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OPTIMIZATION OF THE BLANKHOLDER FORCE WITH APPLICATION TO NUMISHEET'99 FRONT DOOR PANEL

Lanouar Ben Ayed[*], **Arnaud Delamézière**[*], **Jean-Louis Batoz**[*]

and Catherine Knopf-Lenoir[†]

[*] Institut Supérieur d'Ingénierie de la Conception
Equipe de Recherche en Mécanique et Plasturgie
27 rue d'Hellieule, 88100 Saint-Dié-des-Vosges, France
e-mail: arnaud.delameziere@insic.fr, web page: http://www.insic.fr

[†] Université de Technologie de Compiègne,
Laboratoire Roberval, FRE 2833 UTC-CNRS
BP 20529, 60205 Compiègne Cedex, France
Email: catherine.vayssade@utc.fr - Web page: http://www.utc.fr

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Summary. *The difficulties to achieve defect free parts in sheet metal stamping are highlighted by new materials such as dual phase steel or aluminium. Numerical simulations of the process can efficiently help to predict the behavior of the sheet by detecting defects like failure and wrinkling. A satisfactory part could be obtained by controlling the material flow during the forming phase : in some areas the sheet should be almost fixed, in others it should be let free. That control can be achieved through the blankholder pressure or the restraining forces of the drawbeads. Siegert, Häussermann and Haller [1, 2, 3] proposed the design of a deformable flexible blankholder. The aim of this work is to use numerical simulations to optimize different blankholder forces defined on different areas of the blankholder surface. The simulations are performed using Abaqus Explicit. The software is linked with an optimization algorithm based on a response surface method computed with diffuse approximations and coupled with an adaptative strategy to update the research space. The objective function is to minimize the work of the punch. Three inequality constraints functions are defined to avoid necking and wrinkling. This procedure is applied to the front door panel proposed as benchmark in the Numisheet'99 conference.*

1 INTRODUCTION

Sheet metal stamping is one of the most important manufacturing processes used in the automotive industries. Numerical simulations have allowed automotive industry to reduce the lead time to market. In 2002 Kim et al. [4] gave the example of a side panel outer die with reduction pf the manufacturing from 16.5 months to 8.5 months. The quality was improved by 30%.

Several parameters of the process play important roles on the forming of the part, such as the blank contour, the shape of the tools, the blankholder forces, the restraining forces of the drawbeads, or the material of the blank.

The goal is to achieve a defect free part, without any rupture, wrinkling or other geometrical defects.

The paper presents the optimization of the blankholder forces in the different zones of the contact surface. The goal is to control the material flow to avoid any rupture and wrinkling. The numerical simulation of a car front door panel (NUMISHEET'99 benchmark) is carried out using ABAQUS FEM code. The simulation parameters are chosen to ensure the accuracy of the results and to limit the computing time.

In the real situation, drawbeads are present on the blankholder in order to limit the flow of the material in the die cavity. In the present study these drawbeads are not modeled.

The first section presents the objective and constraints functions use to detect failure and wrinkling. The second deals with the optimization algorithm and the third with the results.

2 OBJECTIVE AND CONSTRAINT FUNCTIONS

2.1 Rupture prediction

In stamping, failure appears after necking. Considère proposed the first criteria of necking by assuming that it occurs at a stationary point in the case of uniaxial tension. Swift generalized the criterion in biaxial tension : $\frac{\partial \sigma_I}{\partial \varepsilon_I} \leq \sigma_I$

Hora et al. [5] modified this unstable condition by considering that the state of deformation is plane at the moment of the localized necking appearance and that the maximum principal stress σ_I depends on the maximum principal strain ε_I and on the ratio of deformation $\beta = \frac{\Delta \varepsilon_{II}}{\Delta \varepsilon_I}$

The unstable condition proposed by Hora is: $\sigma_I^{cr} = \frac{\partial \sigma_I}{\partial \varepsilon_I} + \frac{\partial \sigma_I}{\partial \beta} \frac{d\beta}{d\varepsilon_I} \leq \sigma_I$

That criterion is called the modified maximum force criterion (MMFC) and used to define a constraint function.

2.2 Wrinkling

Wrinkling is an extremely complex process which is not depending only of local loads and conditions in the blank.

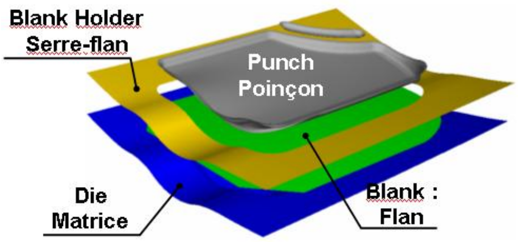
Sheet wrinkling is studied in the context of plastic buckling theory of thin sheets. Brunet et al. [6] developed a simple criterion to estimate the tendency of wrinkling based on the work of Hutchinson, Neale and Tugcu, taking into account the conditions of stress and strain and the local geometry for the portion of the blank under the punch.

For the portion under the blankholder, based on the work of Labergere [7], a geometrical criterion is defined according to the angle of inclination θi between the blankholder surfaces and an element of the blank.

3 RESULTS

The optimization results obtained for the industrial application by using the methodology of optimization describes previously is presented.

That benchmark is a front door panel proposed at Numisheet'99.



Thickness $h_0 = 1.0$mm.
Material : Steel
$E = 220.0$ GPa, $\upsilon = 0.3$,
$r_0 = 1.73$, $r_{45} = 1.23$, $r_{90} = 2.02$.
$\varepsilon = K(\varepsilon_0 + \varepsilon^p)^n$;
$K = 521.16$ MPa, $\varepsilon_0 = 0.00626$, $n = 0.214$.
Friction m =0.15.
Initial total BH force : 300kN.

Figure 1: Geometry and parameters of the front door panel stamping

The benchmark was proposed with different drawbeads lines. The optimization procedure is going to replace the actual drawbeads by different blankholder forces.

This application presents significant wrinkles, specially in the zone under the blank holder. For each optimization stage the optimum solution is carried out after three actualizations of the research domain. Indeed the total number of numerical simulations to carry out is equal to 120. In figure 2 we present the optimum forces obtained for each blankholder. After optimization we succeed to limit the maximum inclination angle to one degree. The indicator of wrinkling in the zone under the punch is equal to 4.5 and the indicator of necking is equal to 0.975. In figure 3 we present the thickness distribution for a total unique blankholder force equal to 300 kN and for seven optimum blankholder forces obtained through the optimization process.

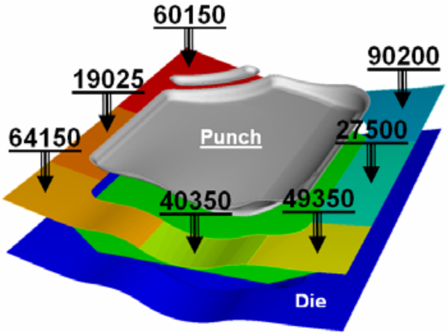
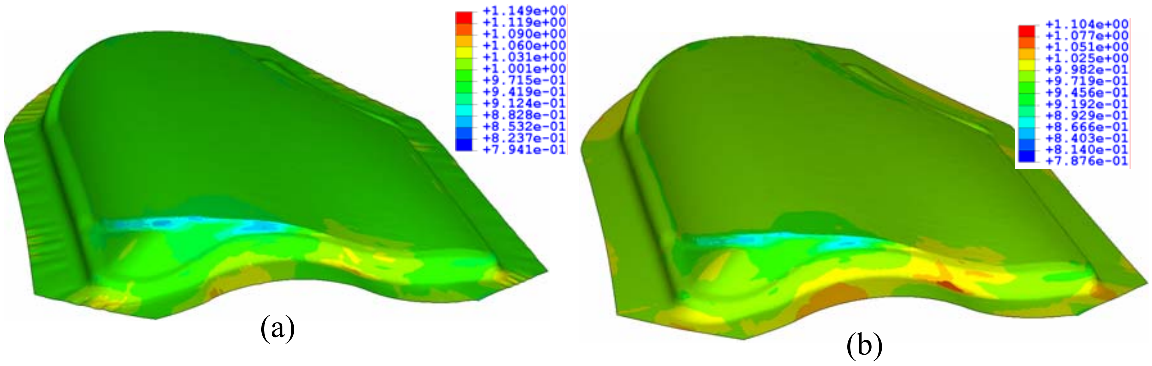


Figure 2: Optimum blankholder forces distribution (N)

It should be noted that the sum of the optimum blankholder forces (351 kN) is almost equal to the initial blankholder force (300 kN). Indeed by adjusting the blankholder forces in space we can limit the formation of strong ondulations under the blankholder. The total external work consumed by the forming press was reduced by 1.6%.



(a) (b)

Figure 3: Thickness distribution: (a) Before and (b) after optimization.

4 CONCLUSIONS

Regarding the optimization technique we developed a strategy based on an adaptive response surface method where at each response set the minimum of objective function is found taking the constraints into account. Three inequality constraints functions were defined to avoid necking and wrinkling. Overall satisfactory results are obtained to achieve a better control of the strains in the sheet. The methodology has been also used to control the blankholder force during the punch displacement [8].

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