Four Steps to a Perfect Pressing Process

By Glenn Nausley, President, Promess Inc.

A fuel injector is just a small solenoid with a couple of moving parts, but that doesn't mean it's easy to assemble. When signaled by the engine control unit, a fuel injector opens and sprays pressurized fuel into the engine. That opening, albeit it small, must be tightly controlled.

Recently, we worked on a project to assemble fuel injectors. The nozzle needed to open 600 microns ±5 microns. We had to press a pin into an armature, and the pin had to protrude from the bottom of the armature by 15 millimeters. The parts were seemingly very simple, but in fact, they were made to a tolerance of ±2 microns!

The manufacturer had been pressing the pin to a dead stop. In other words, the press would apply force until the pin bottomed out on a block. The fixture held the dimension. But, because of deflections and other factors, the manufacturer wasn't getting the accuracy it required.

The problem with pressing parts to a dead stop is that it doesn't account for normal variations in the parts. Problems are caught by measuring assemblies off-line and hoping a defect is detected before dozens or hundreds of faulty assemblies are produced. Manufacturing engineers then respond to the problem by tweaking the fixture or adjusting the settings on the press.

We have a better way. We solved the fuel injector problem with an Electro-Mechanical Assembly Press and a fixture equipped with a high-resolution digital probe to measure the length of the pin as it is being pressed. The press applies force to the pin until the probe tells it to stop. Once the pin is pressed, the load is removed, and now the press essentially becomes a gauge. Indeed, our assembly fixture is designed to hold the part exactly the same way as the manufacturer's offline gauge, so there was a direct correlation between how the part was assembled and how it was measured.

LVDTs are used to measure the depth of bushings as they are pressed into a control arm. The bushing is pressed in partway, the arm is allowed to relax, and a measurement is taken. This process is repeated until the bushing has been located precisely.

The Electro-Mechanical Assembly Press is a fully electric, programmable ballscrew press with integrated motion control and monitoring. Promess offers 33 different servo presses with capacities ranging from less than an ounce to more than 200,000 pounds.

With the Promess approach to assembly, we gauge every single assembly we make. We press what we think is a perfect part, we take the load off it, and we measure it. If we spot a trend one way or another, the system automatically adjusts the pressing process on the fly. It's a self-correcting process.

Getting to that point doesn't happen by accident. As sophisticated as our sensors, presses and software are, a perfect pressing process still requires a good deal of forethought. Following these four steps will ensure that your pressing process achieves the results you desire.

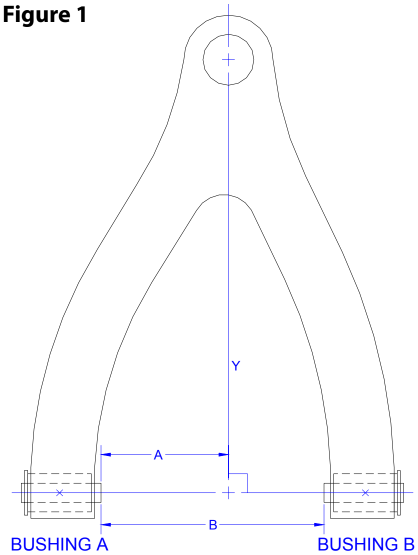
Step 1: Determine the Critical Parameters

The first step in designing a perfect pressing operation is to determine the critical parameters of the assembly. Note that this is different from the critical dimensions of the individual parts that make up the assembly.

In some cases, a critical parameter could be a specific dimension—for example, the distance between two ends of a control arm assembly, or how wide a valve opens on a fuel injector. In other cases, it could be a specific operating parameter, such as the amount of pressure needed to trigger a hydraulic relief valve, or the amount of torque needed to actuate a hinge. Understanding the function of the assembly will help you determine which dimensions, tolerances and parameters are critical and which aren't.

Control arms are a good example. The upper and lower control arms of a vehicle connect the front suspension to the frame. Each arm is connected to the wheel through a ball joint, and to the frame through bushings.

Figure 1



An engineering drawing of a control arm assembly lists dozens of dimensions, but only two really matter. (See Fig. 1.) One is the distance between the bushings (Line B). That dimension has to be held, because when the control arm is installed, it slides over another part and gets secured with pins. If that dimension is too tight, the arm won't fit. If it's too loose, the assembly will be sloppy.

The other critical dimension is the relationship of the two bushings to the ball joint (Line A). The end of each bushing must be a specific distance to a line extending from the center of the ball joint bore (Line Y) perpendicular to the center line running through the inner sleeves of the bushings. That relationship is important because it affects the alignment of the vehicle. In the old days, every car would get a front-end alignment at the end of the assembly line. Today, vehicles are assembled so accurately that alignment is no longer necessary.

Determining the critical parameters of the assembly is best done before the parts have been finalized and before the pressing station has been designed and commissioned. Unfortunately, this is often not the case.

Often, engineers tighten the tolerances on parts in an attempt to get better repeatability and control over their pressing process, even though those tolerances may only be indirectly related to the critical parameter or function they actually want to achieve.

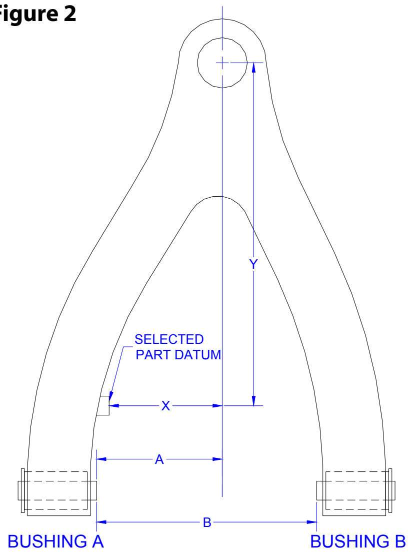
That approach can be costly. Manufacturing very precise parts is expensive. By using the Promess approach—assembling to a function—engineers often discover that they can loosen up part tolerances and save money. Depending on the part and the application, engineers can typically save 20 to 30 percent per part. Savings of 50 percent or more is not unheard of.

Let's go back to the control arm example. We've already noted the two dimensions that are most important to the function of the assembly. To help control those dimensions, you could specify expensive bushings machined to very precise tolerances. Ultimately, however, the length of each bushing is not important. If you carefully control the critical dimensions during assembly, then it doesn't matter whether the length of each bushing is machined to ±0.002 inch or ±0.005 inch.

Step 2: Can it be Measured?

Once you've identified the critical parameters of the assembly, the next step is to determine whether those parameters can be measured during assembly. Many times, the engineering drawing references part datums that are not available until after the part is fully assembled.

Figure 2



Returning to our control arm example, remember that the end of each bushing must be a specific distance to a line extending from the center of the ball joint bore perpendicular to the center line running through the inner sleeves of the bushings. The problem with that is the center line does not exist at the time the bushing is pressed. In this case, the process and product engineers need to work together to select part datums that can be referenced while the bushings are being pressed. (See Fig. 2.) Measuring Line X solves the problem.

Step 3: Designing the Pressing Station

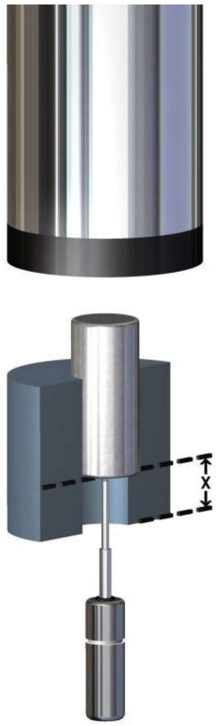
Now it's time to design the pressing station. In designing the station, follow these principles:

First, design the station as a gauging station that also assembles the part. This station must pass a gauge repeatability and reproducibility study (gauge R&R). Assemblies will only be as good as the station can measure. Gauge R&R is a statistical tool that measures the amount of variation in the measurement system arising from the measurement device and the people taking the measurement. When measuring the product of any process, there are two sources of variation: the variation of the process itself and the variation of the measurement system. The purpose of conducting the gauge R&R is to distinguish the former from the latter, and to reduce measurement system variation if it is excessive.

A variety of technologies can used to measure key parameters during pressing, including analog and digital linear variable differential transformers (LVDTs). Which to use depends on your accuracy requirements. An analog probe is typically accurate to ±10 microns, which is fine for control arm assembly. On the other hand, fuel injectors are considerably smaller and require more precision. For that application, a digital probe with an accuracy of ±0.1 micron might be necessary.

Second, the station must be able to measure the part with the press or presses retracted. During the process, the press must retract at least far enough off the part to allow measurements to be taken with the part under little or no load. Engineers also need to provide enough room for the probes. You want to make sure you're holding the parts correctly and measuring the right dimensions. Bear in mind the points that should be held during measurements are not necessarily the points that should be held while the part is being assembled. In addition, there are mechanical techniques to isolate that measurement from the load. It's also possible to back off of the workpiece and measure it in a relaxed state.

For example, in the control arm application, two to four LVDTs are used. The bushing is pressed in partway, the arm is allowed to relax, and a measurement is taken. This process is repeated until the bushing has been located precisely.



The problem with pressing parts to a dead stop is that it doesn't account for normal variations in the parts. Problems are caught by measuring assemblies off-line and hoping a defect is detected before dozens or hundreds of faulty assemblies are produced. A better way is to use an Electro-Mechanical Assembly Press and a fixture equipped with a probe to measure the length of the part as it is being pressed. The press applies force until the probe tells it to stop.

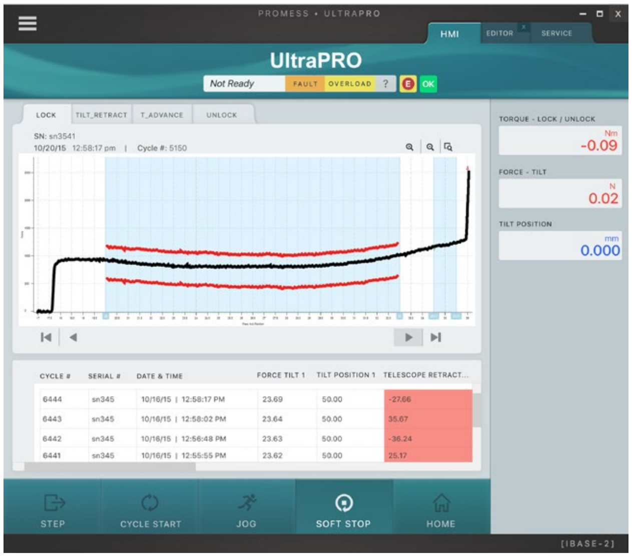
Sometimes, it's not possible to measure the part in a relaxed state. In that case, a probe can be used solely to measure deflection of the part, and the press can be programmed to compensate for that distance.

Finally, ensure that the station design allows for the refixturing of assembled parts (that is, assembled to the extent they leave this station). This allows for station mastering, gauge R&R studies, and process debug and verification.

This approach is a departure from traditional press-fit assembly. We're not using a pneumatic or hydraulic cylinder to press a part to a dead stop. We're not trying to hold tolerances with mechanics. Instead, we're measuring the critical parameters of the assembly and adjusting on the fly.

The old saying, "garbage in, garbage out," applies when it comes to designing fixtures for this approach. A traditional press-fit station is designed to hold the base part rigidly while a bushing, bearing or other part is pressed into it. But, that's not how you would hold the parts if you were making critical measurements. A different approach is required. The station must be designed to measure parts as if it were a gauging station.

For the press-and-gauge approach to work, fixture design cannot be an afterthought. The station must be designed to measure the assembly's critical parameters, and that often requires a different mindset. Indeed, gauge designers and machine designers are typically two different people. The machine builder is thinking about robustness and how to hold the part while 1,000 pounds of force is applied to it. The gauge designer is thinking about datums, dimensions and repeatability. In the press-and-gauge approach, however, the machine designer must wear both hats.



Measuring both force and distance during the pressing operation can give assemblers valuable information about the quality of the parts and the assembly.

Step 4: Off-Line Gauging and Making a Master

If an external off-line gauge is required, it should be designed to duplicate the fixturing and location techniques designed into the pressing station. This helps to provide consistency and correlation between the pressing station's measurements and those of the off-line gauge.

Although our press-and-gauge technique can obviate the need for off-line gauges, most manufacturers still use them, even if it's just to verify the performance of the assembly system. Even so, we have many customers that used to perform offline gauging on every assembly produced by their hydraulic or pneumatic presses. Now, after switching to our Electro-Mechanical Assembly Presses, they might check a press-fit assembly once a day, if that.

Finally, engineers will want to assemble a master part that can be used to master both the pressing station and the offline gauge.

To achieve a perfect pressing process, engineers need to plan ahead. Determining what to measure and how to measure it will enable you to design an effective pressing station.