Learning Cold Forming Technology
—A Young Engineer’s Perspective

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Young engineers certainly have many challenges before them when confronted with learning cold forming technology. Presently, there is no definitive source material on the cold forming of fasteners. Much of what has been learned results from years of “hands-on” shop-floor experience. Once an employee retires, a vast amount of knowledge is lost unless the information is properly documented or passed on to another individual within the organization. For an engineer to become successful in the subject of fastener sequence and tool design, one must develop solid relationships with outside contacts, establish good rapport with both machine operators and tool room personnel and utilize sequence design and process simulation software.

Formal education provides a foundation for Design Engineers to develop their skills in the science of metal forming. Engineers are educated on manufacturing techniques, stress, strain, etc., but typically have no practical experience with actual metal forming. In today’s competitive market, young engineers must accelerate the learning curve in the practical aspects of fastener cold heading. Developing practical expertise begins with shadowing both machine operators and tool room personnel and conducting simulations via software applications to predict metal flow.

Understand Basic Design Rules, Machinery Capabilities & Material Selection

While machine operators and tool room personnel are busy with setups and production runs, the engineer can perform the necessary research to provide co-workers with the optimal forming sequences on new parts and improved tool design on troublesome jobs. The cold forming of fasteners is governed by some basic design rules. Break the rules and the penalty is tool fracture and part defects. Try and upset a part more than 2-1/4 diameters in one blow and the part will buckle. Trap extruding of steel beyond 75% area of reduction will lead to tool failure. Learning the fundamental rules of cold heading is the first step prior to designing the progression plan.

In conjunction with the basic design rules, the engineer must also comprehend machine capabilities. An optimal tool design may not be advantageous for the available equipment within a facility. When developing progression plans and tool designs, not all machine parameters are apparent such as maximum cutoff diameter, machine tonnage and minimum and maximum cutoff lengths. For example, a rivet with a short shoulder and tight tolerances necessitates the need for a solid die and special lubrication for the wire (Figure 1). However, using the special lubricant is not feasible on all heading machines because the wire coating clogs the oil lines. As an alternative, the part could be manufactured without the special wire coating, but small vent holes would need to be drilled in the solid die (Figure 2). Consequently, this design could lead to debris plugging the vent holes, resulting in under-filled parts from oil being trapped in the die. A small die insert could be used to form the short shoulder in a two-piece die, however this method is conducive to die separation from accumulating debris between the inserts during operation.

Also, the proper selection of tool steels must accompany all successful production runs. Recognizing the causes of tool failure is essential before modifying existing tool materials. Types of tool failure include wear, plastic deformation, catastrophic breakage and fatigue. If die inserts fail by chipping, opting for tool steel with increased toughness may remedy the situation. Choosing the correct interference fit between the die casing and die insert also improves the odds for achieving optimum tool life. A two-point variance in the heat treatment of tool steel can mean the difference in the tool failing during operation or being capable of producing the entire lot. Outside contacts, i.e., consultants and reliable heat-treat professionals, often provide valuable input regarding the appropriate design, surface finish and heat treatment of tool steels. Engineers who studied tool steel performance properties while in college are better equipped to communicate effectively with tool and heat-treat suppliers.

Effective Use of Design & Simulation Programs

Along with operator experience and consultants, software programs are excellent support tools in facilitating achievements in forming sequence and tool design. The interactive design program, NAGFORM offers a series of potential sequence designs to form a part. After choosing a feasible forming sequence for the available equipment, NAGSIM can be used to simulate and analyze the forming process. NAGSIM is a finite element analysis program that determines material flow and stress distribution in the forming tools.

Using design and simulation programs to reduce the number of shop-floor trials is one method to increase productivity and reduce tool costs. Many times after a die insert or punch fails, the tool cannot be reworked and tool costs directly affect company profits. The following examples illustrate the resolution of forming issues experienced at Brainard Rivet.

Eliminating Extrusion Die Fracture. NAGFORM and NAGSIM were utilized to avoid die fracture in the extrusion...
station on a transfer machine. Broken extrusion dies were a common occurrence during production runs for a particular fastener. The fastener had been produced using 0.344" (8.7 mm) diameter wire and double extruding in the first transfer machine station (Figure 3). The extrusion die insert was failing after producing only a fraction of the 100,000-piece lot. NAGFORM provided a series of alternate sequence designs to manufacture the part. NAGSIM was then utilized to simulate and analyze the metal forming process (Figure 4). The forming sequence was redesigned using 0.236" (6 mm) diameter wire with a single extrusion (Figure 5) and modifying the punch geometry in the second station. All of the subsequent 100,000-piece orders were produced without incident.

Maximizing Material Upset. NAGFORM and NAGSIM were also used to maximize material upset per heading station and for even distribution of the forces required to manufacture a part. Figure 6 represents the difference in pre-forms after revising the second punch for a transfer machine. Part B

Fig. 4 — NAGSIM metal forming process simulation/analysis.

Fig. 3 — Cut slug from 0.344" (8.7 mm) diameter wire (left) and double extruded blank from first station (right).

Fig. 5 — 0.236" (6 mm) diameter wire (left) with single extrusion (right) used in forming sequence redesign.
in Figure 6 clearly shows that more material has been deformed in the first blow.

Part B also displays good material flow lines that are necessary to avoid part defects such as surface laps that are formed in successive operations. Now, less material will be required in order to upset the head on the fastener.

The performance of the computer simulation indicates how far the punch must be displaced from the second die in a transfer machine. The machine operators can use this information to reduce the number of shop trials during a setup.

**Reducing Tooling Failures.** High tool costs, excessive machine downtime and loss of productivity are all results of failed tooling. For example, on a 125,000-piece lot at Brainard Rivet, ten die inserts were used to form the shoulder on a flat head rivet. Reducing the number of inserts from ten to two per order resulted from redesigning the punch and changing to tool steel with increased toughness. The new punch design yielded the pre-form seen on the right in Figure 7.

**Conclusion**

Engineers new to the field of metal forming are often eager to make improvements in fastener manufacturing. A team approach is essential during the development and implementation of both new and revised forming designs. Management, engineers and machine operators are all part of the solution.

With perseverance, novice engineers can bridge the gap between practical experience and the science of metal forming, and ultimately find their niche within the organization.

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