2018 FIA Theory & Applications of Forging & Die Design Topics

Forging Overview
Forging is a method of shaping metals and alloys into parts of useful shapes. It is an art that has developed over thousands of years. It is still developing. Because of its long history, many of the terms used reflect ancient practices, and some of them have lost their original meaning. Therefore, we will establish a common language by reviewing all forging processes for which dies will have to be designed.

Forging Materials
Forging can produce practically all important metals and alloys; however, there can be great differences in these metals' flow strengths and workability. Even for the same material, these properties may also greatly change according to temperature, strain rate, and the cleanliness of the material.

Forging Operations
Closed die forging, open die forging, extrusion, drawing, rolling, shearing and trimming are operations used in producing high-quality forgings. These operations have some similarities, but they also have significant differences. It is important to understand the design details associated with each operation.

Forging Equipment
Forging hammers, mechanical presses, hydraulic presses and screw presses are all used in forge shops. The behaviors and limitations of each piece of equipment are critical to know when determining which should be used for a job.

Factors Affecting the Forging Process
When a die designer receives a request for a die, they follow an extremely complex process in which a variety of factors are weighed, their interactions considered and, if necessary, several interactions performed to arrive at a solution. We will review some of these interactions and show how to quantify many aspects of die design.

Forging Defects
Geometrical- and material-induced defects can occur during forging. Geometrical defects can be corrected by changing the die design. Material defects can be minimized by forging under the right conditions.

Mechanical Behavior of Metals
The deformation of the workpiece may be expressed numerically by its dimensions before and after forging. The shape change and its effects are thus easily described by strain to which the material is subjected.

Stress Encountered in Forging
Flow stress is a fundamental metal characteristic of great importance. It is the stress that must be applied to make a metal deform plastically.

Predicting Forging Loads: Simple Upsetting
Often, approximate values for forging loads can be determined by assuming simple shapes for the workpieces. The upsetting of cylinders and forging of slabs with flat dies will be presented.

Predicting Forging Loads: Impression Die Forging
In forging, metal flow, die fill and forging load are largely determined by (a) the resistance of the forging material to flow, (b) the friction and cooling effects at the die-material interface, and (c) the complexity of the forging shape. These issues will be discussed.

Mechanical Fundamentals
Stress and strain are critical concepts in understanding how the metal behaviors under the influence of the die. At low temperatures, metals become stronger as more deformation is imposed. At high temperatures, the rate of deformation strongly influences the metal's resistance to flow. Die deflection is also dependent on the stresses generated during forging.

Physics Fundamentals
The concepts of force, energy, work and power are important in producing a successful forging and using forging equipment effectively. All these entities are related to each other, yet the way each can be harnessed within a forging operation needs to be understood separately.

Contact Fundamentals
The interface between the die and the workpiece is important for frictional resistance. Friction is a very powerful controlling factor in forging. Lubrication is often required to control the friction, reduce die wear, prevent welding and aid in part removal.

Thermal Fundamentals
Heat can be transferred by conduction, convection or radiation. All three modes of heat flow are present in a forging operation. It is important to understand the dominant mode, so that energy can be effectively used in heating the workpiece to the proper forging temperature.

Simulation Software
The current standard for metalforming simulations includes robust and thoroughly validated process models, which are fast, cost effective and relatively easy to use. Designers and engineers in even small companies can run simulations on their personal computers.

Forging Die Failures
Forging dies can fail in service. Such failures are undesirable. When a failure does occur, it is important that the root cause for the failure be found and the conditions for the failure be avoided or minimized in the future.

Preforming for Impression Die Forging
One of the most important aspects of impression die forging is the proper design of preforming operations and of the blocker dies. This helps achieve adequate metal distribution. Thus, in the finish-forging operation, defect-free metal flow and complete die filling can be achieved, and metal losses into the flash can be minimized.

Impression Die Forging
The die designer's goal is to produce a closed die forging at the lowest cost that has the physical and mechanical properties necessary to meet the customer's requirements. To attain this goal, the designer must consider those factors that govern metal flow and die filling, so as to produce defect-free parts with the required properties.

Die Block Design
Hammer and press die differences, die block sizes, die inserts, die shanks and holders, location of die stations and multiple impression dies are features that will be presented.

Trimming, Special Processes
In this section, we will cover plastic deformation processes that are not conventional forging in the strict sense, but are indispensable to the forging industry as a whole, such as shearing, trimming, piercing, bending, coining and hot padding.

Economics in Die Design
The cost of die materials is a relatively low percentage of the overall cost of sinking a die. Using a typical hammer as an example, the cost of the material for a new die is approximately 18 percent to 25 percent of the total cost. This means that you as a die designer have much control of over 75 percent of the cost of producing a die.

Effect of Shape on Forging Pressure and Die Filling
Most impression die forgings are of complex shape. In such complex shapes, smooth, proper metal flow and die filling are necessary for forging a defect-free part with the required mechanical properties.

Extending Die Life by Design
In order to satisfy demands for lower costs and shorter production preparation times, it is vital that we are able to predict the die life. This presentation focuses on the wear analysis of a closed die, and die design. In general, the possible causes of die failure in metal forming include catastrophic fracture, excessive bulk plastic deformation and wear.

Die Wear in Hot Forging
Die life in a forging operation is dependent on the mechanical properties of the die steel at the surface conditions. Properties of die steel, which determine their selection as die material for hot forgings, are the ability to harden uniformly, resist wear, resistance to plastic deformation, the ability to withstand shock and the ability to resist heat checking.

Guidelines for Precision Hot Forging
Economic pressures have forced even the most reluctant forgers to improve their present manufacturing techniques, so they can be cost competitive and maintain higher quality than rival processes. Reduced cost and increased quality of forgings benefit the forging industry, first by increasing profit margins, and also by helping to maintain markets or regain those lost in recent years.

Manufacture of Close-Tolerance Forging Dies
Forgings made in impression dies will be dimensionally accurate only if the finished cavity in each die half is the correct shape and if the two cavities are exactly aligned when the dies are installed in the hammer or press. In this section, we will consider only the first point: making dimensionally correct cavities.

Concurrent Part Engineering and Die Manufacturing
Class focus is on bringing tooling into design early to reduce lead times. Working concurrently with early part design to order and prep material, begin die design, machine parting lines and locks, rough mill impressions, and conduct early trim work, will provide the customer with a quality forging in a timely manner.

Problem-Solving Session
On the last day, the class will divide into small groups. Aided by an instructor, each group will review and tentatively solve an assigned die design problem.

Students are encouraged to submit a real-life problem from their company for the problem-solving session. A problem-solving report form will be sent to registrants in advance, providing an opportunity to submit a "problem" for consideration. A brief statement of the problem, material being forged, drawings of parts and/or dies, sample part (if size permits), and a description of effort (what has been tried that did not work) will be needed.