Forging Solutions
Design Engineering Information From FIA

Cold Forging – Case Studies

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CASE STUDY FROM THE FILES:

Forged tube support replaced bar stock, eliminated all machining and cuts cost by 85%

In a concerted effort to reduce costs of its metal components, a major manufacturer of medium- and heavy-duty industrial and agricultural equipment worked closely with a local forging company to redesign a machined bar stock component as a more cost-effective forging. After conversion, the results were better than expected, for a simply configured, volume-sensitive component. The steel forging cost less than one-sixth that of machined bar stock.

Previously, four different operations were required to produce the part. First, a long piece of 1020 hot-rolled bar was cut in two, then flame cut, ground, and was finally placed into a lathe fixture where the bottom was turned. By making it a forging, the company was able to produce it close enough to net shape to eliminate all machining operations—a reduction from four in-plant operations down to none. See top figure. As received from the forger, the components were directly installed on the equipment. See bottom figure.

![The as forged steel tube support was ready for assembly, as compared to the bar stock version, which required extensive machining.]

COST ANALYSIS FOR STEEL TUBE SUPPORT

- **TOTAL COST OF MACHINED BAR STOCK = 100%**
  - RAW MATERIAL COST = 7%
  - SAW, FLAME CUT, SHOT BLAST = 10%
  - BORE OPERATION, DEBURR = 83%
- **TOTAL COST OF FORGING = 15%**
CASE STUDY FROM THE FILES:

Cold-forged control arm replaced stamping, achieved overall economy in trucks, autos

Initial cost is not always the overriding selection criterion for metal components. Design flexibility, lighter weight, or other advantages can make steel forgings with a higher initial cost into a cost-effective solution in the long run. Such is the case with a cold-forged upper control arm assembly, which had design advantages by replacing a stamped configuration. See figure.

Conceived for light- and medium-duty trucks, the one-piece forged assembly was light in weight and stronger than the stamping it replaced. While not less expensive than a stamping, the cold forging provided savings in the overall chassis design.

The arm provided ample room for larger shock assemblies, as well as additional clearances that allowed use of a shorter chassis to accommodate an independent front suspension for the four-wheel-drive versions of the trucks. This design freedom allowed for greater weight reduction in the chassis designs.

The cold forging permitted use of a standard shock absorber, allowing engineers to employ a conventional spring and lower arm suspension system. The shock absorber was mounted on the lower arm, then routed up through the space between the two legs of the upper arm and into the chassis. In contrast, a stamping's web did not allow such mounting, requiring attachment fore or aft of the upper arm and, consequently, a longer chassis.

The cold forgings were also lighter than stampings, saving about 2 lb. per vehicle to further boost mileage ratings. More importantly, related designs achieved similar success over stampings. An upper control arm for a mini-van allowed greater design freedom in vehicle styling, such as the aerodynamic front end; a stamping might have made it much longer. Similarly, a front tension strut achieved tight tolerances and good mechanical properties without heat treatment.

Highly automated production was also a contributor to these successful "ready-to-install" assemblies. After undergoing warm and cold forging operations, the part was painted and baked. A multi-station transfer machine then drilled four rivet holes and bored two eyes for the bushings, which were inserted on each side. Finally, the ball joint was assembled by riveting it to the bent (and coined) nose.

The cold forged upper control arm assembly for light trucks had a significant design advantage over stamped alternatives. It produced cost savings elsewhere in the vehicle.
CASE STUDY FROM THE FILES:

CVJ 'tulip' finished as-forged, cut cost and eliminated expensive machining operations

Due to the refinement of the forging process, a critical component of a CVJ (constant velocity joint) for front-wheel-drive systems became more cost-effective and more efficiently made. The "tulip" features a sliding joint that accommodates the ups and downs of the suspension and the steering gears' turns while simultaneously transmitting power to the wheels. See figure.

Previously hot forged and subsequently machined, the tulip required very difficult machining. Not only did the three tracks require turning and grinding, but the trimming operation also involved interrupted cuts. This resulted in high tool wear and made it very difficult to attain the accuracy required. While the grinding operation was necessary to achieve the desired surface finish, it also created another potential problem: distortion upon subsequent induction hardening.

By switching to warm forging (actually warm extrusion at about 1200°F) the number of operations to machine the tulip were significantly reduced. After warm forming and just prior to cooling, the component was coined or sized to its final form, and then induction hardened. Since all cutting, grinding, and turning were eliminated, the resulting cost savings was considerable.
CASE STUDY FROM THE FILES:
*Capability analysis brought process into control, boosted quality of forged automotive parts*

Capability studies are powerful tools in controlling the forging process. In this example (relatively high volume aluminum die forgings), too many automotive parts were being produced outside the specification range. Although practically all parts could be reworked to bring them within the blueprint tolerance range, adjusting the process should theoretically produce all parts to specification.

To analyze the situation, engineers conducted a capability study using the die closure dimension (thickness), which is normally the dimension of interest for evaluating how well the process is "in control." If this dimension is correct, so are all other dimensions.

Initial capability analysis showed that the spread was too wide for the specification, and that the process was off center, as indicated by a low process capability index or $C_{pk}$. By definition, $C_{pk} = \frac{\text{specification tolerance range}}{\pm 3\sigma}$ of the process capability range. A process capability index, $C_{pk}$, of greater than 1.33 means that more than 99.94% of the forged products are within the specified blueprint tolerance.

Adjusting specific process variables brought the process back into control, achieving a $C_{pk}$ of 1.3820 versus the initial value of 0.0123. See table. The adjustments also brought the mean value much closer to center. See figure above. Consequently, all parts produced after process adjustment fell within the specification limits. Rework dropped from 49% to 0.

Other benefits included not only reduced inspection, but also the elimination of part sorting and restriking or oth-
erwise reworking parts to make them acceptable. Correspondingly, productivity and cost effectiveness also increased.

Finally, once the process was centered with a relatively high $C_p$, it was relatively simple to maintain. Only statistical sampling and plotting of control chart points were necessary to monitor production. Once a process is adjusted, it tends to stay "in control."

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before</th>
<th>After</th>
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<tbody>
<tr>
<td>Mean</td>
<td>2.9543</td>
<td>2.9085</td>
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<tr>
<td>Std. dev.</td>
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<td>0.0081</td>
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<td>% &gt; U.S.L.</td>
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<tr>
<td>$C_{pk}$</td>
<td>0.0123</td>
<td>1.3820</td>
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</tbody>
</table>

Process capability, % of blueprint tolerance:

| Specification limits (L.S.L. - U.S.L.) | 2.870-2.960|
| 3σ limits (Before) | 2.870-3.039|
| 3σ limits (After) | 2.884-2.933|
| 4σ limits (Before) | 2.842-3.067|
| 4σ limits (After) | 2.876-2.941|
CASE STUDY FROM THE FILES:

Co-operative redesign delivered forged stop nut, eliminated machining, and consolidated parts

Because of cooperative engineering between a forging company and customer, a stop nut for a pipeline ball valve was redesigned as a steel forging. See figure. Significant cost savings was achieved as a result of part consolidation and elimination of virtually all machining operations. The successful design was then adopted for the entire family of parts.

With a basically square configuration, the stop nut fits on the stem of a ball valve and indicates the direction of flow. Its square shape allows it to be used in conjunction with an actuator or a tool to open and close the ball valve on cross-country pipelines that carry oil, gas, petroleum products, and other liquids and gases.

Originally made from square stock, the old design required extensive machining, including turning, milling and broaching a spline on the internal diameter. A two-piece cap, consisting of a round component and a pointer (to indicate flow direction) was then assembled with two hex-head cap screws and washers.

To eliminate expensive machining and reduce the number of components, a cold forging was designed that featured a blind spline and an integral cap with pointer—all in one piece. After cold forging the square stock with multiple "strikes," the only additional operation required was drilling a hole in the top. The customer then stocked the forging as a finished part.
CASE STUDY FROM THE FILES:

Forged aluminum ejector cut cost, provided critical dimensions

Forged from 2014 aluminum alloy, an ice-cube ejector for refrigerators held up where cast, powder metal, and plastic components just could not perform. The 1 oz. forging provided the required strength and critical dimensions needed to mesh with mating parts and function without water leaking, which would stop the icemaker from operating.

In the interest of cost savings, the manufacturer explored non-forging options. If water leaked and froze, the casting snapped in half under pressure when trying to push down and eject the ice cubes. It was the same result with both the powder metal (PM) and plastic versions. Although plastic and PM parts cost less initially, continual replacement of parts in the field was an extremely costly option and a short-lived one. The OEM certainly did not want its reputation tarnished. Forgings provided superior strength and unmatched service life. According to the forger, life cycle cost savings were significant.

Conventionally forged from 6 in. sections cut from 1 in. diameter 12 ft. long rods, the aluminum ejector was forged two at a time to maintain size and maximize die life. See figure. Flash was removed by clipping and, at the same time, a shaving operation was performed on the web thickness. The parts were then solution heat treated and aged to provide the required in-service strength and proper hardness for machining. Next, the forging went into an automatically fed saw that made two parts from one forging. Prior to vibratory deburring, parts were gauged to ensure straightness and thickness from one end of the part to another. After drilling and counter-boring of the center hole, the parts were clear anodized for additional corrosion resistance.

For proper function, the ejector had to meet stringent engineering specification, including a number of critical dimensions. For example, the pad diameters had to be accurate to prevent leading water and restriction of ejector movement. For the center pad, diameter was held to 0.798 to 0.810 in.

Web thickness also was critical in meeting assembly tolerances for mating parts. Essentially, the draft was shaved off, creating a straight wall. Excess thickness (0.095 to 0.085 in., as forged) was reduced to 0.085 in.

Even though dimensional tolerance of the forge was considered minimal for this part, secondary operations like shaving and automatic sawing hold critical dimensions to the close tolerances required.
CASE STUDY FROM THE FILES:

Switch from hard-to-get tubing to rolled ring cut lead time

Initially made of heavy-wall tubing, a small ring gear was delivered on a timely basis because it was converted to a rolled ring. Originally, the manufacturer was taking tubing and cutting it into cylindrical sections, which were then contoured. Unfortunately, the heavy tubing was not readily available, thereby extending the lead time beyond acceptable limits.

Fortunately, the manufacturer contacted a rolled-ring producer who could supply rolled rings in shorter lead times. Not surprisingly, price was competitive with tubing.

The initial conversion from tubing was a ring about 10 in. in diameter and 1 1/2 in. thick.

However, the forger was able to convert additional parts into rolled rings, using the same material for different sized parts. For the customer, who had previously bought a different size tubing for each different ring, this translated into an important benefit: inventory reduction. Additionally, the forger was able to further contour the forged ring and provide closer-to-finish tolerances than tubing. This addition generated extra cost savings for the customer by reducing the amount of material removed and machining time. See figure.