HOT FORGING:
TRENDS AND APPLICATIONS

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Outline

• Global Competition in Forging
• Improvement of Profitability
• Computer Aided Engineering
• Warm Forging
• Tool Design
• Forging Equipment
• Information Management and Training
Global Competition in Forging

- Forging firms from developing countries, especially China and India, have expanded globally by improving their technology and delivering cost-effective solutions.
- They also have an inexpensive and highly motivated labor force as well as support from their government in the form of tax breaks, free training, and a favorable foreign exchange rate.
Global Competition in Forging

• The forging industry of industrialized countries can only survive by:
  – reducing labor costs,
  – increasing material utilization
  – continually developing innovative designs
  – delivering assembly-ready components and/or sub-assemblies.
  – by maintaining a technological advantage over their competition.
Improvement of Profitability

• In hot forging, material represents 40 to 60 percent of total forging costs, depending upon the part complexity, material type and the production volume.

• Flash losses can be in the range of 30 to 60 percent.

• Quality is a must.

• Lead times and on-time delivery are major concerns.
Improvement of Profitability

- Increase material utilization (reduction of flash)
- Reduce defects and scrap rate
- Reduce die wear
- Increase utilization rate of forging equipment
- Process optimization by use of computer aided engineering (CAE) tools
- Increase automation and decrease labor content
- Efficient information management
- Training of personnel/access to advanced technology.
Computer aided engineering (CAE) helps to:

- develop die design and establish process parameters by a) predicting metal flow and final dimensions of the part, b) preventing flow induced defects such as laps and c) predicting temperatures (warm forging operations) so that part properties, friction conditions, and die life can be controlled.

- predict and improve grain flow and microstructure, reduce scrap, optimize product design and increase die life.
The accuracy of FE process simulation depends on reliable input data namely

- CAD data of the die geometry,
- characteristics of the forging equipment used,
- flow stress of the deforming material as a function of strain, strain rate and temperature in the range relevant to the process being analyzed, and
- friction characteristics at the interface between the deforming material and the die.
Determination of Flow Stress and Friction

- The cylinder compression test is widely used to estimate the material properties and microstructure of the forging material at room and elevated temperatures.

- Friction coefficient/factor can be determined by using the double cup extrusion test (cold forging) or the ring compression test (cold or hot forging).
CAE in Forging

• Double Cup Extrusion Test
  – The ratio \( H_1/H_2 \) is an indication of the magnitude of friction. When \( H_1 = H_2 \), the friction is zero.
• Double Cup Extrusion Test

Friction Factor Obtained For Different Lubricants

Friction Factor (m)

Mec Homat | MCI | Phoscoating | Daido

Lubricants Evaluated
CAE in Forging

- In the ring test, a flat ring-shape specimen is compressed to a known reduction.
- The internal diameter of the ring is reduced if friction is high, and is increased if friction is low.

![Diagram showing compressed ring and metal flow direction with low and high friction scenarios.](image)
CAE in Forging: Case Studies

1. Material Yield Improvement in Hot Forging
2. Prediction of Defects
3. Simulation of Heat Treatment
4. Microstructure Evaluation
5. Design Verification
Material Yield Improvement

- Hot forging of aluminum upper control arms:
  - Induction heating of forging stock.
  - Two stage hot rolling of incoming forging stock for material volume distribution.
  - Hot bending.
  - Blocker forging
  - Finisher forging
  - Trimming.
Material Yield Improvement

Billet
Rolled preform
Bent preform
Blocker forging (may be in 1 or 2 stages)
Finisher forging
Flash to be trimmed
Material Yield Improvement

- **Step 1:** 3D simulation of current billet preforming (reducer rolling) and forging operations to validate the FE simulation model of the forging process.

![3D simulation images]

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Step 2: 2D simulations at various sections/locations on the preform using the assumptions of plane strain/axisymmetric flow to optimize the shape & size of the preform and the design of the blocker die.
• **Step 3:** 3D simulation of sections which cannot be analyzed in 2D FEM using simplifying assumptions.
Material Yield Improvement

- **Step 4:** Final validation of the optimized preform shape and blocker design using 3D simulation of the forging process.

- **Step 5:** Forging trials with the new preform geometry and blocker die design.
Material Yield Improvement

- In this case study, material yield was increased from 71 % to 86 % by preform optimization.
- Additional 3-4 % improvement is expected by blocker die design to give a final yield improvement of 18 – 19 %.
Material Yield Improvement

- Hot forging of front axle beams (Ervasti et al, 2005):
  - The amount of flash obtained in production constituted 35% of the total workpiece weight, which was equal to 115.4 kg.
  - Using CAE, the material yield was increased by 2.5 to 7.6%.
The reducer rolls were redesigned to reduce the flash generated in production.
Prediction and Elimination of Defects

Chevron cracks in multi-pass forward extrusion

(a) 1\textsuperscript{st} pass  (b) 2\textsuperscript{nd} pass  (c) 3\textsuperscript{rd} pass  (d) Experiment
Simulation of Heat Treatment

Through FE simulation it is possible to predict microstructures and residual stresses (Walters, 2005).
We conducted orbital forging simulations using DEFORM-3D® to develop a robust assembly process for a wheel bearing. The same process can be applied to ring and wheel rolling.
FE modeling coupled with microstructure modeling was used to predict different grain sizes for Rene 88 (a nickel based superalloy) disks with a) coarse (ASTM 6), b) medium (ASTM 8), and c) fine (ASTM 12) grain sizes (Hardwicke et al, 2000).
Design Verification using FEA

Process simulation for an aluminum aircraft wheel (dia. $\approx 19$ in.) using FE simulation.
Principle of multiple action tooling with example parts

Courtesy Yamanaka
• Ceramic inserts are used routinely in hot forging applications where die wear is a major problem and the part shape is simple and axisymmetric.

• R & D is in progress to use ceramic inserts for hot forging of helical gears (Felde et al, 2005).
The DualDRIVE® design developed by Mueller Weingarten significantly increases die life in hot forging by reducing the die contact time.
Axial Closed Die Rolling

1. Upsetting

2. Axial closed die rolling

3. Tooth rolling (same machine)

F = axial rolling force
M = torque of lower die
$\alpha$ = angle of inclination of upper die towards vertical line
$A_t$ = total area of the workpiece
$A_p$ = forming zone when axial-closed-die rolling
$\Delta_t$ = reduction per revolution

Courtesy SMS Eumuco

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Automation in Hammer Forging

- Modern hydraulic double-acting hammers with blow energy control can be automated by using two robots resulting in improved part quality, reduce scrap rates, increase output and reduce labor costs.
Information Management

• Helpful for storing and retrieving data pertaining to:
  – tool designs,
  – changing tool materials,
  – product specification,
  – process instructions,
  – just-in-time jobs/rush jobs,
  – process control plan,
  – tool life tracking,
  – machine specifications and drawings,
  – press stress analysis,
  – engineering drawing management, and
  – dimensional control plans.
Summary

• Global competition will continue to increase.
• Continuous improvements are necessary for optimum resource utilization (material, equipment, personnel)
• Continuous training of personnel, and knowledge and application of latest technology are necessary to remain competitive.
• Cooperation with customers as well as with selected universities and research centers is helpful in keeping up with latest developments and trends.