

Final Element Simulation of Blankholder's Lift-off in a Deep Drawing Tool Using Abaqus/Standard

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Abstract:

In the deep drawing tools for forming car body parts, heavy blankholders are used to prevent buckling and wrinkling of the blank. During each press cycle, those large masses need to be lifted, raising thereby the structural dynamic load on the deep drawing tool and on the press. Therefore a detailed knowledge about the blankholder's lift-off event is essential for an accurate and robust design of forming tools. In this paper, a dynamic finite element method (FEM) simulation of a blankholder's lift-off in a selected automotive deep drawing tool is presented enabling identification of regions of critical stresses. The FEM model is built within the Abaqus/CAE environment and solved with Abaqus/Standard. Each dynamic analysis is preceded by a static analysis where the gravity load is applied and the lifting bolts are pre-stressed. A special emphasis is put on modeling the elastomer dampers, which are installed between lifting bolts and the blankholder to avoid hard impacts during the lift-off event. Those dampers are modelled using a hyperelastic material with hysteresis. In addition, an experimental validation of a blankholder's vibration under operating loading was carried out. The simulation results are in good agreement with the measurements.

Keywords: Blankholder, Deep Drawing Tool, Elastomer Damper, Vibration, Mechanical Press

1. Introduction

With new press systems with higher strokes rates (Osakada, 2011) emerging, further savings in cost and time in the production of sheet blank parts are possible. One drawback of the stroke rate increase is that also the loading on the deep drawing tool and its components rises. Especially, the dynamic loads on the blankholder - used to prevent buckling and wrinkling of the sheet blank - can get considerably higher, as during each press cycle, its large mass needs to be lifted. This could in the worst case not only lead to the damage of the blankholder structure, but also affect the forming tool and press. Therefore, a detailed knowledge about the blankholder's lift-off event is essential for an accurate and robust design of deep drawing tools. Such a dynamic structural problem can, for example, be investigated by means of numerical simulation. In (Swidergal,

2014), the coupled multibody finite element method (MBS-FEM) is used to analyze the vibration of the blankholder. Another well-established simulation method is the implicit FEM. In this work the detailed implicit FEM analysis of a blankholder's lift-off event will be conducted. To the author's best knowledge, no paper is published in which such investigation has been presented.

2. Developing the FE model of the blankholder

The FEM model of the blankholder is built within the Abaqus/CAE environment. From the CAD geometry of the complete deep drawing tool the subassembly of the blankholder is extracted and imported into Abaqus/CAE. Using the neutral Parasolid format, an automatic positioning of all components is established. Sharp edges and sliver faces are defeatured to avoid bad shaped elements during meshing. The blankholder is meshed with quadratic tetrahedrons of type C3D10 and for all other metal components the linear hexahedral elements of type C3D8R are used. For elastomers also a hybrid formulation is activated. The final meshed assembly of the blankholder can be seen in Figure 1.

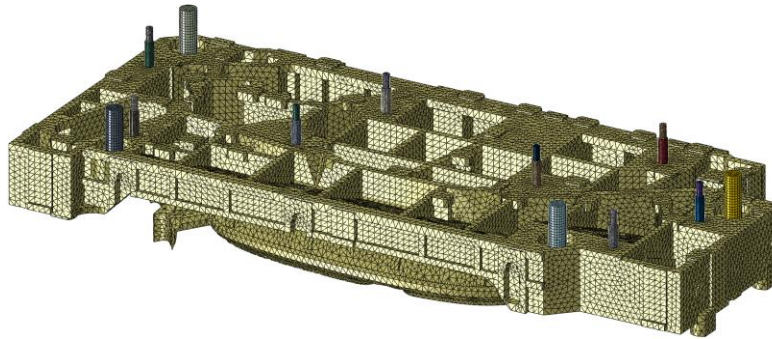


Figure 1. FEM model of the blankholder assembly.

In the model all parts are defined deformable. Their material parameters are assigned using homogeneous section definition. For example, for the blankholder, which is made of cast iron EN-GJS-600-3, an elasto-plastic material definition, with properties listed in Table 1, is used.

Table 1. Material properties of EN-GJS-600-3.

Property	Unit	Value
Young's modulus	MPa	174000
Mass density	MPa	7200
Poisson's ratio	-	0.275
Yield strength	MPa	370
Ultimate strength	MPa	600

In the investigated deep drawing tool, eight so called lifting bolts are used to lift the blankholder. In addition, several sliding pads and guide pillars are installed to ensure that the blankholder can only translate vertically. Therefore, as a first approximation, modeling the lift-off event can be reduced to one lifting bolt only.

2.1 Modeling the lifting bolt

The model of the lifting bolt assembly is shown in Figure 2. Here, the upper die and the blankholder are simplified by a solid cylinder. To account for the proper weight, an extra nonstructural mass is added and distributed on underlying mesh nodes. The matrix, which supports the blankholder and prevents it from falling when the gravity is activated, is modeled as analytical rigid shell part. The lifting bolt is tied to the upper die by the means of a tie constraint. For all other interactions a surface-to-surface contact formulation is used. In addition, a frictional behavior is included in the interaction properties.

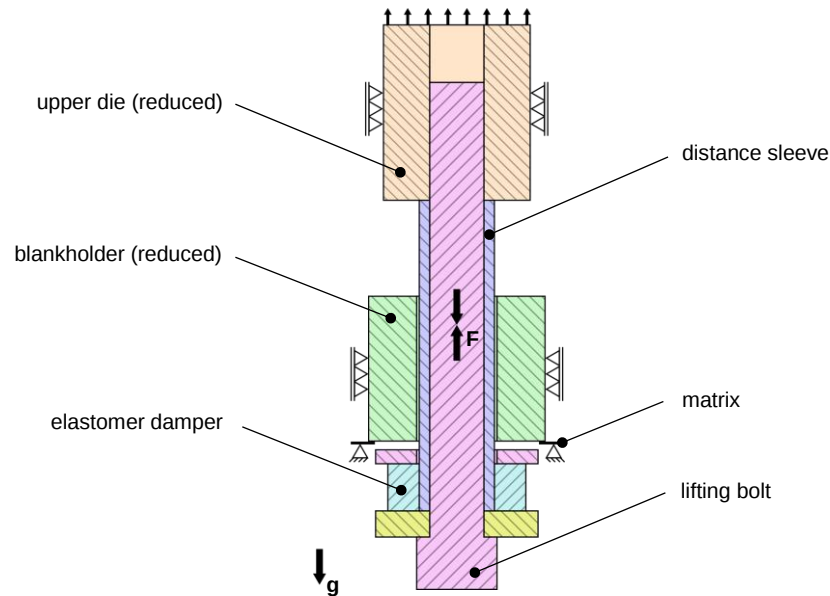


Figure 2. Schematic view of the blankholder's lifting bolt model.

The movement of the upper die is defined in an implicit dynamic analysis step and is realized by a displacement boundary condition with a tabular amplitude, which describes the motion of the press slide at specific stroke rate. The dynamic analysis is preceded by a static analysis where the gravity load is applied and the lifting bolt is pre-stressed.

2.2 Modeling the elastomer damper

Between the lifting bolt and blankholder, elastomer dampers are installed to avoid hard impacts during the lift-off event. Those dampers are made of carbon filled elastomer rubber which possesses highly non-linear stiffness characteristics. To obtain that characteristic uniaxial compression tests were carried out. The result of this experiment for strain rate $\dot{\epsilon} \sim 0.03 \text{ s}^{-1}$ can be seen in Figure 4.

In FEM, the elastomers are typically modeled using a hyperelastic material formulation, which utilizes the strain potential energy for computing the stresses. In Abaqus, there are several forms of strain potentials available to model approximately incompressible isotropic elastomers (Abaqus, 2015). If only uniaxial material test data are available, the Marlow model (Marlow, 2003) is recommended (Abaqus, 2015). This is an isotropic, incompressible hyperelastic model, with the strain energy potential defined as

$$U = U_{dev}(\bar{I}_1) + U_{vol}(J_{el}),$$

where U is the strain energy per unit of reference volume, with U_{dev} as its deviatoric part and U_{vol} as its volumetric part; $\bar{I}_1$ is the first deviatoric strain invariant defined as

$$\bar{I}_1 = \bar{\lambda}_1^2 + \bar{\lambda}_2^2 + \bar{\lambda}_3^2,$$

where the deviatoric stretches $\bar{\lambda}_i = J^{-\frac{1}{3}}\lambda_i$; J is the total volume ratio; J_{el} is the elastic volume ratio and λ_i are the principal stretches (Abaqus, 2015). Hereafter, the Marlow model is chosen.

To represent the energy dissipation in the elastomer damper, a hysteresis model (Bergström, 2000) is used. This model is controlled by four parameters, which were further investigated. An optimization study with curve fitting is carried out to obtain their values.

Table 2. Parameters of the hysteresis model.

Property	Unit	Value
Stress Scaling Factor S	-	1.6
Creep Parameter A	s ⁻¹ MPa ^{-m}	0.7
Eff. Stress Exponent m	-	2
Creep Strain Exponent C	MPa	-0.5

Finally, with the hysteresis parameters shown in Table 2 a good agreement between measured and simulated damper response curve is found, as can be seen in Figure 4.

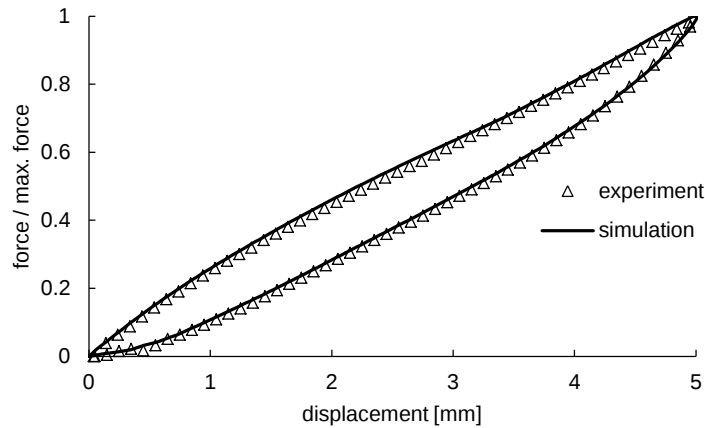


Figure 4. Uniaxial response of the elastomer damper.

In the end, the FEM model is solved in parallel with Abaqus/Standard.

3. Results and discussion

In Figure 5, the von Mises stress of the lifting bolt assembly for the highest stroke rate is shown.

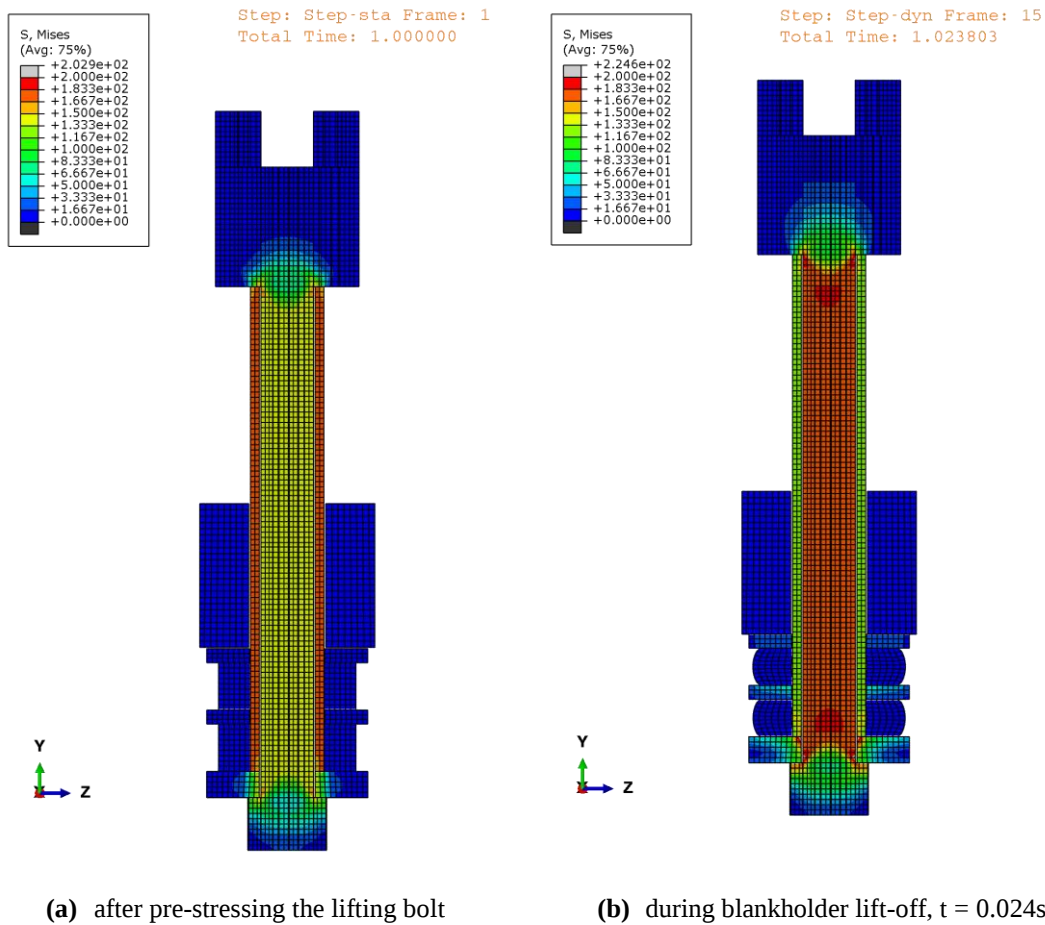


Figure 5. Von Mises stress in the lifting bolt assembly.

In Figure 5a stress state after pre-stressing the lifting bolt can be seen, whereas in Figure 5b stress state during blankholder lift-off at time $t = 0.024$ s is presented. Comparing both states, an increase in stress during the lift-off event can be observed. In the reduced blankholder structure, for the assumed stroke rate, the highest stresses of about 12 MPa occurs at time $t = 0.024$ s. Similarly, the stress in the lifting bolt increases, reaching 206 MPa, which is about 23% more compared to the pre-stressed state. For validation, the numerically obtained velocity response of the complete (non-

reduced) blankholder assembly was compared to the signal gained in experiments, which were carried out under operational loading. The both velocity responses are shown in Figure 6.

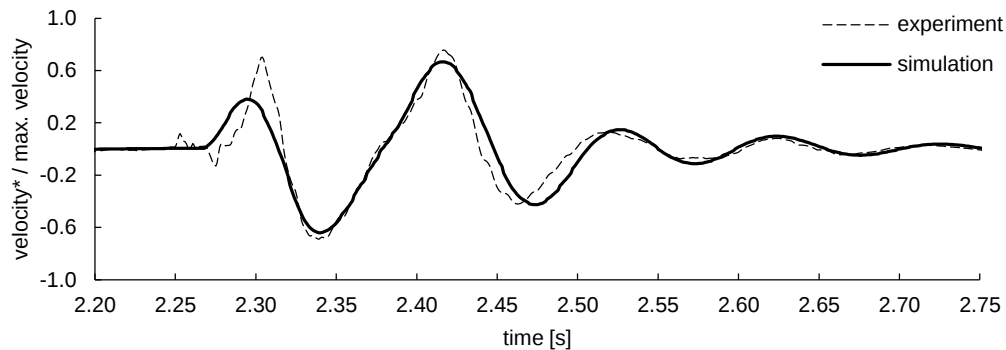


Figure 6. Vertical velocity of the blankholder (*highpass, cutoff freq.: 5Hz).

It can be seen, that the simulation results are in good agreement with the measurements. Moreover, during the lift-off event, the blankholder vibrates three times before it comes to a rest.

4. Summary and conclusion

In this work, a finite element analysis of the blankholder lift-off event in Abaqus/Standard was successfully conducted. Based on an experimental validation, the simulated resulting dynamic loading on the blankholder showed good agreement with measurements. In addition, the regions of critical stresses in the blankholder structure could be identified. Thanks to this knowledge, a deeper understanding about the blankholder's lift-off event was gained. Therefore, the structural dynamic loading on the deep drawing tool and indirectly on the press can now be predicted. Hence, with this approach, more accurate and robust design of forming tools in the future is possible. Further work on modeling the complete deep drawing tool in Abaqus/Standard is in progress.

5. References

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