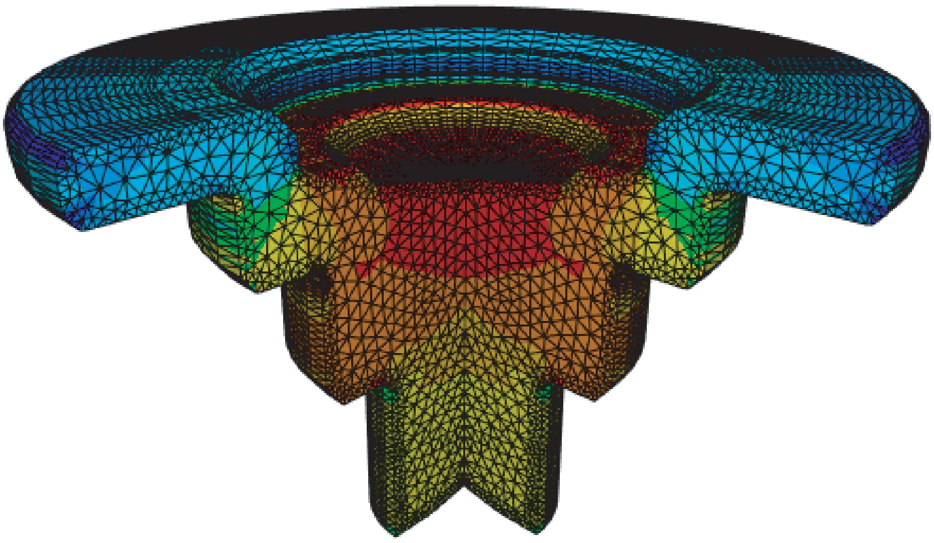
May 2020

Uni-TechSpace



Cold Forming Simulation at Unisteel

Cold forging simulation involves the usage of computational software to perform Finite Element Analysis (FEA) on cold forming processes. At Unisteel, simulation software is applied in a wide range of cold-forming processes including extrusion, closed-die forging, piercing, trimming and stamping, all of which are the core technologies of Unisteel.

Finite Element Method (FEM) is a numerical method used in simulation software to break down a complex, continuous shape into finite number of discrete elements with simple geometry such as triangle or rectangle (2D plane) and tetrahedron or hexahedron (3D geometry) whose mechanical behaviours are far simpler to calculate and interpolate. This discretization is known as meshing, the resulting structure as mesh. A high-quality mesh setup ensures accurate approximation of the forming process without ballooning the computational time required.

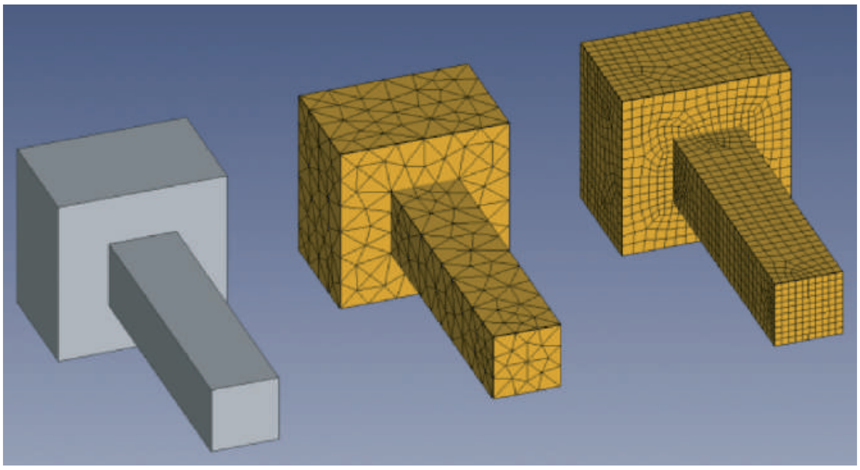


Figure 1 Geometry with tetrahedral and hexahedral meshes (FreeCAD, 2020)

Typically for a simulation to be carried out, the software also needs the material properties of the formed object. In cold forming simulation, the input are the stress-strain flow curves that describe plastic deformation behaviours of a material at different strain rates and temperatures; whereas in strength evaluation, the material properties used are tensile strength, elastic modulus, Poisson's ratio etc. Other inputs include machine properties which act as the loading condition (tonnage, stroke speed and distance etc.), friction and thermal conditions.

Once the simulation is completed, results that are normally studied in a cold forming simulation are the forming pressure, stresses, strains, and resultant hardness. It is also possible to observe the material flow and contact with the tools at each time step, to check for burrs, folds, and die cavity filling. In addition, it is possible to obtain information about critical tool loads in the process and hence derive counteractions in a very early stage of the development process.

Simulation Utilisations & Case Studies at Unisteel

Product Design

With computational simulation, we could readily give feedback to our customers on part designs, be it on Design for Manufacturability (DFM) or structural integrity of the product. We can check for any geometries that are difficult to cold-form, or shape profiles that accumulate large amount of stresses and act as stress concentration points, then suggest plausible solutions.

Process Design

With the ability to predict changes in pressure, part hardness and stresses during forming, we can determine the suitable operation to be used, in order to ensure that the forged items are able to meet customer expectations in terms of form, dimensions, and mechanical requirements, as well as maintain long tool life.

Case Study

In a past customer inquiry, we were requested to investigate a brass part with a through hole and chamfers on both sides of the hole. While it would be more efficient to achieve this profile using hole piercing and chamfering in the same progression as forging of the rest of the part geometry in a press machine, it was a concern that the resultant stress would compromise the part strength due to its narrow width and low tensile and shear strengths of the brass material.

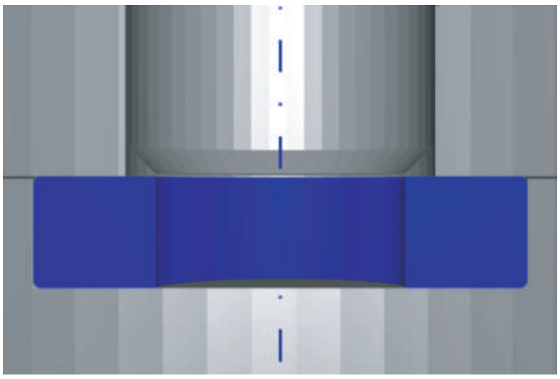


Figure 2 Chamfering simulation setup

With a quick simulation of the scenario, we could study the impact of performing chamfering on the edges of the pierced hole, in the form of stresses in the X, Y, and Z directions around the hole. In the end, we found that the material would be weakened considerably if chamfered and hence machining would be a more suitable solution to produce this geometry.

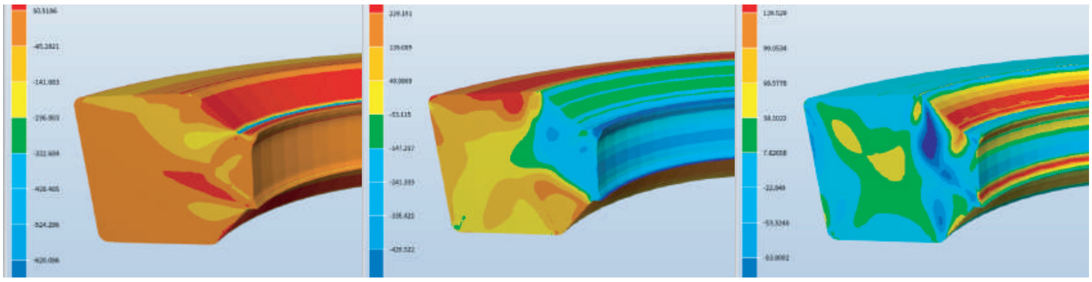


Figure 3 Chamfering simulation results in XX (left), YY (middle), and ZZ (right) directions

Tool Life

Design engineers at Unisteel also make use of the simulation software to predict the tool lifetime of active tool elements including punch and forming die, which is advantageous in tool material selection, identification of potential tool failures, and thus lengthening of tool life.

Case Study

For example, in past case, we were trying to solve the crack formation issue faced during cold heading of a screw part made of stainless steel 302HQ, whereby, the die insert piece made of high speed steel encountered frequent premature breakage. We explored several options including not controlling the screw shank length with the die punch pin and switching to a carbide die insert piece.

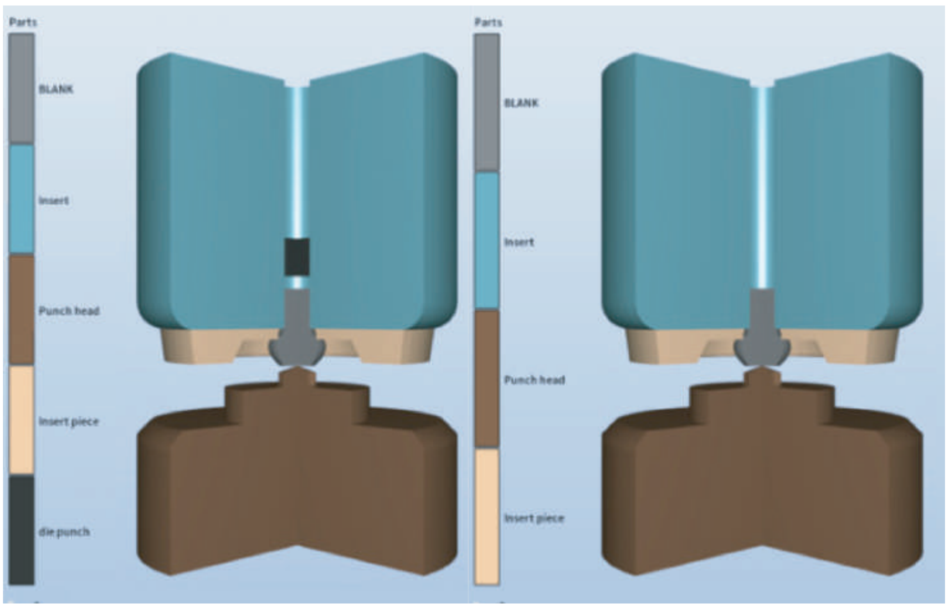


Figure 4 Cold heading simulation setup with (left) and without (right) shank length limitation

Through FEA simulation, we discovered that attempting to control the screw shank length would cause extremely high stress and material fold at the screw recess due to material backflow. The forming pressure induced is also higher than the compressive strength of the high-speed steel die piece.

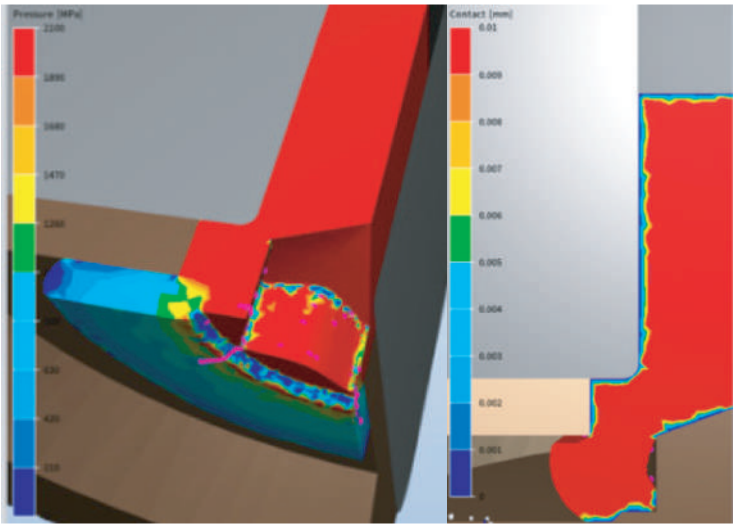


Figure 5 Pressure and contact results with shank length limitation

Even without controlling the screw length with a die punch pin, forming pressure at the screw recess remain high and at approximately 2200MPa, the peak pressure still exceeds the HSS compressive strength. However, the material contact in the die cavity is dramatically improved and with the usage of a carbide die piece, its compressive strength is able to withstand the pressure encountered.

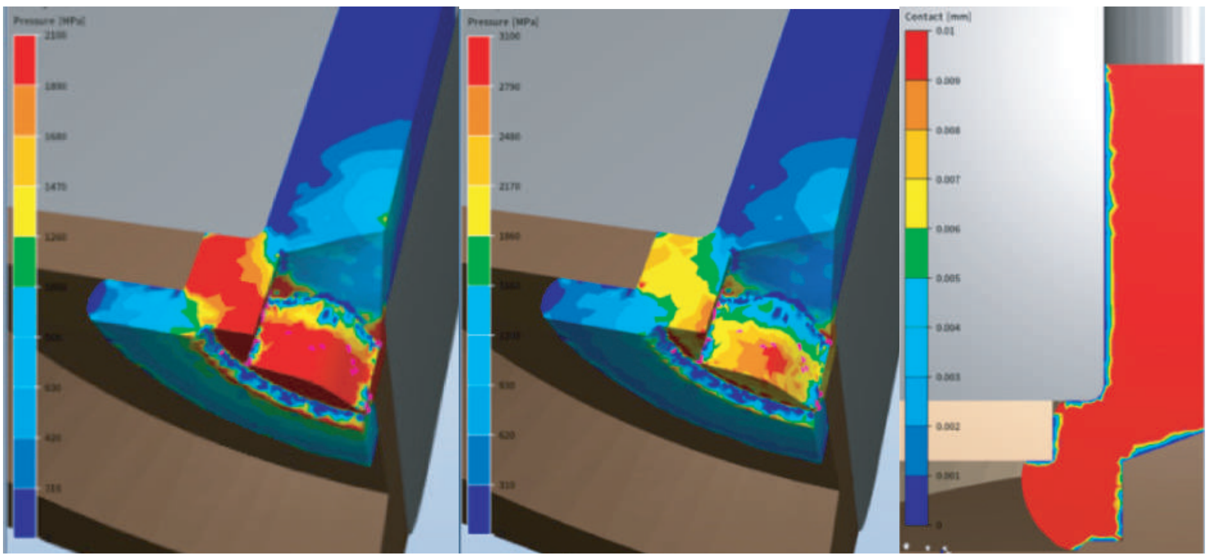


Figure 6 Pressure and contact results without shank length limitation

Benefits of FEM Simulation

The utilisation of FEM simulation in conjunction with design software allows us to have a fast and accurate prediction of material behaviours during cold forging. This entails several invaluable advantages, including:

- Design aid: we are better equipped to make iterative design improvements rapidly between design and simulation software
- Quick design validation: reduces the extent of trial-and-error required in tool and process design, and identifies any potential failures, which leads to:
- Product quality assurance
- Reduced lead time
- Cost savings
- Tool life improvement

As part of Unisteel's effort in changing and improving, FEM simulation is a useful tool adopted by our experienced design engineers to provide value-added services to our customers.

Resources

Ref 1: FreeCAD, 2020, "FEM Mesh" (https://wiki.freecadweb.org/FEM_Mesh/en)