Quantifying the amount of restraining due to friction in the different areas of drawing tools: a numerical analysis

Eneko-Saenz-de-Argandona[1*], *Alaitz* Zabala[1], *Ainhoa* Guinea[1], *Daniel* Cañizares[2] and *Joseba* Mendiguren[1]

[1] Mondragon Unibertsitatea, Loramendi 4, Mondragon 20500, Gipuzkoa, Spain
[2] Autoform Engineering S L, Carrer de Joan d'Àustria, 116, 08018 Barcelona, Spain

Abstract. It is nowadays well known that depending on the tool surface topography, sheet surface topography, lubricant nature and amount, and process variables a wide range of coefficient of friction (COF) values coexist in the very same drawing operation. Furthermore, and as shown in a previous publication of the research group, the tool finishing is not homogeneous and different roughness values are observed in industrial tooling. So the question that arrives in this situation is what areas of the tool have a greater impact in the material restraining and therefore more efforts should be applied when polishing them. The present work numerically analyses three industrial drawing operations of big automotive components. A classification of the different areas of the tool is carried out and friction is activated and deactivated in different numerical simulations. A comparison in terms of draw in, material formability (based on FLD), major strain and thinning is carried out. As a result, a classification of the tool areas that most impact have in the restraining of the material is carried out.

Keywords: Tool roughness; coefficient of friction; draw in; forming limit diagram.

1 Introduction

Sheet metal forming through stamping involves the use of specific tooling that is manufactured through machining and polishing to achieve the required surface roughness for functionality. Studies show that surface roughness in tooling is not uniform, with roughness values varying across different areas [1]. Furthermore, surface roughness directly affects friction coefficients and impacts the drawability of sheet metal components [2,3].

The main objective of this research is to identify the tooling areas that most influence material restraining during drawing operations. To achieve this, a zonal differentiation of the tooling is conducted for three industrial drawing processes involving large automotive components. Simulations, utilizing advanced numerical solutions within AutoForm, are performed by alternately activating and deactivating friction in these zones, resulting in variations in material flow. The study assesses draw-in, material formability (based on FLD), major strain, and thinning to determine the significance of each zone in material restraining. Ultimately, the goal is to propose tooling manufacturing strategies that minimize costs while maintaining tooling performance and component quality.

2 Methodology and results

The impact of the different areas of the tooling on the drawability of automotive components was evaluated through numerical analysis. AutoForm R8 forming software was used as the forming simulation code. The research approach included the following phases:

- Components and materials selection: In order to evaluate the importance of the different tool areas, three industrial components [1] were selected as demonstrators as shown in Fig. 1: components with high draw-in values and materials with low mechanical properties were selected.

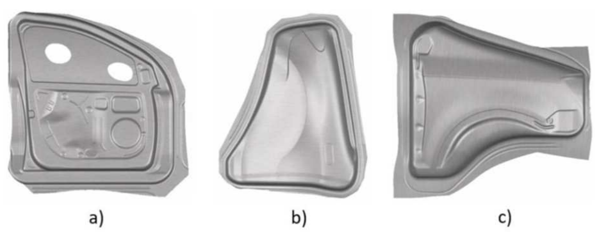

Fig. 1. Selected industrial benchmark: a) steel inner door, b) aluminium fender and c) steel fender

- Zonal differentiation of the tooling. A discretization of the most relevant areas in terms of restraining zones is carried out. Fig.2 shows the selected zones.

* Corresponding author: esaenzdeargan@mondragon.edu

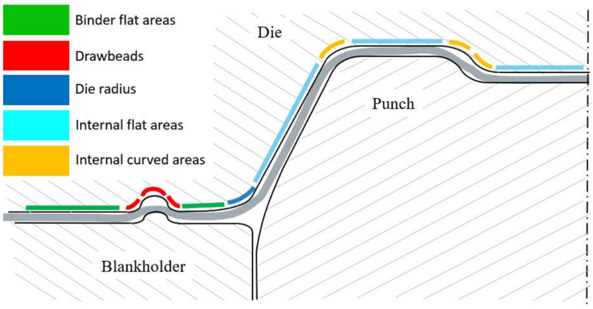

Fig. 2. Schematic representation of the main areas of the drawing tool.

- Friction activation and deactivation at the different zones: taking as the reference situation the absence of friction, so no friction is applied to any area of the tooling zones, seven different variations, where one of the zones was activation at each variation, were analysed for each of the demonstrators.
- Final analysis: the significance of each zone in material restraining was analysed by comparing the draw-in, the material formability (based on FLD), the major strain and the thinning for each of the simulations.

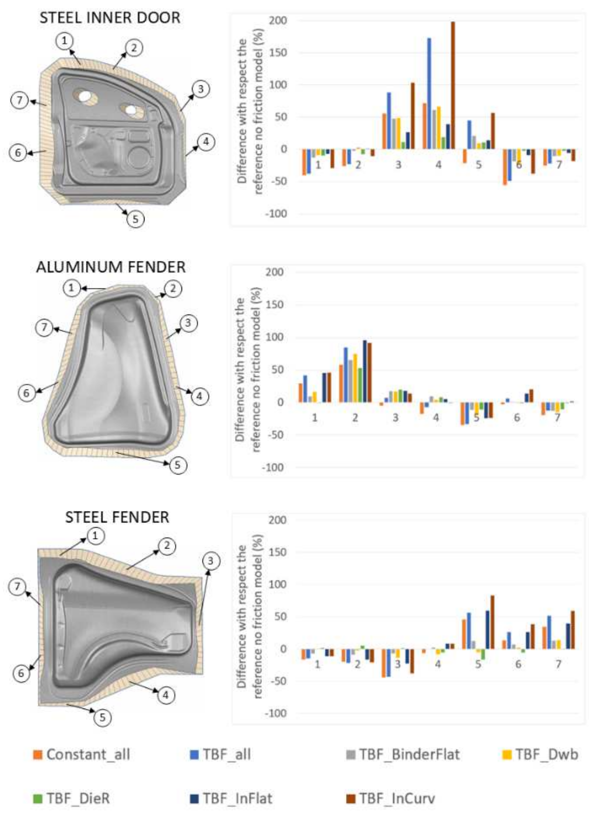

Fig. 3. Draw-in prediction for the three industrial components. On the left side, the draw-in field view under the reference case (no friction model) is shown. On the right side, the difference in draw-in (calculated as a relative percentage to the reference model) is shown for each friction activated area.

At the present technical note the results of the impact of the activated and deactivated zones in terms of draw in and material formability (based on FLD) are presented next. Fig. 3 shows the results regarding the draw-in for the three industrial components. And Fig. 4 shows the FLD diagrams of the demonstrators under the different friction variants.

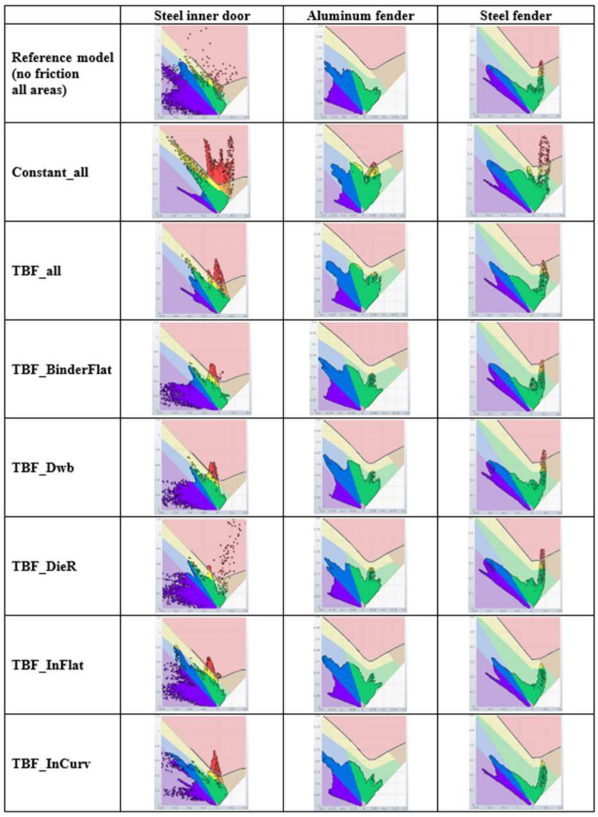

Fig. 4. FLD diagrams for the three industrial components. Major strain (y axes) and minor strain (x axes) are represented.

3 Conclusions

Due to the geometrical complexity of the analysed demonstrators, the observed trends have not always been the same in all the cases.

Concerning the draw-in analysis, the draw-in is mainly affected by the friction coming from the internal flat and curved areas of the tooling. So, when doing the set-up of industrial tools, it is recommended to polish until a good condition is achieved in these areas if the experimental vs numerical draw-in value are compared.

In the drawability analysis based on the FLD, the geometry of the demonstrators play a major role with common results for the aluminium and steel fender which have not been observed in the steel inner door. For both fenders, the area of the die radius, drawbeads and binder play the major role being the effect of the internal flat and curved areas less important. In the case of the inner door, all the areas play a role similar increasing the major strain values in the plain strain area of the FLD.

References

1. A. Zabala, E. Sáenz de Argandoña, D. Cañizares, I. Llavori, N. Otegi, J. Mendiguren, Tribol. Int., **165**, 15, (2022).
2. M. Sigvant, J. Pilthammar, J. Hol, JH. Wiebenga, T. Chezan, B. Carleer, Procedia Manuf., **29**, 7, (2019).
3. J. Hol, JH. Wiebenga, B. Carleer.. J Phys Conf Ser, **896**, 7, (2017).