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Forging Equipment Series – HAMMERS

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Forging Equipment – Hammers

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This will be the first in a series of articles in which various forging equipment types will be examined. The same general approach will be used for each type of equipment covered. First, a general overview of the equipment will be provided, including details about the physics associated with its operation. Simulation will be used to illustrate various points of operation that may not be directly observable during production. Finally, the conclusion will offer a brief overview of the advantages and disadvantages of each type of equipment. In this initial article the forging hammer will be covered. In future articles, we plan on examining mechanical presses, hydraulic presses and screw presses.

A forging hammer uses energy of a moving ram and a die to deform a hot workpiece. The process is similar to the physics of a hammer driving a nail into wood. The deformation speed in a forging hammer is quite high. The die movement is controlled by energy. Multiple hits are common for production forging operations in one die cavity. During a hammer "blow," the die is decelerating throughout the forging stroke as the energy from the moving die is converted into the work of deforming the workpiece. Once the energy has been converted into deformation, die movement halts. In many production shops, multiple die cavities are common.

Forging hammers are powered by gravity, steam and air. Figure 1 shows a typical forging produced on a hammer. Features observed in this forging are: multiple parts produced in a single platter, a significant amount of flash and a relatively modest forged-component size.

Figure 2 shows a schematic of a forging hammer. The ram and the anvil are the two components that hold the upper and lower die blocks. The power cylinder contains a piston, which is used to lift the ram to a specific height. The power cylinder can be used to supply extra energy to the forging process via steam or air. The piston rod connects the piston to the ram.

The Physics of a Forging Hammer

In a forging hammer, mechanical energy is used to lift the ram. Figure 3a illustrates this lifting process. When the ram is raised, all of the energy, which can eventually be used for deforming the workpiece, is stored in the form of potential energy. For a gravity-drop hammer, the potential

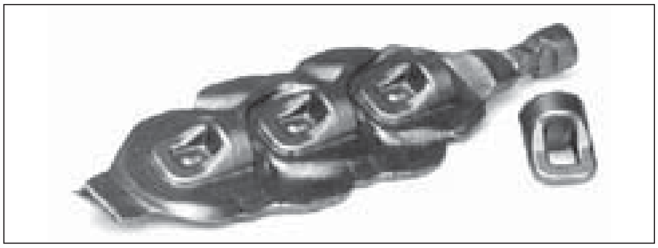

Figure 1. Typical hot forging produced on a hammer. Three components are produced in the single platter. One of the final forgings after trimming is shown on the right.

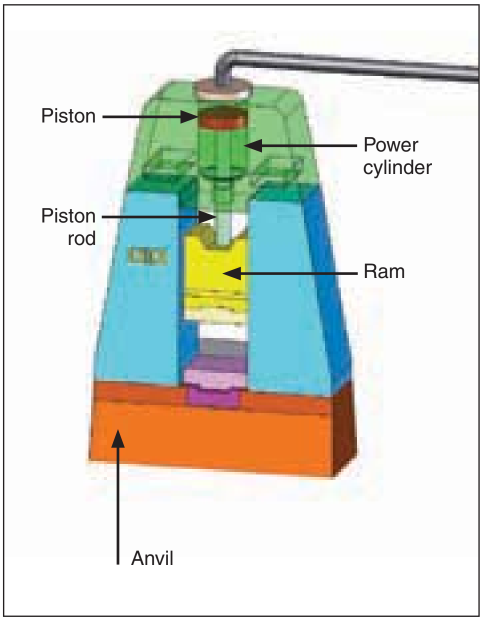

Figure 2. Schematic overview of a forging hammer

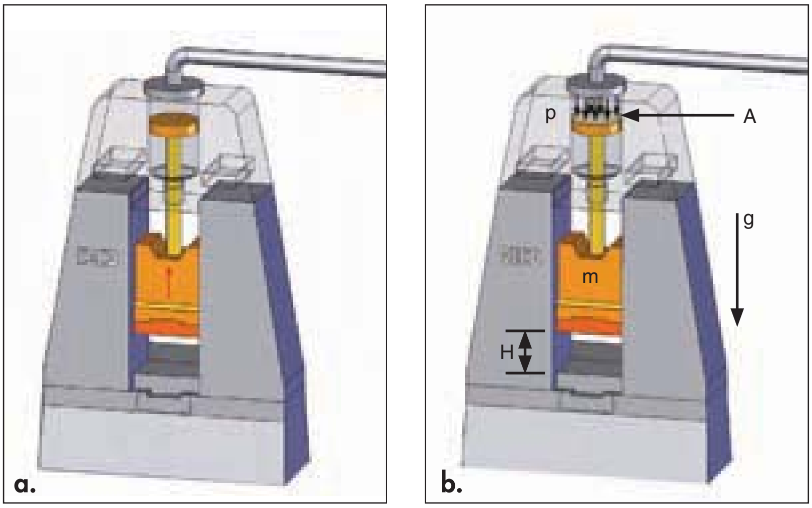

Figure 3. The energy associated with a hammer is initially in the form of potential energy as the ram is lifted as shown in (a). When the ram is released, the potential energy, which is equal to *mHg*, is converted to kinetic energy as shown in (b). In a power hammer, the energy can be augmented by *pAH*. When the ram strikes the workpiece, the kinetic energy is converted to deformation work and elastic stretch of the equipment.

energy is equal to the mass (m) times the drop height (H) times the acceleration due to gravity (g). Figure 3b illustrates these various variables, which contribute to the potential energy.

For a power-drop hammer the potential energy equals the mass times the drop height times the acceleration due to gravity plus the pressure on the piston (p) times the area of the piston (A) times the distance (H). It should be noted that "p" in a power-driven hammer is always less than the supply pressure. The exact value depends on the design of the hammer, the size of the fluid passages, any backpressure in the exhaust line and the acceleration of the piston, but it usually ranges from 40-50% of the supply pressure. When the ram drops, the potential energy is converted into kinetic energy. When the ram hits the workpiece, all the energy is kinetic and is equal to one-half times the mass times the velocity squared ($\frac{1}{2}mv^2$). The kinetic energy of the ram is converted into deformation work in the workpiece as well as elastic strain in the hammer components.

Simulated Operation

Figure 4 shows the simulation of a hammer forging in a single cavity. The ram velocity and the forging load are shown at each point of the process. This simulation is for a five-blow process. The ram velocity reaches a maximum at the point of contact with the workpiece. The ram quickly decelerates as the kinetic energy is converted to deformation work. As shown in Figure 4, it takes several blows to fill out the cavity and produce the forging. Note that the forging load is highest for the last blow in the finisher impression.

Figure 5 shows a multiple-cavity forging simulation. For this simulation there are two blows in the first cavity (the roll), four blows in the second cavity (the preform), three blows in the blocker cavity and finally a single blow in the finisher cavity. Note that the two preforming cavities are located near the edges of the die and the two final cavities are in the center. This configuration is due to the forging loads for the preform operations being much lower than the loads required in the final cavities. Such an arrangement of cavities in the die block makes the die less likely to fracture by catastrophic overload failure.

Other Features and Effects of Hammers

Elastic-Energy Dissipation

Elastic energy is dissipated in the ram, anvil and dies. This energy is not recoverable for doing further work and is thus lost as inefficiency. Small forging loads relative to the equipment size result in little lost energy – high efficiency. This condition matches the high efficiency observed in buster, upset or draw operations. Large forging loads result in much lost energy – low efficiency. Such low-efficiency conditions are observed in large finisher operations, a chilled forging workpiece or material with high flow strength (i.e. stainless steel). Off-center loading and deflection of the piston rod can also result in lower efficiency.

Advantages and Limitations of Forging Hammers

Advantages

- The die/workpiece contact time is shorter than for other equipment, which causes less die chilling of the workpiece.
- Thickness control is very good, since the thickness is a direct consequence of the die design.
- Small hammers can generate relatively large forces.
- Thin parts can be forged on hammers.
- The thickness of the trim lines in a hammer-forged platter is relatively small, which reduces the shearing load needed in the trim press.
- Preforming can be done on the die in hammers, whereas other forging equipment requires that preforms be done outside the press.

Limitations of Hammers

- They are not used for long extrusions.
- Hammer dies do not have knockouts, so low draft angles are not easily accommodated.
- The automation of a hammer operation is not typically practical.
- Hammer operation is normally a 100%-manual operation for the movement of the workpiece onto and off of the die as well as between the cavities on the die.

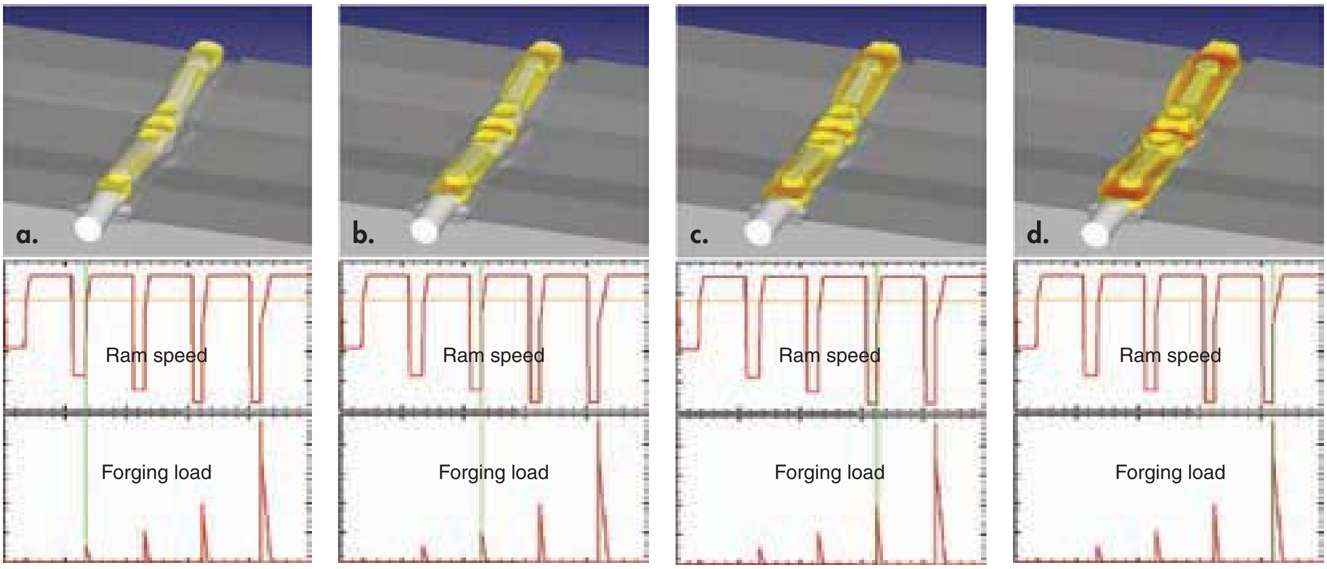

Figure 4. Simulation of a multiple hammer forging: a) after the second blow; b) after the third blow; c) after the fourth blow; and d) after the fifth and final blow. Note that the forging load increases with each subsequent blow, but that the distance that the ram moves during the deformation of the workpiece is smaller. The energy is the same for each blow.

Programmable Control of Hammers

Programmable hammer control can be used to control the energy imparted to the workpiece. The impact velocity – energy – is controlled through the timing of control valves. The deceleration during forging is controlled by the workpiece, material, temperature, die design and process conditions. Blow rate can also be controlled in modern programmable hammers. For these programmable hammers, it should be noted that the bottom position of the ram is fixed due to the die design; likewise, the forging thickness is determined by the die design.

Manual-Controlled Hammers

In manual hammers, the impact velocity is controlled through drop height in gravity hammers and by operator's control linkage in steam hammers. Blow rate is relatively fixed in manual machines and is related to the drop height or the regulation of the air or steam pressure in a power-drop hammer.

Potential Forging Defects on a Hammer

If a hammer is not operated properly there is potential for forging defects to occur. A mismatch between the top and bottom dies will produce improper forgings. Tapered forgings can occur if the die closure is uneven. Although the thickness of the forging is a direct result of the die design, there can be some thickness-control issues due to process variability. Hammer forging can lead to cold shuts.

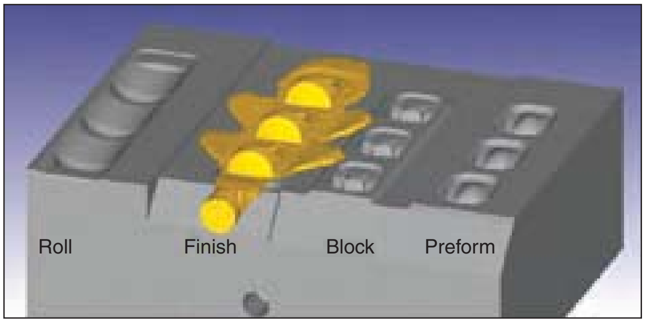

Figure 5. Simulation of a multiple-cavity hammer forging. There are multiple blows in each of the cavities.

Because of the high deformation speeds in hammer forging, laps can occur more readily. Also, other high strain-rate-related defects could occur in hammer forgings.

Summary

Forging hammers are versatile pieces of equipment used in the production of a wide variety of forgings. They are energy-based, so tracking the energy during each step of the operation is key to understanding their operation. Hammers operate at high speeds but with minimal contact time between the workpiece and the dies. Most hammer dies have multiple cavities and require multiple blows to produce the forging. Although programmable hammers exist that can control the energy of a blow, manual movement of the workpiece on and off the die as well as between cavities is the normal mode of operation.

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