The Eight Most Common Mistakes in Selecting a Fastener

by Thomas Doppke

Fastening is often thought of, if at all, as simply putting a bolt in a hole and tightening a nut on the other end. The job of choosing which fastener is to be used is often left to the novice designer or, in larger companies, a "fastener" engineer is appointed. His duties differ little from his fellow designers with the exception that he also gets to pick out the fasteners required. Usually having little or no specific experience, he selects something from a catalog, copies what was done last year or simply guesses. He may get it right the first time or, more probably, after correcting several mistakes and field and/or assembly plant complaints, finds one that works.

As past issues of this magazine have illustrated, joint attachments are more complex than the average engineer or designer realizes. Many things can go wrong; problems may arise from minor issues; they may not be available, or they may not function as expected. In many cases the company may have some directives which must also be considered about what the joint should look like or how it should function. The following are several issues that are usually overlooked or not thought about at all during the selection process. Poor choices in these areas can impact the assembly, functioning, and/or security of the joint. Needless to say, little mistakes can bring down the most carefully thought out designs.

Eight Most Common Mistakes

First, the question of what size and/or strength is often a guess. Strength tables may give the bolt's yield and tensile strengths and the designers use them to select the part based on some standard formula (i.e. use 80% of yield). Good enough for some joints but consider this. What are the service conditions? What loads will impact upon the joint? What else goes into the joint?

When the strength level needs to be increased to meet the load requirements a larger size is often chosen. There is a great difference between strength levels for fasteners. A higher grade of material (such as using a Grade 8.8 steel over a Grade 5.8) will allow a smaller size fastener, with its higher yield strength level to be used. On the negative side, a higher strength level material is also harder. This is a potential problem in areas where hydrogen embrittlement may occur (hardnesses in HRC 35+ area). Also, harder and tighter joints crush soft substrates easily.

Also, as has been the topic in past articles, changes in joint spring rate may be involved. To reiterate joint spring rate quickly; bolts, under load, act as springs, flexing slightly with increasing and decreasing loading. Short fasteners do not have much length to stretch and joints fastened with such parts may be subjected to various problems in service. One way that this lack of length to stretch is usually overcome is to use either a softer bolt (which will stretch more per unit length) or use a longer part with some sort of extension (multiple washers, a spacer, etc.) to increase the overall length requirement. Either way, changes to design, weight, strength and other factors will occur. A rule of thumb is when increasing by one grade decrease the diameter by one size.

When selecting a bolt based upon the strength level needed, consider the surrounding conditions. Smaller parts in a higher grade will save space, inventory, and weight. Softer parts may be cheaper and should be used if weight and space allow and loading is minimal. Don't pick a hard part if the application involves a thin 'stack-up' of components unless the service loads will not exceed 60-70% of the bolt proof load. The reason that many bolts, chosen by guess-work, function at all is that most joints are very over-designed. The bolt is, in almost all cases, very much stronger than the material it is attaching. Plastics are especially tricky; even a tight joint at installation will 'creep' or cold flow under loading after time, losing tension.

Second, bolts are often selected from a catalog with little thought about dimensional tolerances. With the influx of low tech third world manufacturers selling parts at lower cost, the desire is to get fasteners as a commodity (bulk purchase) rather than a blue print specified product has been a drive by purchasing departments as a cost reduction item. For example, many small screws are packed in barrels and are used as ballast in ships and then sold later on the market as bulk fasteners. Many fastener prints do not specify thread allowances, tolerances, and dimensional information. Whereas your old vendor knew what you wanted and gave you a M6 x 1 bolt that fit correctly, you may now need to detail dimensional requirements such as 6g thread fit, parallelism, straightness, and so on.

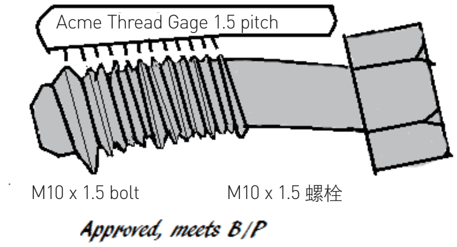
Later on the problems caused by finishes will be pointed out. A famous example "that's not what I wanted" is the case, from one automotive company who shall not be named, of washers which had the holes punched off center. While the OD, ID, and thickness were carefully detailed of the fastener drawing, nowhere did it indicate that the hole was to be in the exact middle. The manufacturer, a third world company, punched the holes out as a secondary operation with a small arbor punch off line (and not always dead center). Many drawings now are using Geometric Tolerancing to specify things that were never considered before. Commonly; that the shanks on longer parts be straight to within a certain tolerance, that the head of the bolt be concentric with the shank, that the underhead surface be flat and parallel to the shank, and so on. One industry study has shown that an off angle bearing surface can affect the final preloading by a value of as much as 50%.

Review the documents that call out the fastener needed. Are they detailed enough that what you needed is clearly specified? Do not think that the manufacturer knows what to make. As the old saying goes-you get what you ask for!

Third, related to dimensional problems is the fact that fasteners today all require some sort of protective finish. In past times these were minimal and offered a short protection time before the onset of corrosion. Today the requirements are often in years. Faced with environmental concerns (i.e. Cadmium ban, heavy metal removal from all coatings, end-of-life) and the longer anti-corrosion requirements, the new finishes have become much thicker.

So much so that they interfere with the fit of the threads, fill the recesses, stick the washers of screw and washer assemblies together, and so on. The force, torque, necessary to overcome the thicker finishes is rarely thought of or even measured. Lab tests are often run with regular finished parts, usually because the new finish parts are rarely available when the tests are run early in the validation process. While some of the new finishes use up torque (leading to under tensioned joints) some are PTFE based and are slipperier than regular. Undersizing threads to accommodate the coatings is a solution, albeit a poor one. Many of the coatings are zinc based paint-like finishes which are irregular in thickness and generally so thick that even undersizing does not help. Increased effort to drive, jamming, and poor drive tool fits are a few of the current problems. Check back issues for a more detailed discussion on this topic (CFW Oct 2012).

Fourth, often a torque value is required for assembly. As mentioned above, finish buildup, dimensional irregularities and even tool functioning can cause variation in the output at same input values. The common mistake is that when a fastener is 'up-graded' the torque value is seldom ever looked at or changed. Last year's value may be inadequate with today's anti-corrosion finish, a new source of parts or even that new, faster tool that the plant has begun using. The big problem with using a torque value is that the force needed to be validated is the tension in the joint. Unless some costly and exotic tests are conducted there is no easy way to measure tension. The use of a torque is a poor substitute but the only practical way available. The method by which a torque



is calculated is that several samples are run in a laboratory and the tension values are plotted against torque readings. If X torque produces Y preload consistently then X torque in production should also produce Y tension.

Make sure that the torque specified is actually giving you the tension that you think. Review what changes were made to improve the assembly looking at the effects of that change on the torque-tension relationship.

Fifth, A design always looks good on paper. The common mistake is to assume that are no errant conditions in the real world which will affect the joint performance.

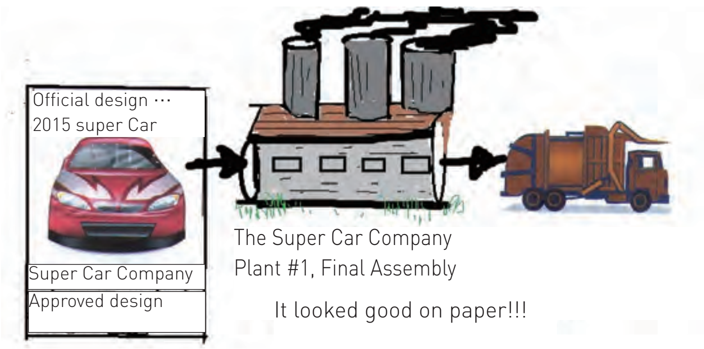
Vibration is the main demon of joint loosening. Both major impacts (hitting a curb) and micro-fretting (small, repetitive and cyclic impacts) can destroy the most secure joint over time. Chemical environment effects are seldom considered. The effect of gasoline splash, various car fluids, cleaning agents, soap and water, and any one of the several hundred fluids found in the typical household may alter that otherwise tight attachment.

Even the direction of loading majorly affects the joint. Loading in the transverse direction (perpendicular to the bolt axis) reduces the tensile strength of the bolt to 60% of its longitudinal value.

Sixth, The assembly process itself is often ignored. Good fastener selection includes knowing how the joint will be assembled. Ergonomic studies assist in reducing operator injury and insuring that the optimum assembly process is considered. Driving a fastener at any direction other than straight down introduces the possibility that an off angle drive may occur, usually with corollary problems such as torque irregularities, jamming, or stripping.

Tooling has never been much of a concern for designers, the plants being left to their own devices as to what to use. However, what tool is used can change the output tension by as much as 100%. A few items relative to the impact of tooling on torque/tension are:

1. A difference exists between tensions obtained by hand and those by faster running tooling; the range of obtainable values (plus and minus 3 sigma values) may vary by up to 100%.
2. Tool speed affects the final torque obtained and even if it can be constantly reached. Imagine a tool running at 2-3,000 RPM, driving a screw with 5 or 6 threads and stopping on an exact 2.2Nm torque. For mathematics people, that is 0.1 second to go from 3000RPM to zero.
3. Many plants have dropped impact tooling as the spread is often greater than the values needed to tighten. Not only



are impact guns uncontrollable but they are also given values as great as +/-100%. The standard model air tool usually runs at +/- 45% of set value or, for example, 30Nm +43.5, -25.5Nm. This range will cause some parts not to be driven (at minus value) and some others to strip (at plus value). The usual range for this value is +/-4.5Nm in most applications. A popular tool today is the high speed hydro pulse gun. It has an extremely fast rundown (5,000 RPM is common). Light weight and portable, it has found favor with the plant tooling engineers.

Seventh, Service and repair are seldom considered when designing an attachment. While we all would like our designs to function forever, things will happen. The usual mistake is to design joints that go together well but are almost impossible to disassemble or replace.

Unless the component is inexpensive and easily replaceable at a low cost, a repair procedure and method should be considered at the initial design stage. A one piece, welded windshield scraper is a cheap item, replaceable with little complaint. But a kitchen appliance needs to have a removable screw on that replacement handle, side panel, etc. or the customer will consider another brand the next time they buy. One car company designed its starter motor nicely in a corner which later entailed jacking up the engine off the mounts to replace it, adding many dollars to the repair bill. Many times the replacement fastener is not readily available; the most notable example was the introduction of the six lobe (star) recess on screws. The auto companies built with this type of screw recess and discovered that even their own dealerships did not have bits to remove and repair the screw. It was several months before the bits were commercially available for the general public.

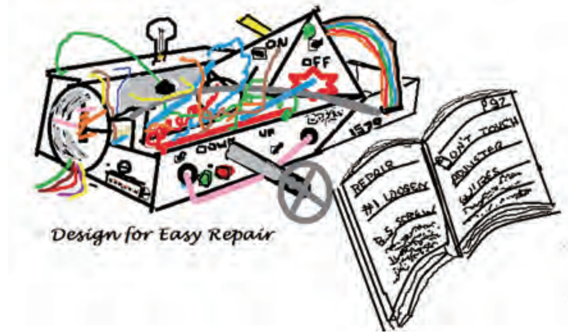
Eighth, Always a consideration but sometimes wrongly so, cost is a mistake made frequently. From day one, the cost of the component is foremost in the minds of the designers, assembly plant, and, of course, the managers. Great pressure is put upon the engineer to reduce cost, save even fractions of a penny, and use whatever stock is left over from last year's gadget. This generally happens at the cost of the integrity of the design. A bit cheaper, it may not last as long as it should and/or run as well. On the other hand, engineers are prone to over designing. A gold plated, egg flipper made of titanium and 6mm thick may be a beautiful product but its functioning can be achieved with a lot less. Choosing between the best design and the cheapest is a hard choice and there is not good advice on this point.

A final note of avoiding mistakes with fasteners and fastening is to look at the entire joint carefully. The attitude is that "its only a bolt, did the same last year, what's to look at?" leads to mistakes and things not considered until problems arise. Even a simple screw into a piece of sheet metal deserves a few minutes thought. Quickly say to yourself, "What loads are expected? What loads will be intermittent, what cyclic? What's it holding together? What's its life expectancy?"

When specifying a part, consider if a bulk part is useable (A nail is a nail isn't it? No, past articles on nails show a great difference in performance and life for even nails). As pointed out above, YOU GET WHAT YOU ASK FOR, NOT WHAT YOU THOUGHT YOU ARE ASKING FOR. To avoid excess cost, specify the dimensions and controls you need to avoid over specifying. One of the factors, the high cost for military hardware, is the fact that they must conform to hundreds of specifications to insure 100% performance.

New changes entail new concerns. Improvement in life performance of parts brought about the numerous problems associated with the new finishes. Jammed and/or stripped parts, recess fills, uneven coatings, loss of torque are just a few concerns to be considered when putting that improvement into the design.

Torque was once considered simple. One value, hand wrenched, everything was OK. Entering new tooling to accommodate increasing production rates,



electric, air, hydraulic. Then even faster tooling, more accurate as sizes were reduced and strength values were designed very close to the ultimate tensile strengths of the joints. A mistake in torque will lead to under loaded parts and failure or overloaded parts and, again, failure. The plus side of torque and fastener selection is most joints are over designed and there is usually some safety margin between maximum plant torque and ultimate failure.

Considered tooling. The plant is almost never a partner in design. They are the ones who will put your design together, and with their own selection of tools. As mentioned, tooling can change the joint tension tremendously (or not at all). It's a toss-up and the designer should know how the joint will be installed.

Take a Minute

Back to the beginning. Take a minute to rapidly consider all these points. Are there any other things that need a moment? Where will this part be used? Many countries do not salt their roads in winter, some heavily coat their roads. Have you considered that this part may be used in the equatorial countries with 100% humidity and 100 F temperatures? How about northern countries, -50F and ice? Is service to be an item? Have you thought out how to repair this part? Replace a fastener easily or weld it and buy a new component?

A minute's thought, stated again, can avoid many of these mistakes in selection of that fastener.