2.31 Project 7
Stretch Forming

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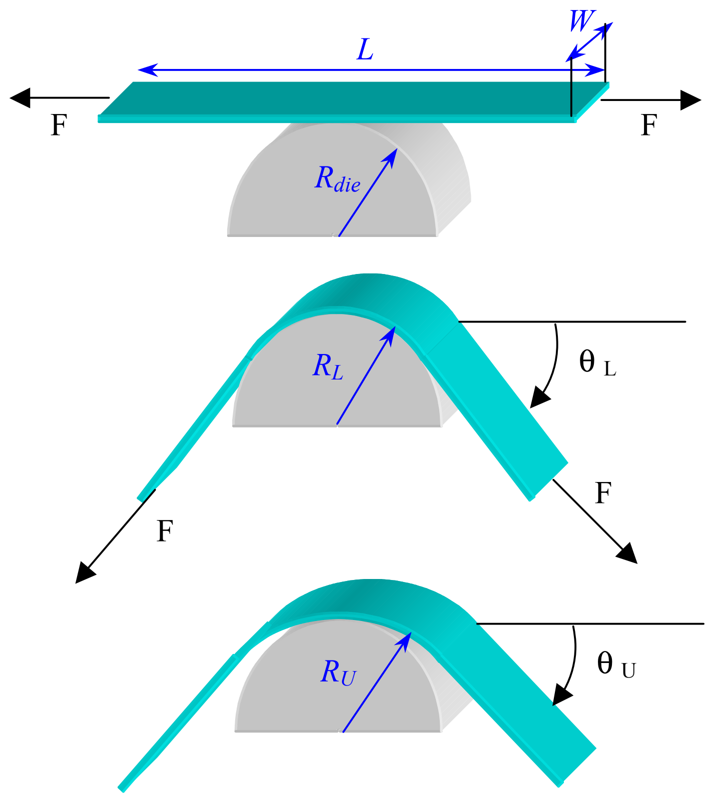
Due Wed, Dec 5 at 9:30 am

For this project we will continue the stretch forming simulation introduced in Assignment 12, to model the springback of the part when unloaded. Due to their high yield strength to elastic modulus ratio, aluminum sheet metal parts tend to have large amounts of springback, and they are therefore hard to manufacture in a precise shape. For the simple bend modeled in the assignment, the radius of the bend and the angle of the flaps will change when the sheet is unloaded. For this simple geometry we can get a fairly good estimate of the final part shape with simple calculations, but for more complex part shapes numerical simulations are the only option.



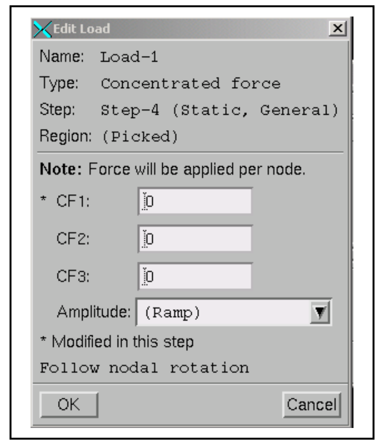

## 1) Pen and Paper

1. Neglecting the effect of the axial force F, estimate the final part shape (bend radius $R_{0,U}$ and flat edges angle $\theta_{0,U}$) based on your estimate for $M_{0,L}$ and the moment-curvature diagram for the sheet. Predict the residual stress profile in the unloaded sheet.
2. The finite element calculation in Assignment 2 provides a good estimate of the actual bending moment in the loaded bent part, $M_{F,L,}$: Use this quantity to obtain a better estimate of the final part shape, $R_{F,U}$ $\theta_{F,U}$. Is the springback (shape change can be quantified in term of $\Delta R/R$) more or less? Why?

## 2) <u>FE model</u>

Modify the FE model of the forming process to include unloading.

STEP : We will model the unloading history through two additional unloading steps: in Step 4 we will release the stretching force F. In Step 5 we will release the constraint on the rotation angle at the edge of the sheet.. So you have to create two additional steps. For each step choose General Static steps, with a step time of 1. Under the incrementation tab choose for each step an initial increment size of 0.1.

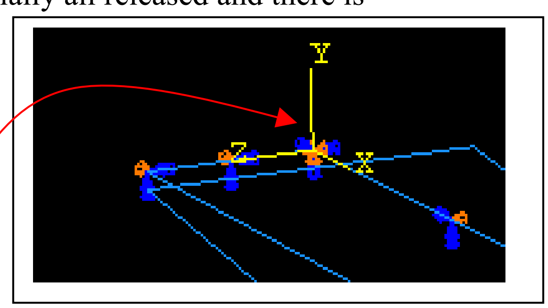



LOAD : In the load manager, you see that by default the stretching load is propagated to all the steps. You need to change this. At step 4 edit the loading condition to ramp down the magnitude of the load to 0.0. At step 5 simply deactivate the loading condition.
In the boundary condition manager, you will find that at this point you should have in your model the following 5 Boundary conditions:

1) encastre of the reference point for the Die. Propagated to all steps
2) XSYMM on the edge of the sheet in the 2-3 plane. Propagated to all.
3) ZSYMM on the edge of the sheet in the 1-2 plane. Propagated to all.
4) Vertical(U2) displacement on the gripped edge of the sheet: created (=0) at step 1, modified (-0.002) at step 2, inactive for steps 3,4,5.
5) Rotation (UR3) for the gripped edge. Created on step 3 and by default propagated to steps 4, 5. This you want to leave propagated in step 4 but you want to <u>deactivate at step 5.</u>

<u>You need to create an additional BC:</u>

6) At the end of step 5 the loading is essentially all released and there is no remaining constraint on the vertical (U2) rigid body motion of the sheet. To avoid this condition, create a new boundary condition in step 5 for the corner point of the sheet on the 2-axis, prescribing its vertical displacement (U2) to be zero. This will move up the sheet from the die, while all the loading is released..




This should work to model the unloading.

Submit the job: note the CPU time from the .dat file. Give a look to the .msg file to see if you have some clue of what's going on.

Look at the results in the VISUALIZATION module of ABAQUS/CAE:
Plot and print contour plots of the following quantities at the end of step 5: S11, SF1, SM1, UR3.

> S11:Are the residual stresses consistent with your pen/paper estimate? Why?
> SF1 and SM1 : are the section forces and moments consistent with expectation?
> UR3: how does the springback angle compare with your estimates?

Now I would like you to look at the effects of the magnitude of the prestretch force on the final part shape and on the residual stresses: run two new simulations: one with 50% of the reference F, and one with 200% of the reference F. Look at the effects on final part shape and residual stresses. Discuss the reasons for the trends you are observing.

All teams should write a short report where they discuss the results of this study.
For the presentations, I would like to have:
Team 5 presenting assignment 12 results
Team 6 discussing the unloading procedure and the theory/simulation comparison
Team 7 discussing the study on the effects of the magnitude of the prestretch force.

For Team 1 (only) I have the following additional study that I would like them to present:

Effects of post-stretch.

In order to reduce springback, often the manufacturing procedure includes an additional step where the axial stretching force is ramped up at the end of the wrapping stage, when the sheet is still conforming to the die. Perform a simulation (loading/unloading) of a stretch forming simulation where, after the sheet is wrapped around the die with the applied pre-stretch force F, the stretching force is ramped up to 250% F before the sheet is unloaded.
Look at the springback and residual stresses. Prepare a discussion to explain to the class how you did your analysis, and what does it tell us in terms of forming operations. If I told you that the die-sheet Coulomb friction coefficient is 0.4, do you think you should include this effect in the simulation? Why?