DEFORM™ Application #253

Fine Blanking Simulation

Background:

To remain competitive, manufacturers are always striving to produce high quality components faster and at a lower cost. The use of Finite Element Method (FEM) systems in product design and development is increasing, especially for investigating and optimizing a product or process. Lead-time reduction for new components is possible through FEM usage.

When applied to metal forming, FEM is a mature tool. Many leading companies have almost two decades of experience in industrial applications. It has proved extremely successful at predicting material flow, forming defects, load requirements and tool stresses. When applied to blanking and piercing operations, the applications are less mature. Until fairly recently, it was not practical to include ductile fracture in a simulation tool capable of analyzing large plastic deformation.

DEFORM™

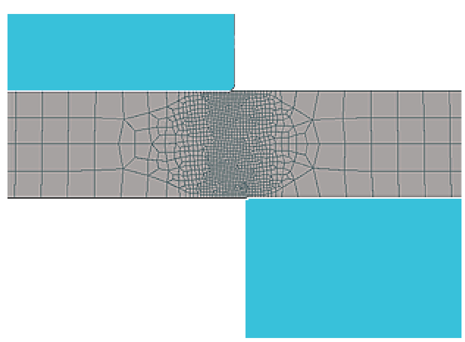
Design Environment for FORMing

Problem:

Blanking and piercing are shearing operations. These involve elastic and plastic deformation, as well as ductile material fracture. Material is stressed between two cutting edges and fracture occurs from void initiation, growth and subsequent hole coalescence. The process takes place through the thickness of the material with very localized deformation in the shear band. The large deformation involved necessitates a specialized metal forming FEM code for practical applications.

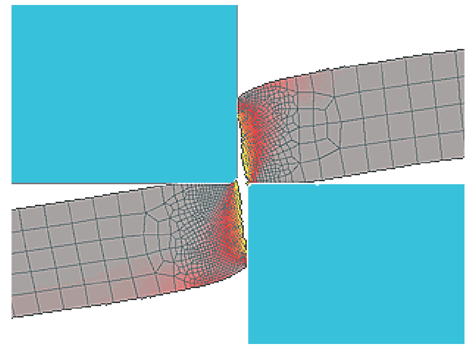
Simulation:

Two-dimensional (2D) axisymmetric or plane strain modeling is quite reasonable for a wide range of sheet, plate, disc or washer components. Of course, to obtain an accurate solution, the mesh should be fine in the region where the fracture occurs. In areas remote from the fracture region, the elements can be relatively coarse to reduce simulation time.



A typical workpiece/die configuration at the start of a blanking simulation is shown. Note the element size gradient.

For practical purposes, a blanking simulation could include a wide range of element sizes, with ratios as high as 25:1 or 100:1.



After the process, the workpiece has been divided into discrete objects, as shown.

Material behavior can be modeled in numerous ways, ranging from a power law to actual flow stress data via a lookup table. Blanking simulation studies have been undertaken on AISI-1045 steel [1], cold rolled strip steels [2] SAE 1137 [3] and SAE 1524 [3]. Additional material properties required are a ductile fracture criterion and an associated critical damage value (CDV). A number of ductile fracture models are built into the DEFORM™ System and can be found in [1]. Some well-known damage models are shown below.

Cockcroft & Latham:

$$\int^{\bar{\varepsilon}_f} \frac{\sigma^*}{\bar{\sigma}} d\bar{\varepsilon} = C_2$$

Rice & Tracy:

$$\int^{\bar{\varepsilon}_f} \exp\left(\frac{\alpha\sigma_m}{\bar{\sigma}}\right) d\bar{\varepsilon} = C_4$$

Oyane:

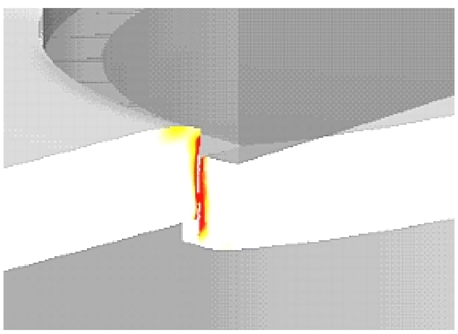
$$\int^{\bar{\varepsilon}_f} \left[1 + \frac{1}{a_o}\frac{\sigma_m}{\bar{\sigma}}\right] d\bar{\varepsilon} = C_5$$

These criteria have been used in a wide range of fracture studies and are well documented in the literature. The McClintock criterion has also been used, with the damage being calculated from the stress and strain. This is a far more complex expression than those shown.

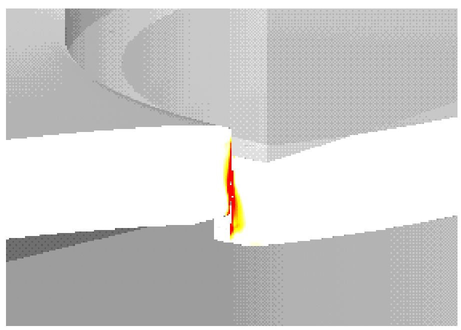
A material's CDV can be established by simulating fracture and correlating the predicted damage with the initiation of cracking in an experiment. Simple test cases include compression and tensile tests.

Results:

Two simulations were run to study a process with and without the use of a spring stripper (blank holder). The stripper held the sheet material down on the die. Without the stripper, the part was free to flex away from the die. This difference influenced the fracture behavior during deformation and the final part shape.

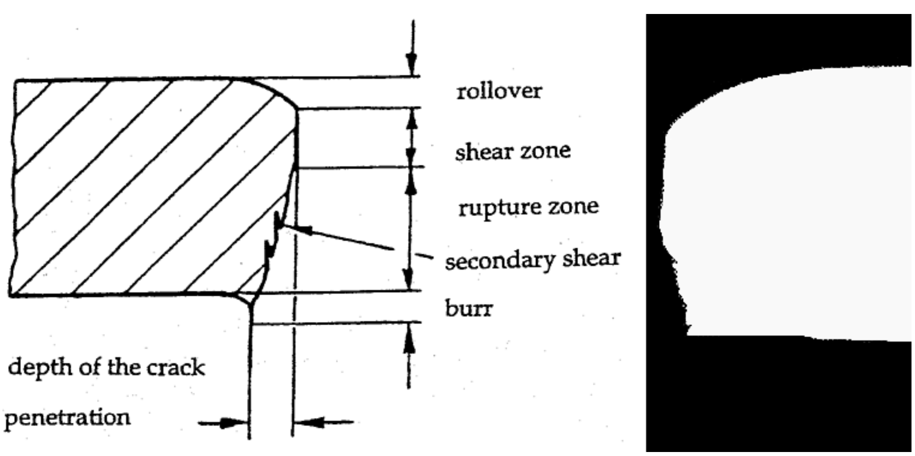


operation with a blank holder



operation without a blank holder

As the damage exceeds the material's CDV, the fracture initiates and propagates through the thickness. The fine elements accurately describe the resultant profile of the fracture surface. As the punch/die clearance is varied, the fracture surface changes profile and the shear zone increases or decreases. Excellent correlation between the simulation and the experiment has been published [2].



The theoretical part edge after blanking (left) and corresponding experimental cross section showing fracture surface (right) are shown.

Wrap-Up:

The DEFORM™ System is capable of simulating blanking and piercing processes. The capabilities are included in the system, with no additional programming required. It is possible to develop different damage models and implement them via user subroutines for research applications.

While the determination of a material's CDV is becoming more commonplace, it still requires a good understanding of the process. On the other hand, the methods used are fairly simple and straight-forward.

References:

1. Kim, Yamanaka & Altan, Prediction and Elimination of Ductile Fracture In Cold Forgings Using FEM Simulations.
2. Taupin, Breitling, Wu & Altan, Material Fracture and Burr Formation in Blanking – Results of FEM Simulations and Comparisons with Experiments.
3. Hoffmann, Santiago-Vega & Vazquez, Prevention of Ductile Fracture in Forward Extrusion.
4. Cockcroft & Latham, Ductility and The Workability of Metals.

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