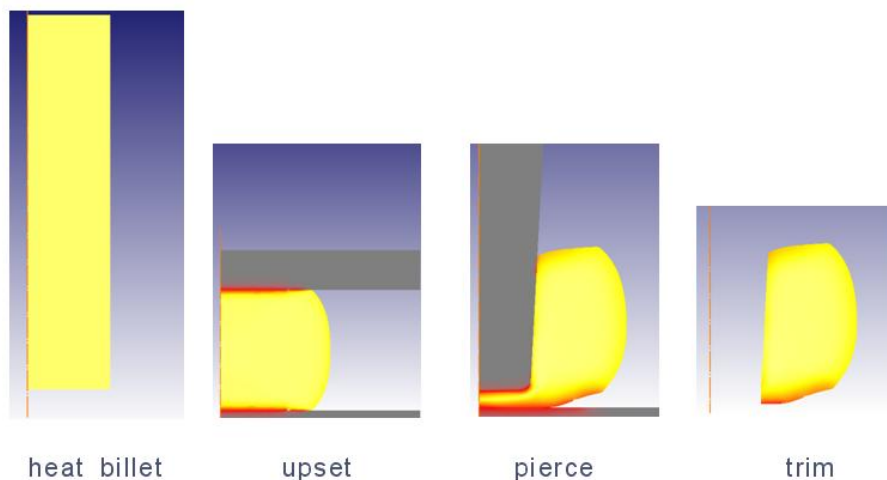


## Eliminating Coal Dust from Ring Rolling Preforms

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In December, 2009, a project was initiated by FIERF to study the elimination of coal dust from ring rolling preforms. Most ring rollers use similar processes to produce the blanks. This includes an upset, open die piercing and trim operation, as shown below.



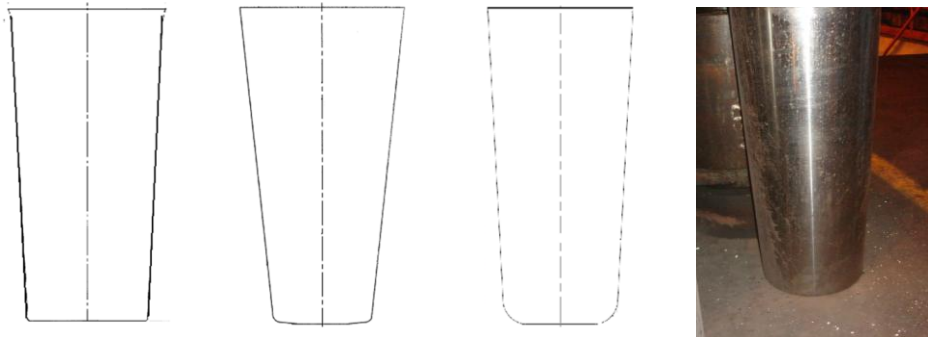
Since the process is essentially open die, removing the punch can be a challenge. Thus, companies have resorted to placing coal dust on the upset billet, which results in a forceful ejection process, as shown below.



Companies have worked on solutions to this problem for decades. In spite of this the majority of companies regularly use the coal dust.

A team consisting of FIERF, Scientific Forming Technologies Corporation, Ringmasters, Frisa and McInnes Rolled Rings was assembled to tackle the project. Other contributors included Bob Fullerton (consultant), A. Finkl & Sons, Bohler - Uddeholm and Case Western Reserve University. This team went through a process that included documenting the 'as is' process for two parts in each of the partner plants. Process simulations were run to identify the root cause of the problem. Multiple team meetings were conducted in person and over the internet to review in-process results and conclusions. New processes were developed, with redesigned punches. A trial, conducted at McInnes Rolled Rings in Erie, Pennsylvania on June 16, 2010, demonstrated that the improvements could produce blanks without coal dust.

The punches are generally produced from alloy steel, such as 4340. They are initially heat treated to a hardness of  $R_c$  40 – 45. Punch design varies by manufacturer, but all include a small to moderate taper on the major diameter. Face designs and corner radii cover a wide range, as shown below. A typical new punch is shown on the right.

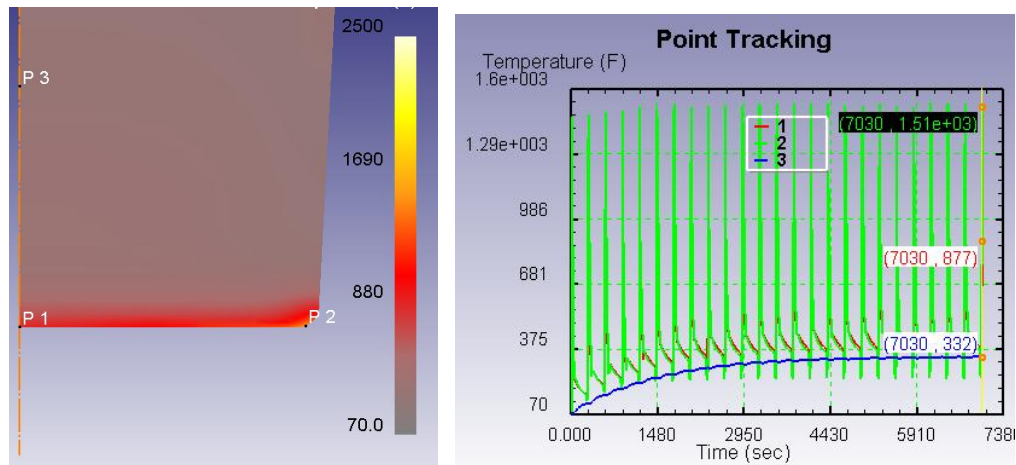


Punches fail by a combination of thermal fatigue, wear and plastic deformation, as shown below.

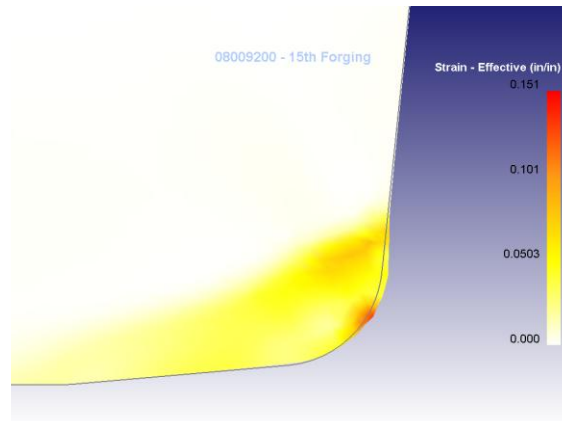


Computer simulations were run using DEFORM™-2D to model the flow, temperature profile in the punch and thermal cycle over a complete production run. Additionally, an elasto-plastic coupled simulation was run on the first and last production part to evaluate tool wear, stress on the die and plastic deformation. The analysis summary could easily consume a 100 page thesis, but will be abbreviated for the sake of this summary. Conclusions were as follows:

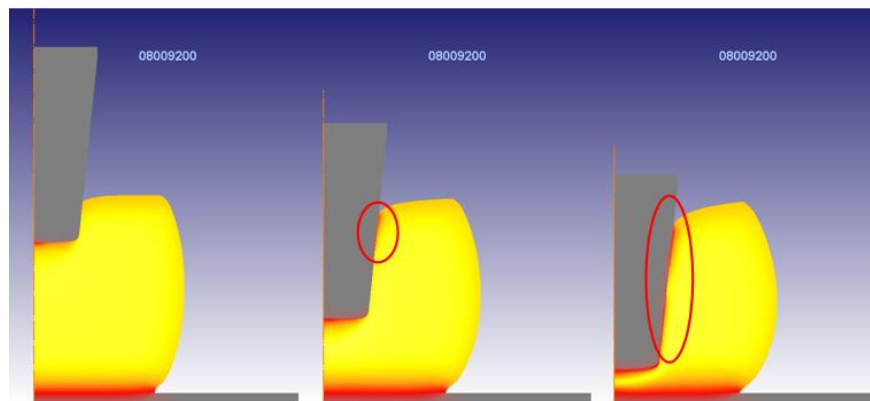
1. The punches are overheating due to extended contact time with the workpiece. Corner temperatures range from 1200 – 1600 degrees F as the punch is being retracted. This leads to severe tempering, resulting in a hardness of  $R_c$  27 – 30.



2. The punches are plastically deforming (yielding), as the strength at temperature of a fully tempered 4340 material is inadequate to withstand the forging pressure.



3. Die wear is high due to the low hardness, punch material and high surface temperature.
4. Tapered punches result in an enforced sticking condition. The punch nose starts the hole with its smallest diameter, to then, on its way into the part, getting bigger along the tapered punch. This starts a thermal shrink fit process, where the workpiece is shrinking (as it cools) and the punch is expanding (as it heats). This is illustrated below.



A range of changes were recommended by the team and contributors to improve the known issues.

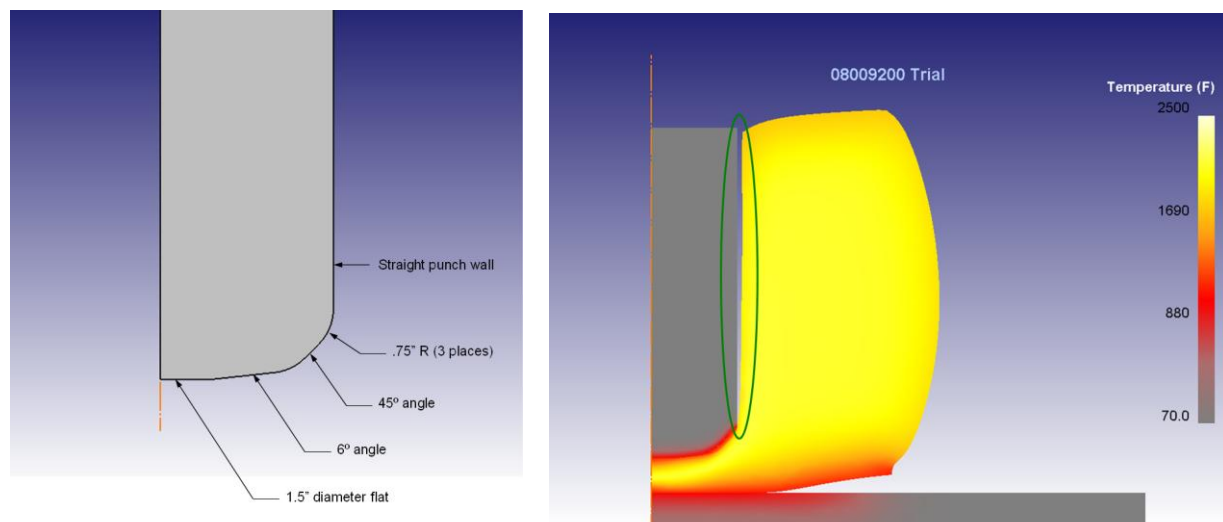
**Die material:** While the 4340 is inexpensive and readily available, it is not an excellent die material. Both A. Finkl&Sons and Boehler Uddeholm recommended alternate die materials, which will be more temper resistant. Unfortunately, the temperatures in excess of 1000 degrees F are fairly routine due to the extended contact time. Thus, the initial trial was run with Inconel 718 material. Follow-up trials will be run with tooling material supplied by that purpose, with an overlay of 718.

**Cooling:** When first evaluating the current processes of cooling within the project partners, it was found that the punch cooling practice was not universally adopted. It

was clear, that the temperature build-up had to be controlled for lubricant adherence. A dip cooling tank was fabricated for the trial.

**Lubrication:** Walter Zepf Spezialschmierstoffe, Konstanz Germany, developed a set of lubricants to test in this process. RZ 10, a water based graphite lube containing 5% graphite and RZ 20, also water based containing 20% graphite, were sprayed only on the bottom face of the punch, not even on its side walls.

**Punch design:** A significantly different punch design was proposed. The nose design was developed to maximize radial flow during piercing. Additionally, sharp corners were eliminated to minimize heat buildup, die wear and plastic deformation. Most importantly, the taper was eliminated. Multiple simulations run during the development phase showed that the primary sticking mechanism on the top of the punch was eliminated. The design elements of the new punch are shown on the left. The simulation showing clearance with the workpiece is shown on the right.



On June 16, 2009, an initial trial was run at McInnes Rolled Rings in Erie, PA. Two of the worst cases were tested to see how the new process would perform. It was reported that some of these worst case scenarios could result in sticking on a new punch during the first forging operation. It was further reported, that historically a partial hole was punched, then the punch was retracted and additional coal dust was applied in the pre-punched hole.

The trial, implementing new punch design, cooling and lubrication without coal dust was successful and no sticking or tendency to stick was observed. The trial was conducted on stainless steel blank material, a punching depth of 7.5 to 9.25 inches and a blank weight range of 400 to 900 lbs.



The initial trial was viewed as a success and preparations are in process to implement the findings of this project into production, especially the automation of cooling and lubricant application.