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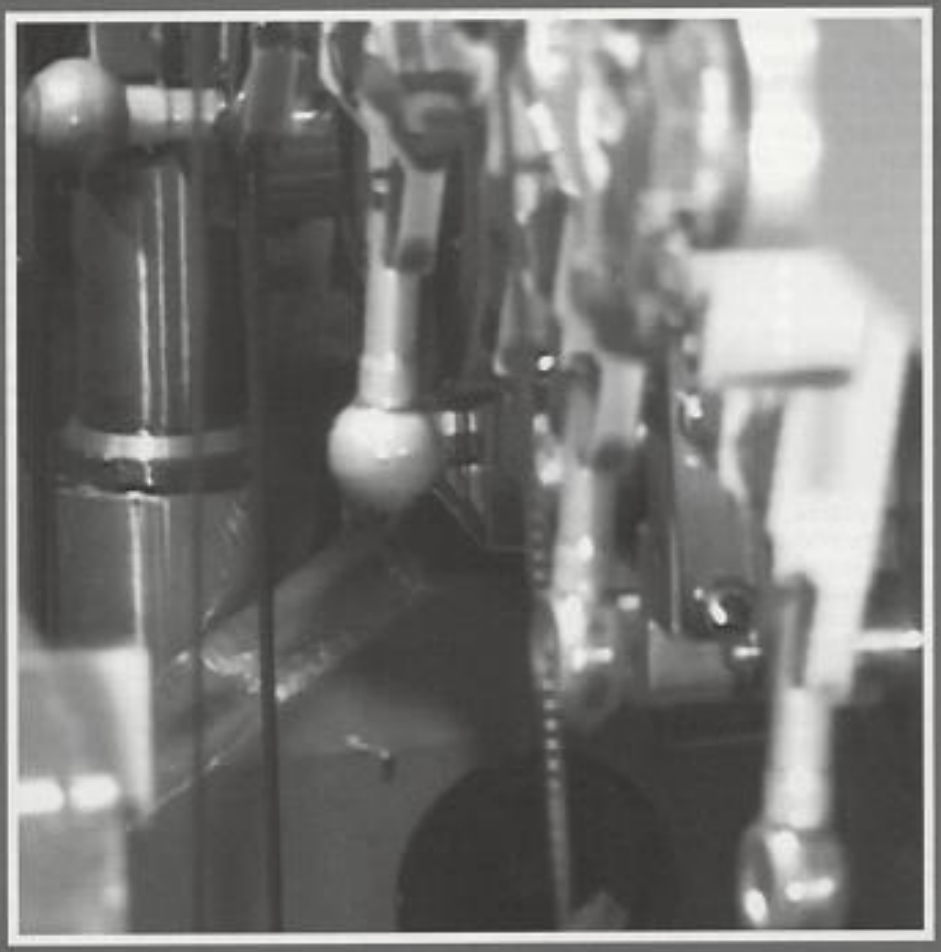

INSIDE:

- EMPHASIS: SIMULATION & SOFTWARE
- ROUNDUP: TESTING & GAGING
- ROUNDUP: PROCESS CONTROL
- SPOTLIGHT: FEEDING

Inside: **Fastener Focus**

Why You Should Use Design Software

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Two easy-to-use computer programs optimize the forming sequence and improve quality of cold formed parts.

The design of the manufacturing process for cold formed parts includes design of forming sequence, selection of appropriate forming machines and design of tooling. It is influenced by a multitude of factors including part geometry, part material, available equipment, lot size, etc.

Mostly, forming design is done by experienced designers based on their prior experience with similar parts. A certain amount of trial and error has to be done to debug the design. For simple parts that can be made on single die machines, this method of developing design may be adequate. However, for complex parts or for parts made on multi-die machines, the design is usually not optimal from the viewpoint of effort, time and cost spent. In addition, part quality issues can remain, which slow down the production.

Forming-design software products have emerged in the market that can help optimize the design of the manufacturing process for formed parts. NAGFORM and NAGSIM.2D are two such tools, developed and marketed by Metal Forming Systems, Inc.

Software for Cost Estimating & Initial Design Development

NAGFORM is a rule-based software program that can determine alternative forming sequences from the final formed part geometry. Because forming sequences can be determined quickly (usually within a few minutes) NAGFORM is ideal for cost estimating tasks and developing initial design concepts.

The part geometry is input as a collection of simple shapes called primitives. Hollow shapes are constructed using tubular primitives or by subtracting primitives from a solid shape. Currently, part geometry is limited to round parts and parts with symmetrical shapes such as polygon, six lobes, round with flats, etc. Part geometry from other CAD systems such as AutoCad can also be brought in DXF format.

The software includes a database of commonly used part materials. The user can also add new materials or modify existing materials in the database. Material properties required for load estimation are the flow properties of a material at the forming temperature. NAGFORM also has a machine database that stores specifications of the available machines. The user can add machines or modify specifications of the existing machines.

As the final part geometry can be formed using different wire/rod diameters and forming processes, a number of alternative forming sequences for forming a part are developed. All of the alternative sequences satisfy the set forming rules. Design output includes alternative forming sequences, load and pressure calculations, DXF output of sequence designs and a machine selection summary.

An attractive feature is the ability to create reusable templates. Any sequence design generated can be saved as a template. The forming sequence for family of parts, with the same shape, but different dimensions, can be designed quickly with minimal effort and time.

Imitating a designer, NAGFORM determines a forming sequence for a part using a rule-based logic. The set limits of the forming rules define whether a particular forming operation is possible. The user can change these limits. The software tries to find all possible sequence designs under the specified conditions of wire/rod diameter, number of operations, type of forming machine/press, etc. For most parts, a number of alternative designs are obtained in a matter of minutes.

Software for Simulating Processes Involving Large Metal Deformation

NAGFORM uses simple analyses for load and pressure calculations. It is not a Finite Element Analysis (FEA) program and does not simulate the deformation in any forming operation. Therefore, it cannot predict non-fill and other forming defects. For complex forming operations where simple forming rules may not apply, the part deformation needs to be simulated by an FEA program to debug the forming operation.

NAGSIM.2D is a FEA program for simulating processes involving large metal deformation. It can handle two-dimensional deformation of parts that are round or long. Its GUI (Graphic User Interface) has been specifically designed for forming in single die or multi-die forming machines and presses. The program has process templates that create a default analysis file at the start to help users who are not familiar with FEA procedures. It is simple to use and does not require extensive background in FEA.

This software has powerful features of automatic meshing and remeshing. During simulation of metal flow, tool stresses and strains can be predicted at each stage of deformation. The results include animation of the metal deformation, a detailed description of geometry, stresses and strains, tool stresses, nodal forces, etc.

Simple & Accurate

Users at FASTCO Industries say they like NAGFORM and NAGSIM.2D because the programs are very simple to use. After one day of training in NAGSIM.2D FEA program, FASTCO users were able to simulate a number of their problem parts and resolve the issues without any help from the vendor, Metal Forming Systems, Inc. We at FASTCO have

performed more than 40 simulations using NAGSIM.2D. It has predicted the metal flow very accurately for all the situations where we could check the results against the actual part made on the machine. NAGSIM.2D is helping us to find solutions on the computer instead of building the tools and conducting costly trials on the machine.

Building a Database of Parts & Sequences

The NAGFORM program has the capability to search for similar parts and create reusable templates of sequence designs. These capabilities help us to bring uniformity in our designs and prevent reinventing designs by locating similar parts and the company's designs done in the past. We have also started to create a database of all our parts and their sequence designs. The company plans to use this database at the cost estimating as well as tool design phases to take advantage of its previous knowledge of forming parts.

Resolving Quality Issues

The quality department at FASTCO loves NAGSIM.2D because it is able to show its customers how the part will be formed. The metal flow is predicted so accurately that the quality staff is able to discuss forming issues among themselves and with their customers even before manufacturing any part or building any tools. An example is the part shown on the NAGSIM screen in **Figure 1**.

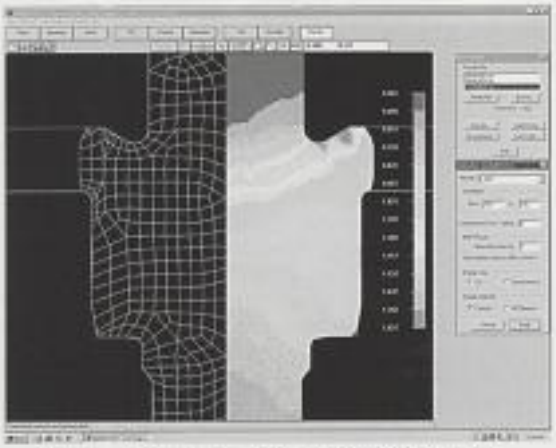

Fig. 1 — Simulation of Final Forming Operation.

Simulation of the forming operations showed that there would be a slight underfill in the middle of part shoulder. FASTCO relayed this concern to its customer before building the tooling. Because the customer did not feel that the underfill was of any consequence, the part was manufactured according to the designed sequence. The final part, as shown in **Figure 2**, shows the underfill predicted by the simulation. And as the manufacturing concern was already addressed, it saved us several hours and pounds of scrap. Additionally, simulation allows us to investigate different options for resolving quality issues without building the tooling and without having to conduct trials at the production machine.

Fig. 2 — Part Formed with slight under-fill at shoulder as predicted.

The part shown in **Figure 3** had no problems in manufacturing, but was breaking off during the assembly process.

Fig. 3 — Cracked during assembly.

FASTCO simulated its manufacturing process to see if any changes could be made to alleviate the breakage problem. The simulation showed large strain at the section where the part was breaking in the assembly. Note that in the simulation, **Figure 4**, the rectangular section of the head was approximated by a circular section so that the forming process could be simulated in NAGSIM.2D.

The company simulated a number of design options and found one that reduced the critical strain without the added tooling cost, **Figure 5**. Parts were formed according to the redesigned forming operations. The customer has not reported any part cracking after the design changes made on the basis of simulation. And costly trial and error development was saved on the machine.

Fig. 4 — Simulation of forming strains.

Fig. 5 — Reduced strains with redesigned process.

Resolving Manufacturing Problems

Figure 6 shows a cup type part that was cracking on the outside free surface during the final forming operation (part on left). The forming sequence for this part was simulated. The results showed large strains in the part at and near the free surface of the part, **Figure 7**.

Fig. 6 — Formed part before (l), after (r) tooling changes.

At FASTCO, we investigated a number of forming design changes. The one change showed much less strains in the cup at and near the free surface **Figure 8**. Tooling changes were made and the part was manufactured with the redesigned tooling resulting in greatly reducing the defect.

Figure 9 (next page) shows another part that had a quality concern. The part was not filling properly at the corner. After

Fig. 7 — Part before tooling changes.

Fig. 8 — Part after tooling changes.

Fig. 9 — Formed part not filled at the corner.

the machine operators claimed that it could not be filled any better, the forming operation was simulated. The simulation clearly showed where the problem was, and allowed an informed decision as to how to remove it. The tooling changes were made and the part was formed with the revised tooling. **Figure 10** shows the part filled better at the corner. This verified the improvement as predicted by the simulation, as seen in **Figure 11**.

Fig. 10 — Formed part after tooling changes.

Fig. 11 — Simulation that predicted improvement.

Developing the Optimal Forming Sequence with Minimal Effort & Time

Design software such as NAGFORM and NAGSIM.2D should be used up front before building any tooling.

This would help determine the optimal forming sequence requiring minimum tooling changes. Start with NAGFORM to give you different design alternatives as well as point to the designs used in the past for similar parts. Use your experience to select one or two sequence designs. Simulate these in NAGSIM.2D to debug and make the final selection. Then build your tooling. You can save yourself several hours of frustration, machine time, cost and scrap by eliminating possible mistakes up front.

We are adapting this procedure of using NAGFORM and NAGSIM.2D to obtain optimal forming sequence wherever possible. This approach cuts down the time needed to develop the forming sequence and to obtain the final acceptable part on the machine. An example part manufactured using this approach is shown in **Figure 12**. The part required a large amount of material to be upset. NAGFORM was used to help arrive at a progression. The tooling was then designed and the process was simulated using NAGSIM.2D software. Changes to the design were made based on the simulation. The initial setup on the header went incredibly well. No tooling revisions were required.

Fig. 12 — Forming sequence developed using NAGFORM and NAGSIM.2D.

Manufacturing from the sample run to production went very smoothly. Additionally, it took less than half of the time normally required to manufacture an acceptable part.

Tool Life

On the part shown in **Figure 13**, we were experiencing premature failure of the extrude pin of a rectangular section. To analyze the forming operation in NAGSIM.2D, the company simulated the process assuming plane strain conditions at the pin **Figure 14**. Through simulation, the company was able to know what was happening as well as why it was happening. The pin was then redesigned to allow the part to be extracted without any resistance from the pin. This particular design change was simulated in order to verify our intent. And as a result of this, pin life was increased from 2000 to 45,000 pieces per pin.

Fig. 13 — This pin had resistance to extraction at rectangular section.

Fig. 14 — Simulation shows material moving into relief section of pin.

Linking These Programs Together

Metal Forming Systems, Inc., is linking the two programs NAGFORM and NAGSIM.2D together to further reduce the time taken to develop a forming sequence. NAGFORM will not only generate part forming sequence, but also create "Default Tooling" and a NAGSIM.2D analysis file automatically within a few minutes.

This together with changes in computer hardware and software to reduce the time to simulate, would make it possible to develop a debugged forming sequence within a couple of hours with minimal human effort.

Conclusion

Engineering design software products are available that can greatly reduce the time and effort required to develop the manufacturing process for formed parts.

Such software also helps to improve the quality of the fasteners and parts being produced. It is time for the cold forming and fastener industry to adapt the new technology to improve its productivity. Competition from overseas and other competing technologies make it essential for the industry to upgrade the existing manufacturing technology for survival in the long run.

For additional information on NAGFORM and NAGSIM.2D software, contact the authors. FTI

Company Profiles...

***Metal Forming Systems, Inc.**, provides breakthrough technology for forming process design. The company is the developer and supplier of NAGFORM software for forming progression design and NAGSIM.2D for the validation of forming progression designs through the simulation process. According to Metal Forming Systems, Inc., these software packages help the users develop forming sequences within a short time and with least effort.*

***FASTCO Industries Inc.**, specializes in the manufacture of cold formed industrial products. The company serves the automotive, furniture and snowmobile manufacturing industries.*

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