T013: Hammer Stiffness Calibration

Introduction

This document explains how to determine a suitable stiffness value for a specific forging hammer.

Problem Description

Die movement on a forging hammer is said to be "energy-controlled". Each blow starts with an initial kinetic energy and ends when that energy is consumed. Not all of the energy goes into deforming the workpiece, though. Some is lost to inefficiencies in the system, which include friction and elastic deflection of the dies, ram and anvil.

DEFORM movement controls directly affect how much deformation takes place in hammer forging simulations. Energy and mass inputs are obtained from equipment specifications or simple calculations. These do well to define the initial energy. Yet, energy losses must still be accounted for in some way.

A common approach is to use the efficiency input to account for all energy losses. With this method, efficiency must be manually adjusted in each operation based on hammer size, part size and estimated forming load. For example, a large (stiff) hammer can forge a given part more efficiently than a smaller one. The use of a constant efficiency is unlikely to produce consistent results, as different forging processes require different efficiency settings, even though they are run on the same hammer.

A better approach incorporates a constant stiffness input that accounts for the variable inefficiencies, such as deflection. Stiffness calculations assume that the hammer system acts as a simple spring, where displacement and energy (loss) increases as load increases. A constant efficiency input is then only used to account for the constant inefficiencies, such as friction. The benefit of this approach is that each hammer in your forge shop can be characterized by its own stiffness and efficiency constants.

Solution

The appropriate hammer stiffness constant can be determined by using a practical correlation method. Before proceeding, it is of utmost importance that the user first confirms all other major process variables (temperature, material, friction, etc.) through correlation. Special attention should be paid to accurate

temperature, due to its' influence on flow stress. Failure to confirm the proper process variables will result in an inaccurate stiffness and efficiency values.

Stiffness characterization involves running a series of identical simulations using different stiffness values. Each simulation should model the entire hammer forging process, for example from bust to finish. The predicted shape and the number of "working" blows can then be compared to actual results. The ideal stiffness value is the one that produces the best match to reality, in both shape and blows.

The procedure is as follows:

1. Choose a forging job to use for the calibration testing. Collect relevant process information during the forging run. Information should include the blow energy, number of blows, temperatures, time between blows and transfer times. Photos of the actual parts output from each operation is also required. Dimensions measuring the final part thickness are helpful.

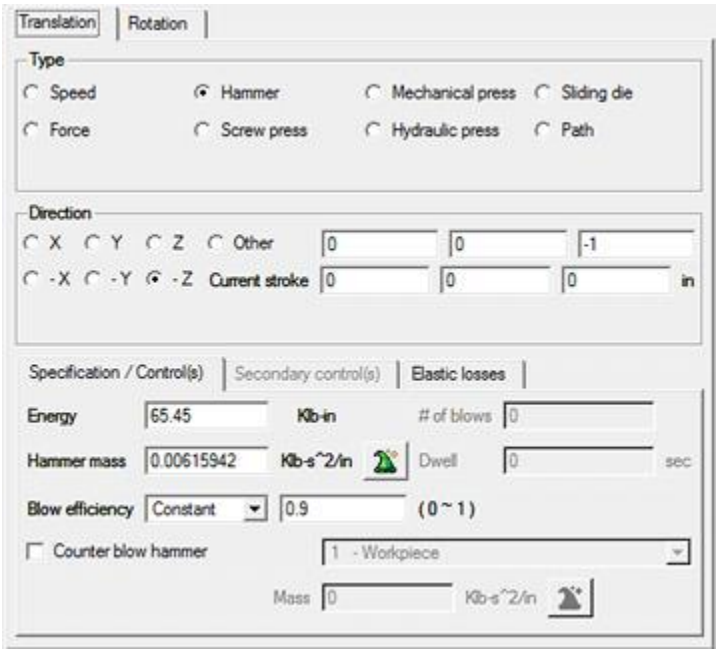


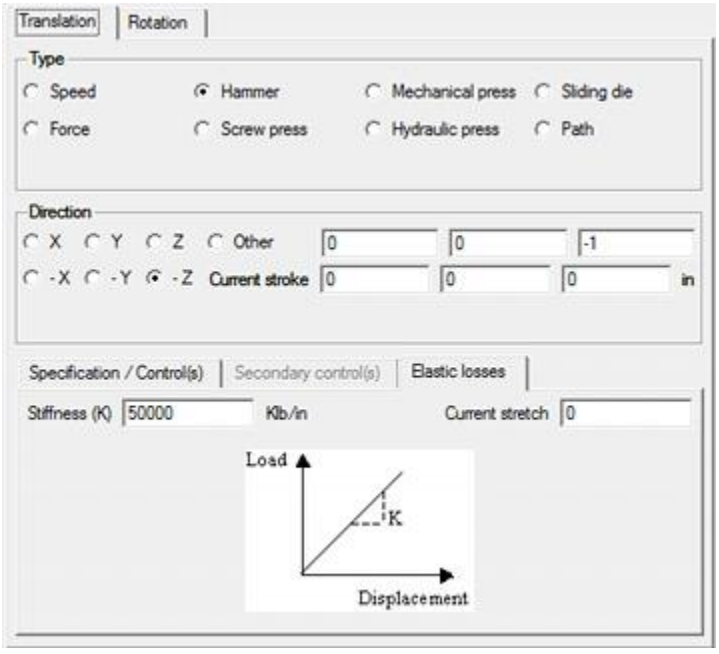
2. Create a DEFORM simulation using the most accurate input information that you have identified. Include all heat transfer operations, such as transfer time from the furnace to the press. Temperature is the most critical consideration so make sure the temperature of the workpiece going into the first operation matches the measured temperature from the shop floor.

3. Set up the forging operations with the following hammer movement controls:

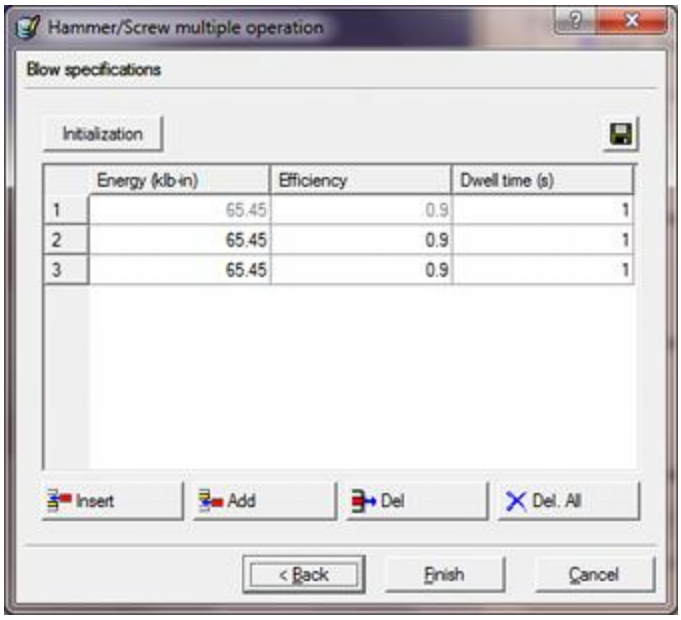
- Specification/Control(s) tab
    - Energy - From hammer specs or calculated (ram weight x drop height)

    - Hammer mass - Mass of ram and attached die
    - Blow efficiency - Assume to be 0.90 or 0.95 (your preference)
- Elastic losses tab
    - Stiffness (K) - Adjust accordingly (try an initial value of 30,000 Klb/in [3.39x109 N/mm])





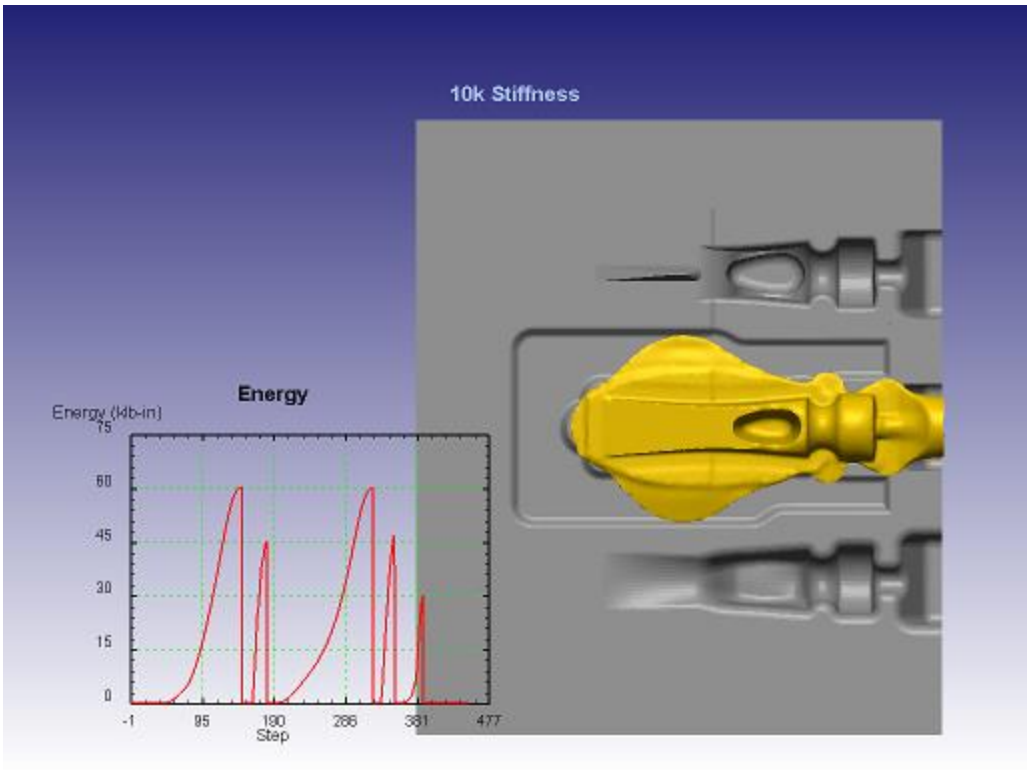
4. Set up each forging operation to run the same number of blows as experienced on the shop floor. Specify an appropriate time between blows. A time of one second is often suitable.



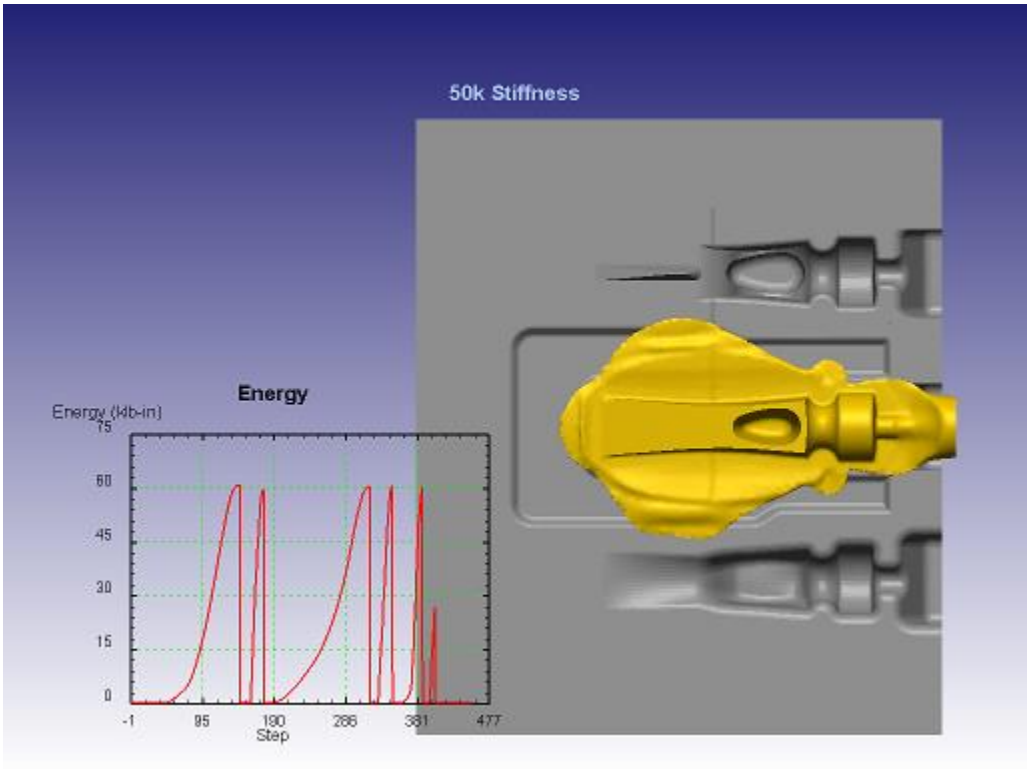
5. Run the entire sequence of forging and heat transfer operations. Be sure to simulate transfer time between operations.

6. Evaluate the simulation result by comparing it to the physical parts. Compare the amount of fill, die closure and number of "working" blows for each operation. The following are some questions to consider. Does the simulated part fill to the same extent as the actual part? Does the amount of flash look similar? Do the specified number of blows deform the part too much or do they fail to deform the part enough? Were there any "non-working" blows in the simulation? Those would be blows where a stopping control (fully closed dies) had been reached during a prior blow of a particular operation.

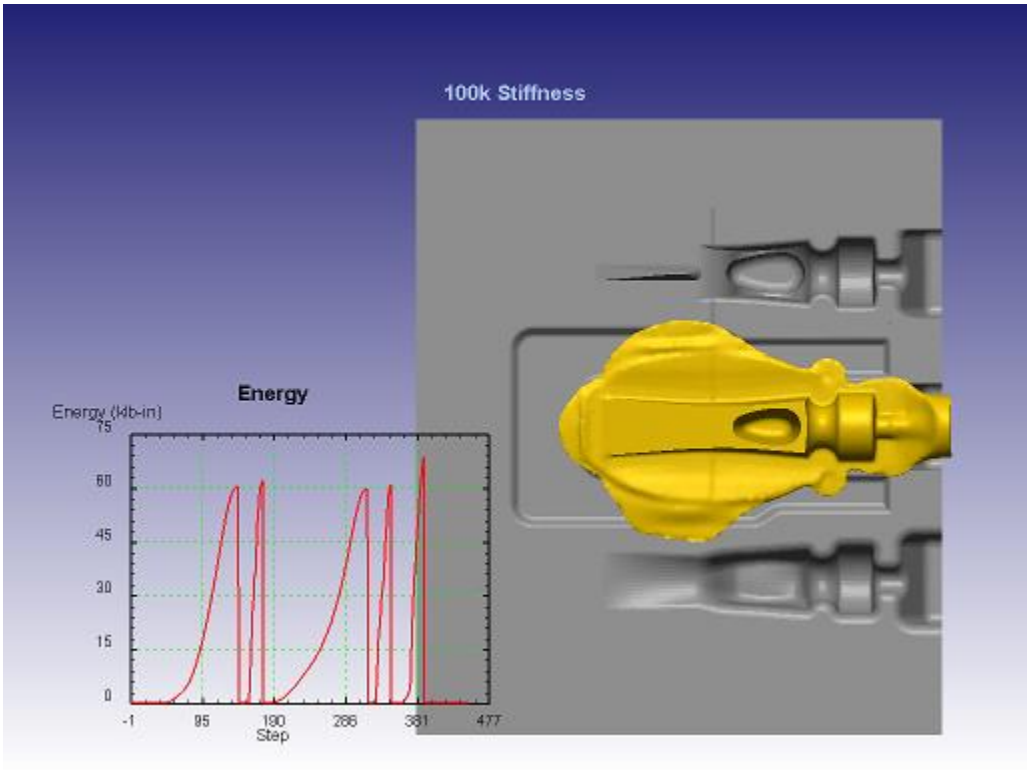
7. Adjust the stiffness value accordingly and repeat the simulation procedure. Leave all settings the same as in steps 2-5, except for stiffness. If the part was fully formed in too few blows, then the hammer was defined too stiff and the stiffness should be adjusted lower. If the part was not fully formed after all of the blows, then the hammer was defined too soft and the stiffness should be adjusted higher. Repeat this procedure until you have identified an ideal stiffness value.


10k Stiffness
Energy
Energy (kb-in)
75
60
45
30
15
0
-1
95
190
286
381
477
Step

Simulation results at a low stiffness (above) predicted insufficient fill and flash over the target number of blows. The graph displays the energy consumed by plastic deformation of the workpiece. The last blow does not appear on the graph because it produced no workpiece deformation. Stiffness was set too low in this iteration.

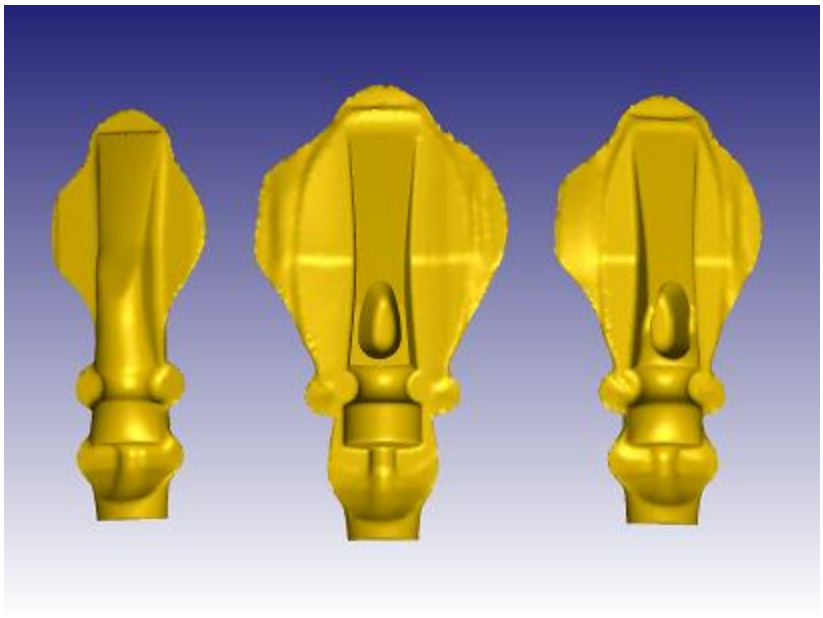


Simulation results at a moderate stiffness (above) predicted fill and flash that matched physical parts well. The target number of blows were all run and produced deformation. Stiffness was ideal in this iteration.



Simulation results at a high stiffness (above) predicted too much fill and flash. The final blow was not run because the finisher dies closed one blow too early. Stiffness was too high in this iteration.

The ideal stiffness has been determined when you find a value that provides proper flow, fill and flash in the same amount of blows as experienced on the shop floor. The simulated results should match the actual results well in not only the finisher operation, but all operations. Once the ideal stiffness has been determined, it can be used in all future simulations for jobs that run across this particular hammer. The results of subsequent jobs should also match well if the ideal stiffness value has been properly calibrated.



Example courtesy of Vaughan & Bushnell Manufacturing Co.

Related Information

Please see the following references for more information on hammer forging equipment.

- *Forging Power Diagrams: The Common Denominator*. Bulletin 236-L. Chambersburg Engineering, 1983.

http://www.ajax-ceco.com/applications/documentlibrary/documentlibrary_docs/Forging_Power_Diagrams.pdf

- Altan, Taylan, Gracious Ngaile, and Gangshu Shen. *Cold and Hot Forging: Fundamentals and Applications*. Materials Park, OH: ASM International, 2004. Section 11.4.

http://www.asminternational.org/portal/site/www/AsmStore/ProductDetails/?vgnextoid=bca25860ae0f8110VgnVCM100000701e010aRCRD