Reducing Time to Manufacture Cold Formed Parts with Process Design and Simulation Software

In today's competitive market, a company not only needs to have the expertise to manufacture a formed part at the lowest cost but also the ability to manufacture it in the shortest possible time. The total time taken from the day an order is received to the time when a defect free product is delivered to the customer is critical. In many instances, it decides whether a company is going to get the order or lose it to its competition that can produce the part in a shorter period.

The total time to manufacture a cold-formed part consists of time taken for many different tasks including entering the order in part management system, creating forming sequence design, design tooling, manufacture tooling, produce sample parts for approval, inspection and final debug of the manufacturing process to start producing the parts. Any nonconformity to part specifications can add further time to resolve the issues.

This paper discusses some of these tasks including forming sequence design, design of tooling and debugging the process and tooling design. The total time varies depending upon the product but as an example, if it takes 12 weeks to produce a cold-formed part, the tasks of sequence design, tooling design and debug may take one weeks. This paper presents an approach of automating the tasks that can reduce this portion of the time from one week to one day.

Take a hypothetical scenario that the designer can work with the speed of a computer with parallel processing capabilities. Then he/she may take only 2-3 hours to create the sequence design, design the tooling, prepare the drawings, perform simulation and make changes as needed. It is unlikely scenario but what is possible is that in future we have a computer software program that is taught to perform designer's tasks at electronic speed. Our company, Metal Forming Systems, Inc. continues to extend its design and simulation software programs towards the goal of reducing the time from one week to 2-3 hours. Let us look at individual tasks and see how the time taken can be shortened using the software tools MFSI provides to its customers for process design and simulation.

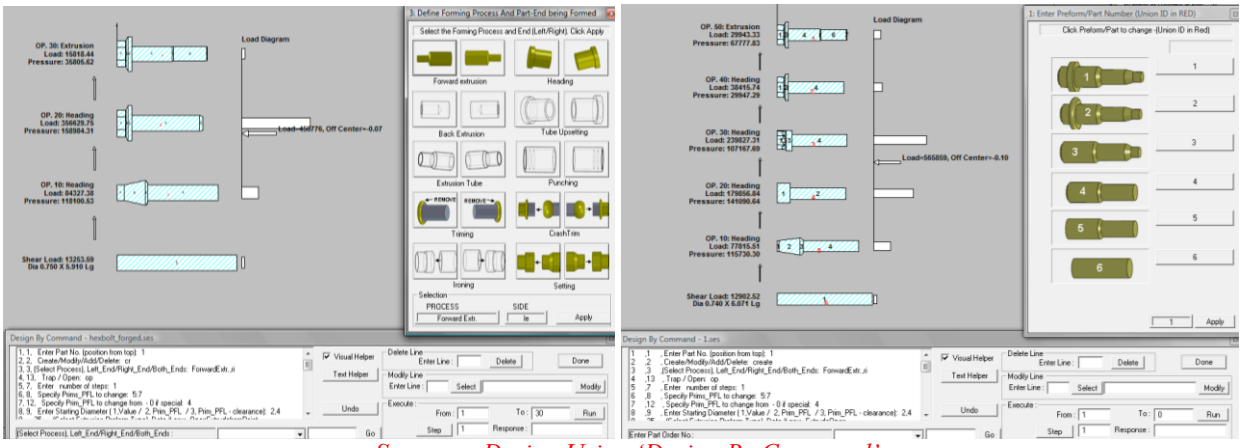
Standardizing and Automating Sequence Design Using 'NAGFORM'

'NAGFORM' is a unique program for determining forming sequence for cold, warm or hot forged parts. Like a designer, it utilizes the forming rules and design logic to create alternative ways of forming a part. 'NAGFORM' has a design procedure called 'Design by Command (DCM) that allows the designers to create their own forging sequence design through an interactive question and answer session. In a way, the designer is telling the program how to design a part. Once the session is recorded in a file, forming sequence design for any similar part with different dimensions can be automatically calculated by the NAGFORM program. The program checks that the sequence design is within the forming rules. If the design is not within rules, it informs of the deviation. The drawings can be automatically created in AutoCAD DXF format and SolidWorks 3D models.

The time to create a sequence design using DCM is less than 1/10 of that taken to create the design manually. For a Spark Plug, if it took, say, 4 hours to create a sequence design manually, it would takes less than 15 minutes with DCM procedure in NAGFORM. The added advantage is that DCM reduces the level of design expertise required of the User. By following the same rules, it always gives the same design irrespective of who is designing and there is no human error in calculations.

'Design by Command' (DCM) is ideal for automating and standardizing forging sequences of product lines such as Fasteners (Standard and Specials) such as Hex bolts, rivets as well as cold formed parts such as spark plugs. The procedure to standardize and automate the sequence design with DCM is quite simple. Divide the parts into groups or families of parts of same shape. If the same part family is manufactured using different forging sequences, further divide into subgroups so there is only one sequence design for a group/subgroup. Using DCM, create a template session file for each forging sequence. To create sequence design for any part with different dimensions, use the template session file of the group to which this part belongs.

There is some effort to divide the parts in ‘Groups’ and create DCM templates. However, the advantages of automating sequence design in terms of saving of time and effort far exceed the time spend to develop. The pictures below show examples of DCM procedure to create sequence designs.

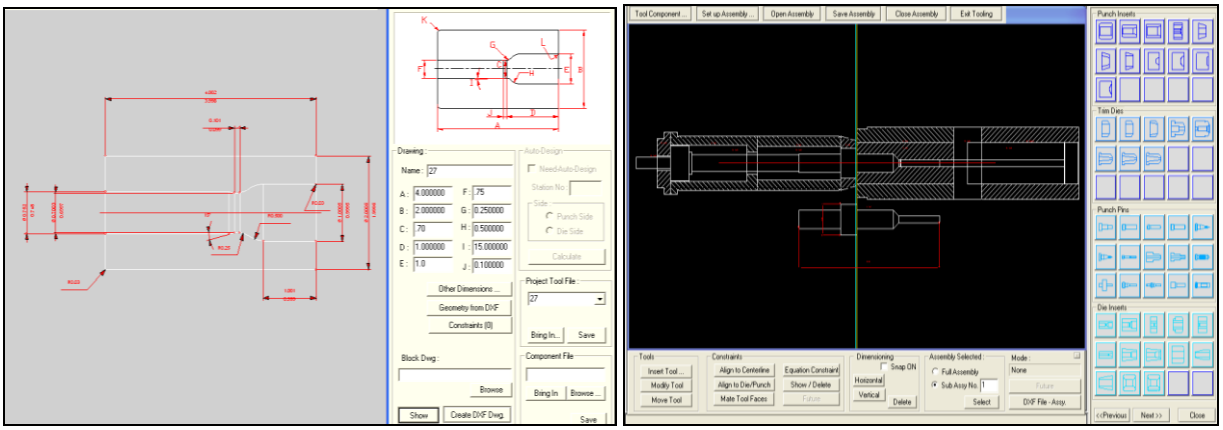


Sequence Design Using ‘Design By Command’

Automating Tooling Design Linked To Progression Design

Once the forging sequence design is automated, it is possible to automate the tooling design based on the sequence design. Because the tooling design requires drafting, plotting and other capabilities that are already available in most 3D CAD system such as SolidWorks, Metal Forming Systems, Inc. is developing the automated tooling design in partnership with a 3D CAD system. The automatic tooling design will be linked to the progression design of NAGFORM program so that as the part dimension changes, the design of the tooling components will automatically change based on certain rules/constrained set up by the designer.

In the absence of a fully automated tooling design system, there are other ways to reduce the time taken for tooling design. In NAGFORM program, templates of some of the standard tooling components are available. The User has to put in only a few dimensions and the program creates dimensioned drawings of the tool within seconds. So the time taken for creating individual dimensioned drawings of the tooling components can be reduced from say ten minutes to one minute.



TOOLING AND ASSEMBLY DESIGN

Simulation Software Linked to Progression Design Software

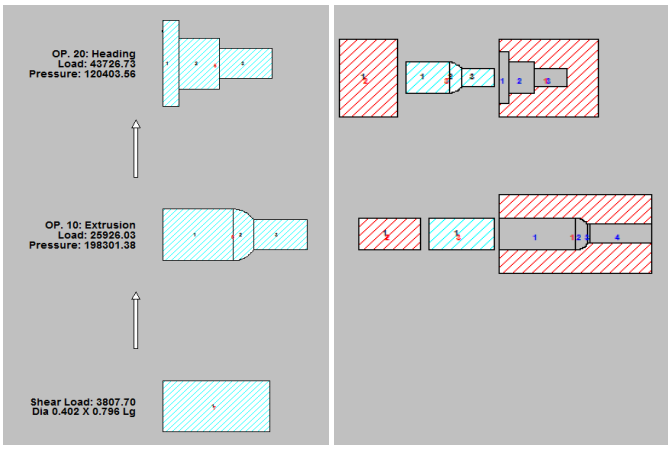
Though it is not essential to perform FEA simulation each time a new progression/ tooling design is created, users who are proficient in simulation software would normally perform simulation of the forging sequence. Especially

for new parts, simulation of the forging sequence operations before building the tooling can cut the part development time to half or less. In some cases, where the progression design had basic flaws, forging simulation can be the saver. Even for standard part, simulation can point out mistakes made in progression design or in dimensions of the tooling components.

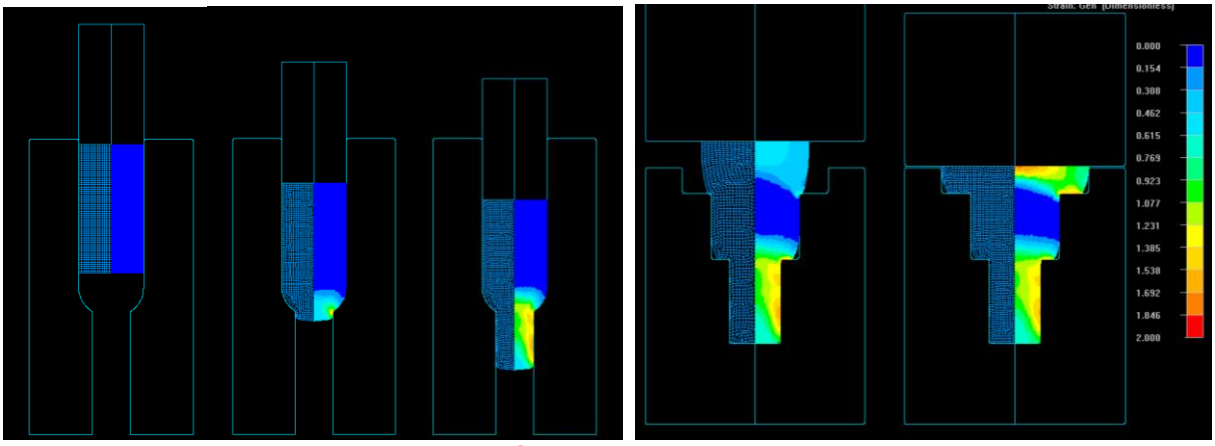
Simulation of two-dimensional forging processes (round or long parts) is very simple. The set up time for creating an analysis file is very small as templates of multi-station operations are used. The run time to perform a 2D simulation of multi-station operations is small and it is getting shorter due to the increasing computing power of new multi-core PCs. Most of the designer's time taken to perform a 2D simulation is in preparing the DXF drawing of the multi-station tooling. Another hindrance to performing a forging simulation is that, some times, the person who wants to perform simulation is not proficient in making tooling drawings.

To reduce the time and effort required to perform a 2D simulation using NAGSIM.2D simulation software, MFSI has developed a direct link between its Progression Design Software (NAGFORM) and its simulation software NAGSIM.2D. The current version of NAGFORM program automatically creates analysis file for NAGSIM.2D for 2-3 operations. Next version of NAGFORM program would automatically create a DXF drawing of default tooling from the progression design and also create the analysis file for NAGSIM.2D simulation software for up to five operations.

The example below shows a simple part and its progression design created in NAGFORM program. The analysis file for NAGSIM.2D simulation was automatically created in NAGFORM in less than a minute. The results of the NAGSIM.2D simulation are shown below.

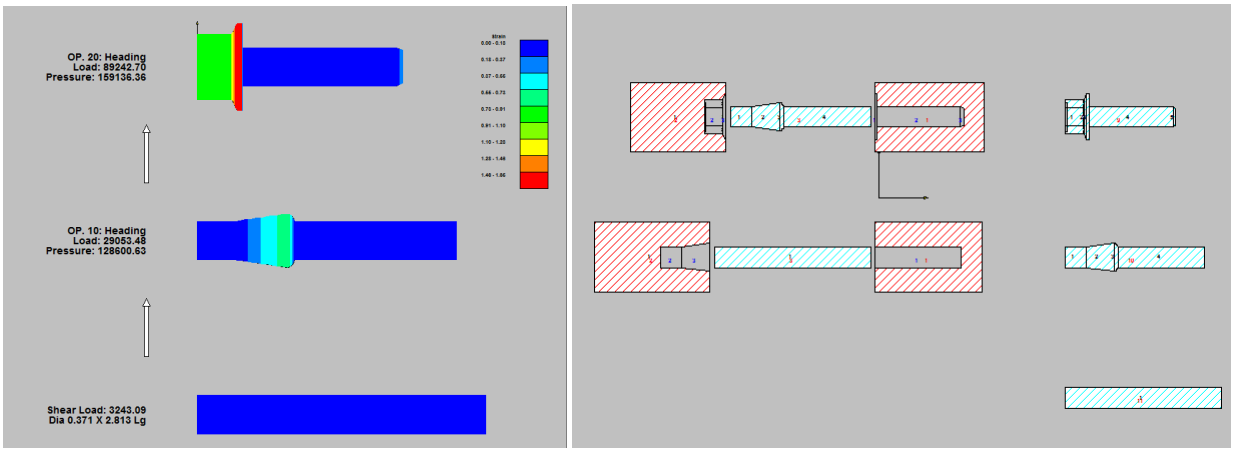


Sequence Design And Default Tooling



Simulation Using NAGSIM.2D

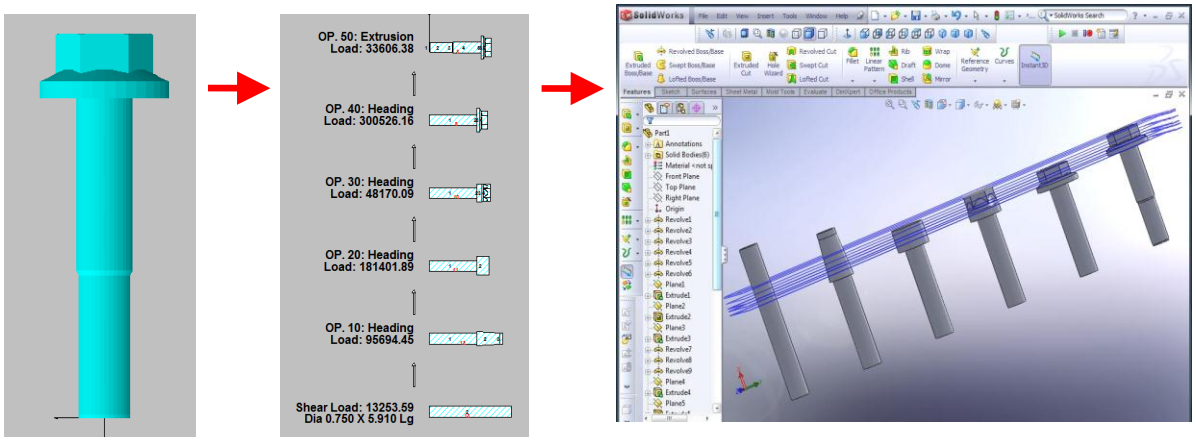
Regarding simulation of the sequence design involving three-dimensional forging processes, the NAGFORM program can create the default tooling drawing, as shown below, for the part shapes created in the program using its primitives.



Hex Progression and Tooling Using NAGFORM

However, this 2D drawing can not be used for 3D simulation in NAGSIM.3D for which 3D CAD models of the part and tools are required. There is considerable time and effort required for creating 3D CAD models of the tooling. In addition, there is a long run time for a 3D simulation.

To reduce the time to prepare 3D CAD models of the default tooling, MFSI plans to create an interface program between NAGFORM and SolidWorks so default tooling is created automatically in SolidWorks.
This would be similar to what has been done to automatically creates the 3D CAD models of sequence design of NAGFORM in SolidWorks

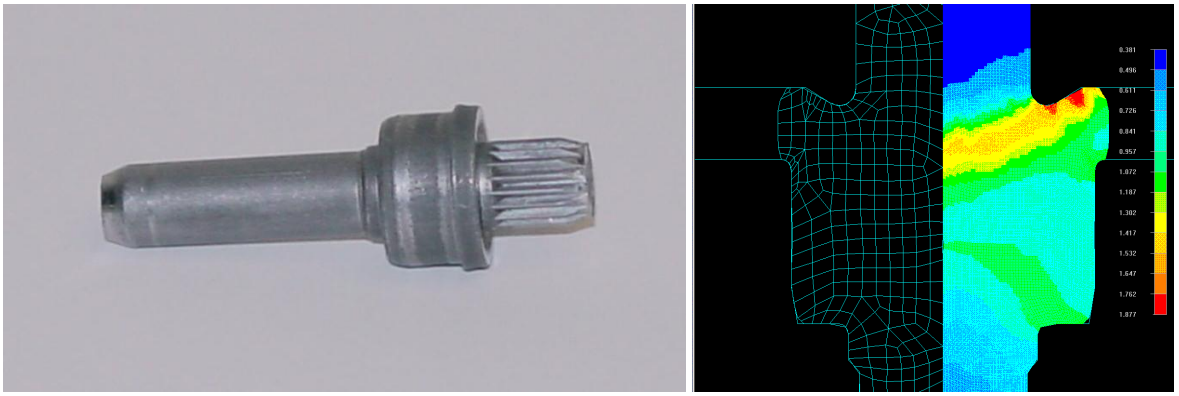


PART MODEL | **SEQUENCE DESIGN USING NAGFORM** | **AUTOMATIC CREATION OF MODEL AND SEQUENCE DESIGN IN SOLIDWORKS**

Simulate To Reduce Time to Manufacture Defect Free Part

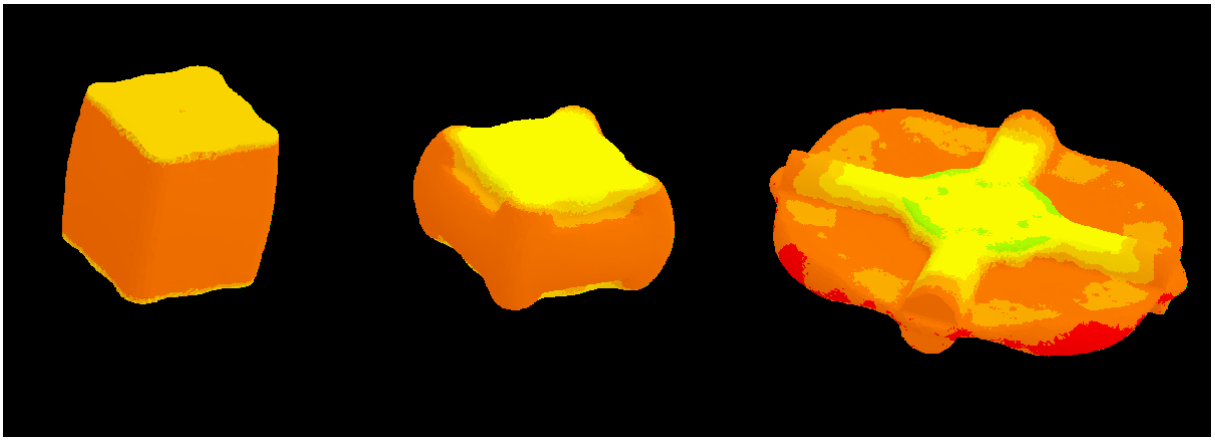
There are many benefits of performing FEA simulation of cold forging processes including prediction of forging defects such as laps, under-fill, internal and surface cracking and resolving tool life issues. The best use of simulation software is when it is performed up front before building the hard tooling. Simulation not only saves cost and resources but also the time to manufacture a defect-free part. There are many examples of organizations using FEA simulation to reduce cost and time. One example reported by FASTCO Industries in an article published in

Aug. 2003 issue of this magazine is specially interesting as it demonstrates how several hours of time was saved up front by simulation. The under-fill was predicted by simulation and this concern was resolved with the customer before building the tooling.



Problem Solving Using NAGSIM.2D (FASTCO)

Benefits of FEA simulation of metal forming processes are not limited to just cold forging. Processes such as warm and hot forging, sheet metal forming, thread rolling and ring rolling are simulated to optimize the manufacturing process and tooling designs. In sheet metal forming, FEA simulation along with Forming Limit Diagrams (FLDs) is used to predict localized necking of the sheet during stretching. In hot forging, FEA simulations are performed to determine the starting blank shape and preforming operations to forge a defect-free part with minimum flash.



Temperature Analysis (Hot Forging) Using NAGSIM.3D

Reduction of run time to perform 3D simulations so these can help up front in the manufacturing cycle remains a priority for MFSI. As computing power with parallel processing increases and software tools to harness that power become available, the simulation time will decrease in years to come.

There are many opportunities for a manufacturing company to reduce the time it takes to manufacture a formed part. Those within the areas of Sequence Design, Tooling Design and Simulation are presented in this paper. Also presented are the challenges for a software company such as MFSI to develop programs that can reduce the time significantly to improve competitiveness of its users.

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