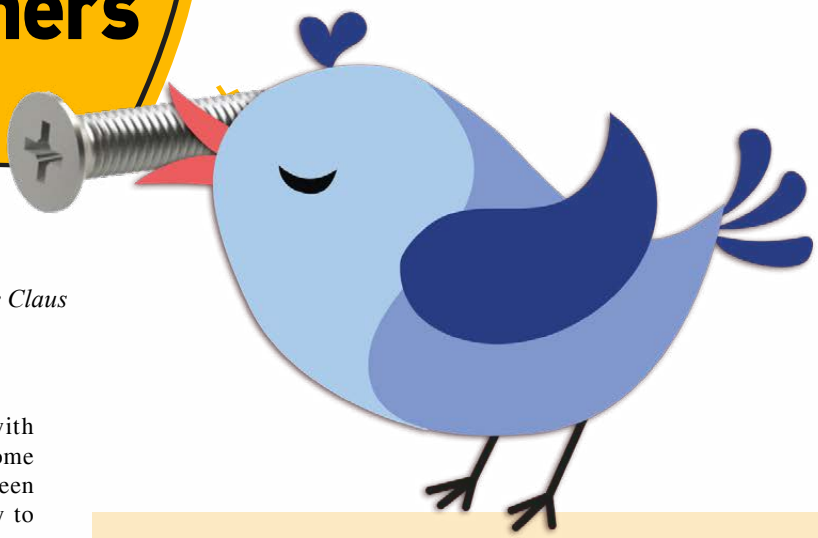
Lightweighting Using Fasteners



by Laurence Claus

Regardless of whether a car is propelled with an internal combustion engine, a battery, or some combination of the two, the last ten years has seen increasing pressure on the automotive industry to dramatically improve the range a car can drive on a single tank of fuel or charge of the battery. Although many competing technologies have emerged to address this issue, one of the favorites has and continues to be making automobiles lighter in weight. **One of the reasons lightweighting is a favorite amongst the automotive OEMs is that it has one of the best returns in fuel savings and increased distance on a single battery charge for the money invested.**

Over the last ten years several car makers have touted with great fanfare the number of kilograms they have been able to remove from their vehicles. One prominent example was Ford Motor Company's 2015 gamble to convert its bestselling F150 pick-up truck to an all-aluminum body and frame. In fact, they were successfully able to remove about 350 kilograms. Since then other OEMs have diligently worked on ways to launch their new and revised vehicle platforms on "diets" as well. For the most part they have been successful.

To accomplish these feats they have had to embrace new technologies and change to using lighter weight materials. As with many technology advancements this can often only happen when other new or improved technologies emerge to help enable the prime new technology succeed. With respect to fasteners, this means three different potential strategies:

1. Direct Lightweighting
2. Improved Fastening Technology
3. Enabling Technology

Direct Lightweighting:

Direct lightweighting is the easiest concept to grasp. This is where the fastener itself is made lighter than a traditional fastener might be. There are several ways to accomplish this, although the most prevalent is to replace a traditional steel fastener with a lighter weight material.

Aluminum:

Aluminum is nearly two-thirds lighter than steel. This, of course, makes it a prime candidate when choosing a lighter weight material for the fastener. Unfortunately, **although aluminum provides such excellent weight savings gains, in term of going head-to-head in strength against steel, even mild steel, there is little comparison.** For example, the highest strength, aerospace grade aluminum used in fasteners is 7075-T6. This has a minimum Tensile Strength of 83 ksi. By comparison a medium strength Grade 5 steel fastener has a minimum Tensile Strength of 120ksi, nearly 30% stronger. Of course, a brute head-to-head strength comparison doesn't tell the entire story. Many designers and engineers who are designing for lightweighting are concerned about Specific Strength or the strength relative to the material's density. When viewed under this lens, aluminum begins to look much more attractive, even though it will never be a viable solution where very high fastener strength is required.

Designers are increasingly reviewing applications that are not critical or require significant strength and considering using aluminum for these. Examples of these solutions include both aluminum machine screws for already tapped holes and aluminum tapping screws for forming treads in plastics. Naturally, one or two small screws converted to aluminum are not going to make a "big splash", but in applications where many similar or identical screws are being used, such an approach may truly bear some fruit.

A good example of this approach involves several different European automotive OEMs. They have worked with local fastener suppliers to develop proprietary, high-strength, aluminum fasteners to replace all the steel fastening on several engineering models. These engines may have several hundred such fasteners on them and this weight savings action reduces engine weight by several kilograms.

Aluminum has also been successfully utilized in thread forming fasteners for plastics. Although strength limitations may prevent them from being used in every case, especially when a highly filled or reinforced engineered plastic is being used, for lower strength plastics they make excellent substitution targets. Again, when used in applications that utilize many fasteners, the weight savings is noticeable.

Titanium:

Titanium is about sixty percent the weight of steel and much stronger than aluminum. Thus, its specific strength tops the chart. For this reason, Titanium has long been utilized in aircraft and defense vehicles. **In addition to being lightweight and strong, Titanium also has excellent corrosion resistance. One significant downside to Titanium is that it is very hard to form** and raw Titanium ore must undergo extensive processing before it is commercially useful, so that Titanium fasteners can be quite expensive. However, if lightweight and performance are desired, Titanium fasteners are perhaps one of the best options available.

The most common variety of Titanium for fasteners is ti-6Al-4V or "6-4 Titanium". This is an alpha/beta alloy of Titanium and provides a good combination of strength and corrosion resistance. It is commonly used for aerospace and biomedical fasteners.

Plastic:

Plastic fasteners have been around for many years. Historically, however, these have been relatively simple designs such as "Christmas Tree" fasteners and plastic rivets that are not expected to do much more than hold the fastened component in-place. Several years ago, however, a German supplier of proprietary thread forming screws began offering their hallmark thread forming screw in plastic. In the same vein that aluminum fasteners do not work with every plastic material, the application range of plastic thread forming fasteners is relatively limited to soft plastics such as Polypropylene and TPO.

Another direct weight savings approach is to develop weight savings designs. Take for example many aerospace fasteners, which contained inwardly dimpled or drilled out heads. These are referred to as "lightening holes" and remove a little mass without compromising strength or fastener integrity. Once again, fasteners with these types of lightening features must be used in high quantities to achieve a noticeable weight savings.

Improved Technology:

Another way to achieve some weight savings is to **utilize fasteners that possess improved technology that provides equal or better performance than a traditional fastener**. Consider the example of a lobulated thread rolling screw. The non-fully round fastener is intended to make thread forming during installation easier. However the non-fully round thread also has less engagement than its fully-round counterparts. To help compensate for the reduction in thread stripping security they often are made longer. Today there are several fully-round, proprietary thread forming screws which outperform these lobulated screws. Since they utilize new technology they often can achieve equal or better performance with smaller or shorter screws. This results in lighter weight screws.

In summary, using new or proprietary technologies will often provide performance improvements that allow the user to achieve the same or better performance than when using older, more traditional fastening technology.

Enabling Technology:

Finally, implementation of new technology often requires complementing new technology to make it work. **Currently, two popular lightweighting trends in automotive body design are to use either a combination of materials (such as steel, aluminum, and magnesium) or to incorporate high and ultra-high strength steel.** The latter is quite popular because the ultra-high strength steel provides lightweighting in the form of thinner sheets while actually obtaining better strength performance because of its high strength qualities. A common problem experienced by both of these trends, however, is that traditional fastening methods such as welding, crimping, or riveting no longer work. Thus, to successfully implement them, they must be accompanied by new fastening technology.

The introduction of new fastening technologies that enable another technology to be feasible is an excellent way for fasteners to play a critical role in the weight savings achieved by these new technologies. There are a number of newer proprietary fastening technologies that enable these technologies, such as self-piercing rivets, flow drill screwing, and friction element welding.

Summary:

In summary fasteners can and do play an important role in lightweighting. Often the fastener itself is lightweighted by utilizing a lightweight material such as aluminum or titanium or by incorporating weight savings design features. Sometimes a new fastener technology performs better than traditional technology allowing the joining to be accomplished with a lighter fastener. Finally, engineers and designers are always developing new ideas and technologies, some of which cannot be realized until a new fastening technology is developed to complement it. Therefore, fasteners are playing a pivotal role in lightweighting efforts. ■