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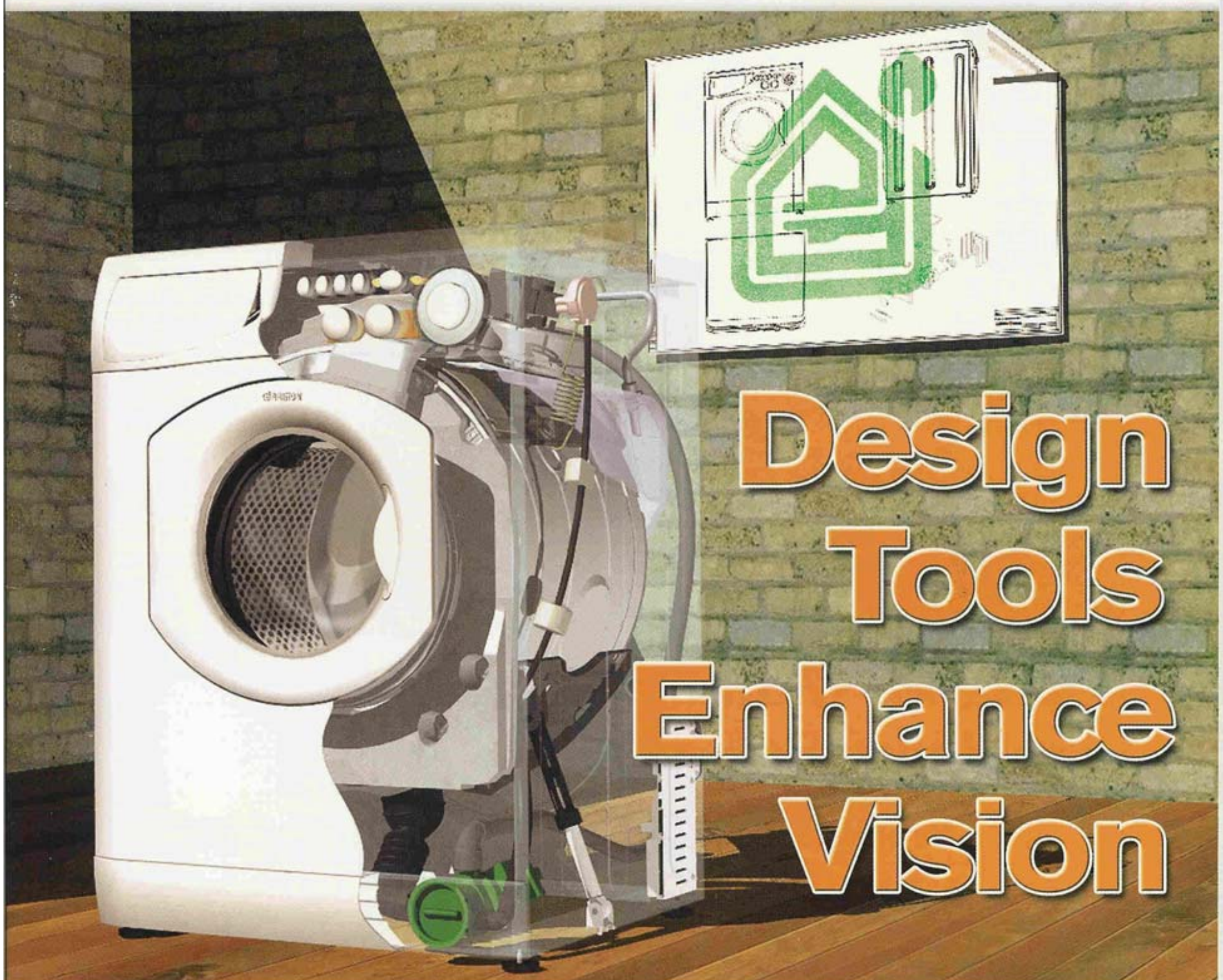

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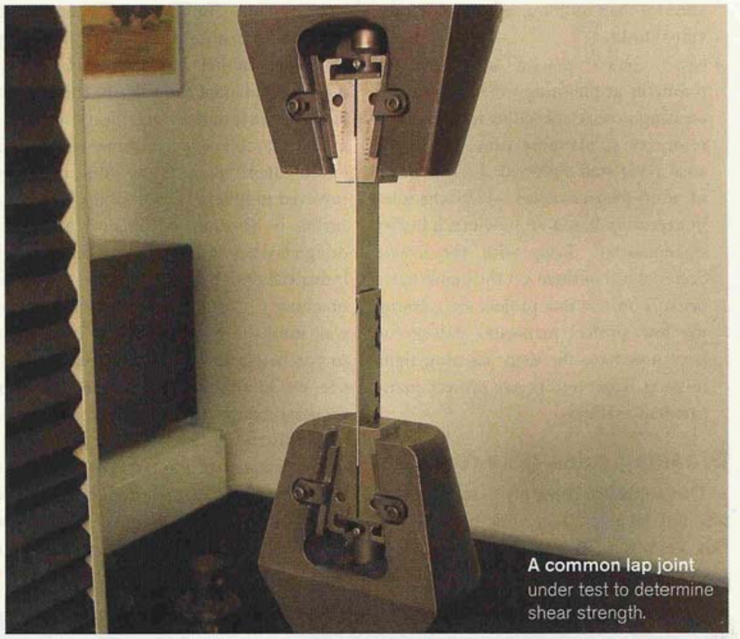
Joint Decisions



A common lap joint under test to determine shear strength.

Selecting joining method should precede joint design.

by david archer

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Many design engineers fail to think about joints as much as they should. Yet understanding the needs and purposes of a given joint is crucial to selecting the most appropriate fastening or joining method for joint, which subsequently affects the design of the joint itself. Beyond that, there are a number of good reasons to think hard about the joints in a product's design.

1. There is a good chance that joint failure is the leading root cause of field failure in the company's products. The data might not reflect that because nearly all field failure and warranty repair data report symptoms, not root causes.
2. It is very likely that more than half the direct labor cost in a product goes to fastening and joining operations.
3. In many classes of products, fasteners comprise about half the total number of components in the product.
4. A product's manufacturing requirements are a direct outcome of its design, and the high labor content devoted to fastening and joining also results in a large portion of assembly equipment budgets and floor space being consumed by these needs.
5. All of a company's investment in market research, innovation, lean manufacturing, and appealing industrial designs are wasted in the customer's eyes if the product fails, underperforms, squeaks or rattles due to a common fastener that is commonly, but incorrectly, applied.
6. Most organizations aren't aware that the cost of a fastener may be only 4 percent of the total installed cost. ***(See Fig. 1)***

In short, whatever a company manufactures, the joints in the product serve as the foundation of that product because failures generally occur at component interfaces.

Since in the current economic climate there is no place to hide design or production inefficiency, cost reduction is a relentless ongoing activity. Many engineers make the mistake of associating the relative influence of joint design in that activity to the proportion of bill of materials costs attributed to fastening and joining. As a result, the majority of assembly cost, and often the root cause of the majority of rework and failures, becomes essentially fixed, doubling the burden of labor and quality improvement that must be found within the rest of the assembly.

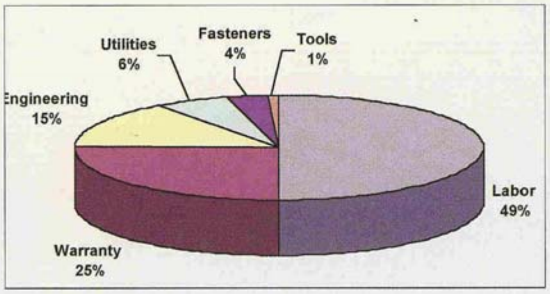

Fig. 1. Results of a study by an automotive OEM on the breakdown of total installed cost of threaded fasteners.

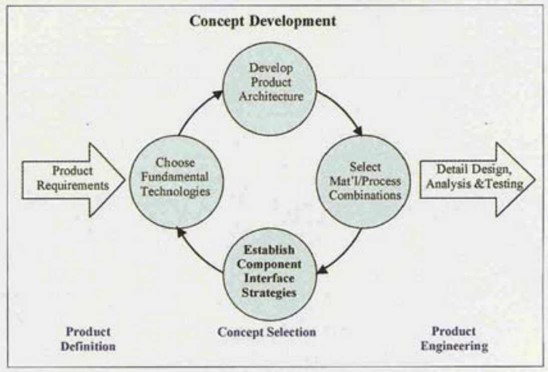

Fig. 2. Suggested relationship of joint design to the product development process.

With this perspective as a backdrop, one can better examine the steps to more effective joint design. The design decisions regarding component interfaces are as critical to the success of a new product as the development of the components themselves. As such, joint design must be seen as an activity fundamental to the development process, as suggested in ***Fig. 2***. Though this may be common sense to many design engineers, it is certainly not common practice for many others, as evidenced by the fact that fasteners are often the last items added to a new product's bill of materials.

As with other aspects of product development, the first joint design decisions are the most influential. Unfortunately, it doesn't always follow that the initial component attachment decisions are fully considered. Too often discussions jump to which rivet size is best or whether a continuous weld or stitch weld should be used without any consideration as to whether riveting or welding was even the best method for those applications. Also overlooked is a reflection on whether the joint even needs to exist in the first place.

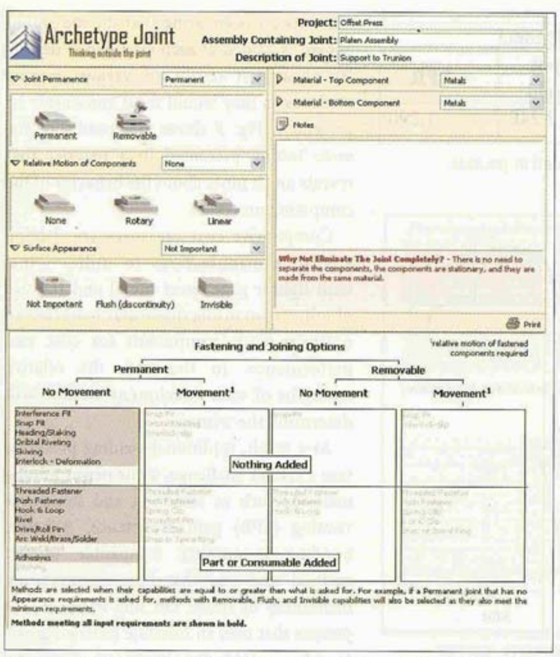

Fig. 3. Screening method for the selection of fastening and joining methods.

Two important drivers for developing lean, simple products are the number of joints that can be dependably eliminated, and the reliability with which the surviving joints can be designed.

For example, while a commonly held belief is that threaded fasteners are used to hold things together, in fact, they are really best at allowing things to be taken apart. A number of simple questions need to be asked in regards to each joint:

- Do the components move in operation?
- If so, is the movement linear or rotary?
- Will the joint need to be serviced?
- Are the components being joined of the same material or different?

By asking such simple questions, one can begin to classify the joint, and then list potential attachment techniques. However, if the joint does not require service, movement or the mating of different materials, it may be a good candidate for elimination altogether.

To be consistently competitive, fastening and joining methods should be selected by a process of elimination that initially assumes all methods are options, rather than by refining the method currently in use. Application of the fundamental joint requirements mentioned will screen out incompatible options, leaving potential solutions to be further investigated. A screening utility containing the more common fastening and joining methods is shown in ***Fig. 3***.

Once potential candidates have been selected, preliminary evaluation can begin. Establishing the right evaluation criteria and the optimal testing method for those criteria are the keys to successful process selection. Critical to improving the efficiency of the evalua-

Average Lap Shear Joint Strength - 14 ga. CR Steel					
Blind Rivet	Adhesive	Hybrid	Solid Rivet	Spot Weld	SPR
1,197	1,931	2,316	1,206	2,240	1,290

Fig. 4. Common presentation of lap shear strength test results measured in pounds.

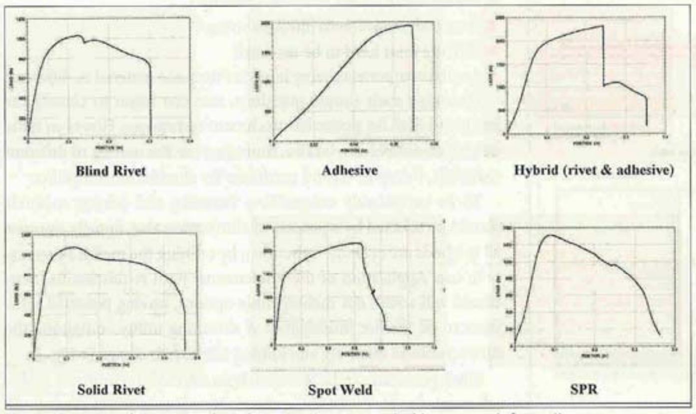

Fig. 5. Results of the same lap shear testing presented in a more informative manner – load vs. position.

tion process is ensuring that the maximum benefit is gained at each step. ***Fig. 4*** depicts lap shear test results of various joining methods as they would most commonly be presented. ***Fig. 5*** shows the results of the same testing presented in a manner that reveals much more about the behavior of the competing processes.

Competitive cost pressures are driving appliance manufactures to utilize joints with lighter gage sheet metal and the use of joints containing dissimilar materials to optimize each component for cost and performance. In the end, the relative strengths of each attachment method will determine the winners.

As a result, traditional welding processes face a greater challenge, while newer joining methods such as clinching and self-pierce riveting (SPR) gain acceptance. Adhesive bonding is another compatible joining method and one that has an interesting dichotomy of traits. On one hand, it is a process that uses an invisible fastener, greatly reduces stress concentrations, eliminates most corrosion problems, and can provide

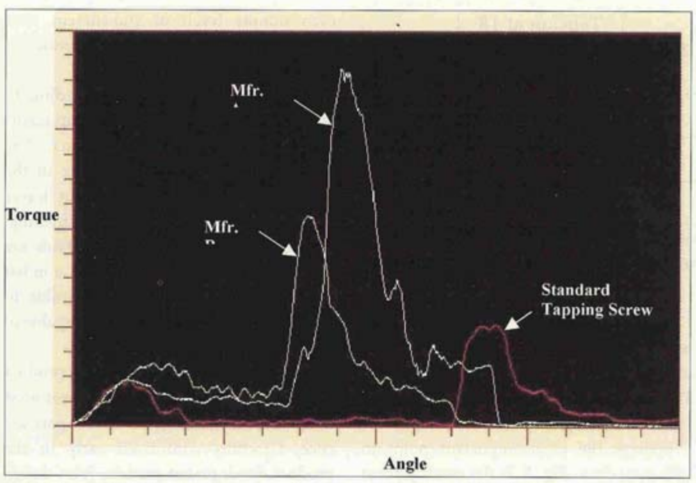

Fig. 6. Torque-to-failure testing comparing recessed head and standard tapping screws into 20 ga. 1020 CR steel.

sealing and damping, all of which makes it appear as the ideal joining method. On the other hand, challenges to acceptance can be found on the production floor, which must deal with issues such as cure times, variations in application and preparation, and the difficulty of real-time assessment of bond strength. One unique aspect of adhesives is that, like thermoplastics, their chemistry can be modified more easily and significantly than joining solutions which rely on metal forming. More than any other process, testing is key to successful adhesive application.

One of the common errors in the application of threaded fasteners with thin materials is using the same evaluation methods for joints with different needs. For example, in a non-structural application where low cost is the key driver, a sheet-metal screw might be driven directly into plain pre-punched holes. In these applications, the key parameter is usually getting the joint to survive the initial installation without thread strip.

For a given material and fastener size, the differentiating factor is often the under-head interface to the bearing material. For this reason tapping screws are available with recesses under the head that allow material to be drawn up into it during tightening. ***Fig. 6*** shows the results of torque-to-failure testing of two different manufacturer's versions of these fasteners in comparison to a standard AB tapping screw. The strip/drive

Nut Member	Failure Torque, (ft-lb)	Rank	Tension at 18 ft-lb target torque, (lb)	Rank
Extruded Hole	41.1	1st	768 lb	3rd
Pierce Nut	40.2	2nd	870 lb	2nd
Clinch Nut	35.0	3rd	1053 lb	1st

Fig. 7. Average torque-to-failure and residual tension of 5/16 - 18 Grade 5 fasteners into various nut members. Clamp plate is 12 ga. galvanized steel.

ratio of the modified head screws is significantly improved.

When threaded fasteners are used in structural application, it is likely that the fastener will need to maintain a clamp load through bolt tension for the joint to perform as expected. Since the joint requirements are different than the previous example, the evaluation criteria should change as well. *Fig. 7* shows the how the "right" answer can change depending on the criteria utilized. If one uses the traditional torque-to-failure test common with sheet metal joints, they will get a different answer than if they were to measure bolt tension at target torque. Tension was measured though the use of ultrasonic testing.

Perhaps the most important point to take away from *Fig. 7* is the small percent of the expected tension that is generally retained in threaded fasteners with very short grip lengths. In this case, the textbook expectation of tension was just over 3,300 lbs. As that bolt will only have stretched about 0.0003 in. to achieve that tension with the short grip length of a 12 ga. sheet, even minute levels of embedment after tightening will result in dramatic reduction in clamp load.

The other common factor leading to tension degradation is where clamp members are not in intimate contact. The means of creating the nut feature in the extruded hole and the pierce nut leaves areas that will relax during tightening. Although secondary locking methods are often successfully employed to combat these conditions, it is more desirable to establish a joint geometry that is capable of maintaining the required tension.

In summary, the convergence of product needs and production realities makes joint design a task requiring part art and part science. Carefully considered early in the product development process, joint design can be transformed from merely a task to a competitive advantage that yields improved product value and function, and customer satisfaction. ■

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