



# Theory & Applications of Forging & Die Design

- Process of Forging
- Factors Affecting the Forging Process
- Mechanical Behavior of Metals
- Stress Encountered in Forging
- Physics Fundamentals
- Forging Die Failures
- Mechanical Fundamentals
- Forging Equipment
- Forging Operations
- Simulation Software
- Die Block Design
- Impression Die Forging

## 48<sup>th</sup> Presentation

*The Theory & Applications of Forging & Die Design course continues to evolve, reflecting new insights into forging technology and the wide availability of metal flow simulation software. This four-day session is taught by a team of industry experts and engineering professors who work together to carefully explain principles and practices. More than 2,500 forging professionals have attended this course over the last 48 years.*

## June 6-9, 2016

1111 Superior Building • Cleveland

Register online at [forging.org/events](http://forging.org/events)

### Forging Industry Association

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# Course Overview

## Process of Forging

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.

## 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 iterations performed to arrive at a solution. We will review some of these interactions and show how to quantify many aspects of die design.

## 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.

## 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.

## 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.

## 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.

## 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 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.

## 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.

# Course Overview Continued

## 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.

## 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.

## 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.

**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.

# Registration, Location, Hotel & Schedule

## Fees and Required Materials

Tuition for Theory & Applications of Forging & Die Design is \$1,399 per student for FIA member organizations, or \$1,999 for non-member organizations. This fee includes class materials, instructor fees, lunch each day and a graduation certificate. **Lodging is not included in tuition** (see “Hotel Accommodations” section below for details). Students are expected to furnish a small, inexpensive calculator for use in class, along with a variable angle, scale and/or straight edge at least nine inches in length.

FIA will honor FIA member registrations first. Member and non-member students will be notified of acceptance on or before May 13, 2016. If FIA cannot accommodate non-member registration, the tuition fee will be returned. Please call the FIA office at 216-781-6260 if you have questions.

## Location

Theory & Applications of Forging & Die Design will be held in Cleveland in the building that is home to FIA headquarters. The building’s address is 1111 Superior Ave., Cleveland, OH 44114. The sessions will take place in the building’s fourth floor conference center.

## Hotel Accommodations

FIA has reserved a block of rooms for Theory & Applications of Forging & Die Design participants at the DoubleTree by Hilton Cleveland Downtown–Lakeside. The hotel is located at 1111 Lakeside Ave., Cleveland, OH 44114, a short five-minute walk from FIA headquarters.

Course participants must make their own hotel reservations. To reserve a room at the discounted rate of \$149/night, call 800-222-TREE and mention FIA, or use the following link:

[http://doubletree.hilton.com/en/dt/groups/personalized/C/CLELSDT-FI4-20160605/index.jhtml?WT.mc\\_id=POG](http://doubletree.hilton.com/en/dt/groups/personalized/C/CLELSDT-FI4-20160605/index.jhtml?WT.mc_id=POG)

**Reservations must be made by May 13 to secure the FIA rate.**

## Registration and Cancellation

Participants should register for the course by completing and returning the enclosed registration form. If necessary, phone registrations may be made with the FIA office, but payment must be received prior to the course start date. FIA will accept and confirm registrations by email on or before May 14th, honoring member requests first. Please do not make air or hotel reservations until you are notified by FIA of acceptance in the course.

Cancellation after May 13, 2016, is subject to the full tuition fee, which will be applied to the operation of the course. Substitutions within a company may be made, but FIA should be notified.

## Class Schedule

Check-in and registration will start at 7:30 a.m. on Monday, June 6. Instruction begins at 8 a.m. that day and each day thereafter, and ends between 4 and 5 p.m. The course ends promptly at 4 p.m. on Thursday, June 9. Attendance for all sessions is mandatory, so flight departures should be scheduled no earlier than 6 p.m. on Thursday. This course provides 27 hours of study and discussion.

## Arrival/Departure Times

Participants should arrive in time for check-in at 7:30 a.m. on Monday, June 6. Formal instruction begins at 8 a.m. Monday and continues through Thursday at 4 p.m. Please do not schedule return flights before 6 p.m. on Thursday, June 9. Taxi fare from Cleveland Hopkins International Airport to the DoubleTree by Hilton Cleveland Downtown–Lakeside is approximately \$40. Attendees can alternatively ride the Rapid Transit train from the airport to the downtown Tower City Station and call for a hotel shuttle at 216-241-5100 (based on availability).



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# REGISTRATION FORM

## REGISTRANT INFORMATION (\*denotes required information)

\*First Name: \_\_\_\_\_ \*Last Name: \_\_\_\_\_

\*Informal First Name (for badges): \_\_\_\_\_ \*Title: \_\_\_\_\_

\*Email: \_\_\_\_\_

## COMPANY INFORMATION (\*denotes required information)

\*Name: \_\_\_\_\_

\*Address: \_\_\_\_\_ \*City: \_\_\_\_\_ \*State/Prov.: \_\_\_\_\_

\*ZIP/Postal Code: \_\_\_\_\_ \*Country: \_\_\_\_\_ \*Phone: \_\_\_\_\_

## REGISTRATION FEES

### Extended Amount

FIA Member Organization \_\_\_\_\_ \$1,399.00 \$ \_\_\_\_\_

Non-Member Organization \_\_\_\_\_ \$1,999.00 \$ \_\_\_\_\_

Total Cost of Extended Items (U.S. Dollars) \_\_\_\_\_ \$ \_\_\_\_\_

## METHOD OF PAYMENT (all fees are due prior to the course start date)

☐ Check enclosed payable to FIA    ☐ Invoice my company    ☐ Credit card  
☐ Visa    ☐ MasterCard  
☐ American Express    ☐ Discover

Card Number: \_\_\_\_\_ Expiration Date: \_\_\_\_\_ Security Code: \_\_\_\_\_

Name on Card: \_\_\_\_\_

Email: \_\_\_\_\_ Phone: \_\_\_\_\_

## HOTEL ACCOMMODATIONS

Course participants must make their own hotel reservations. To reserve a room at the DoubleTree by Hilton Cleveland Downtown-Lakeside for the discounted rate of \$149/night, call 800-222-TREE and mention FIA, or use the following link by May 13:  
[http://doubletree.hilton.com/en/dt/groups/personalized/C/CLELSDT-FI4-20160605/index.jhtml?WT.mc\\_id=POG](http://doubletree.hilton.com/en/dt/groups/personalized/C/CLELSDT-FI4-20160605/index.jhtml?WT.mc_id=POG)

## CANCELLATION

Course fees are non-refundable after May 13, 2016, but substitutions are allowed.

☐ Yes, I plan to submit a problem—including drawings of parts or dies and/or the parts themselves—for study by attendees. FIA will forward a problem description form with confirmation.

**Return form to:** 1111 Superior Ave., Suite 615 • Cleveland, OH 44114  
Phone: 216-781-6260 • Fax: 216-781-0102  
Email: [lisa@forging.org](mailto:lisa@forging.org) • Web: [forging.org](http://forging.org)

