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# Sensitivity analysis on an AC600 aluminum skin component

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# Sensitivity analysis on an AC600 aluminum skin component

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**Abstract.** New materials are been introduced on the car body in order to reduce weight and fulfil the international CO2 emission regulations. Among them, the application of aluminum alloys is increasing for skin panels. Even if these alloys are beneficial for the car design, the manufacturing of these components become more complex. In this regard, numerical simulations have become a necessary tool for die designers. There are multiple factors affecting the accuracy of these simulations e.g. hardening, anisotropy, lubrication, elastic behavior. Numerous studies have been conducted in the last years on high strength steels component stamping and on developing new anisotropic models for aluminum cup drawings. However, the impact of the correct modelling on the latest aluminums for the manufacturing of skin panels has been not yet analyzed. In this work, first, the new AC600 aluminum alloy of JLR-Novelis is characterized for anisotropy, kinematic hardening, friction coefficient, elastic behavior. Next, a sensitivity analysis is conducted on the simulation of a U channel (with drawbeads). Then, the numerical an experimental results are correlated in terms of springback and failure. Finally, some conclusions are drawn.

## 1. Introduction

The weight reduction trend is driving the automotive industry design and development. Clear example of that trend are the nowadays widely used in BIW press hardening and HSS steels aimed at reducing the weight of the primary structure while maintaining if not increasing the safety standards [1]. Traditionally, the outer skins have been designed in soft thin mild steels [2]. However, the trend in recent times, mainly pushed by some OEM, is to introduce aluminium alloys in those components in order to reduce weight [3]. Although the aluminium is an ideal material from a design point of view, it poses some manufacturing issues at die design level. High anisotropy and high springback, associated to its low elastic modulus, together with a limited formability leads to extensive work on the optimization of the stamping tooling [4].

In this work a sensitivity analysis has been conducted on the simulation of an AC600 aluminium roof panel. The basic idea is to be able to asses which are the critical material parameters to be taken into account in order to accurately predict the forming of the component. First, the material characterization is shown. Next, simulations with different material models are conducted. Finally, the springback and formability results are analysed and come conclusions are drawn.

## 2. Material and characterization

Material behaviour for stamping simulations is mainly divided in three aspects: elastic behaviour, plastic yielding and hardening. The elastic behaviour and the yielding can be analysed by combining standard tensile test and loading-unloading tests, Fig. 1 [5]. The hardening on the other hand can be evaluated using different experimental methodologies such as tension-compression or shear test methods [6]. Another critical input for stamping simulations is the friction coefficient definition. In this case a Strip Drawing tests have been conducted to characterize the contact bahavior between the sheet and the die material.

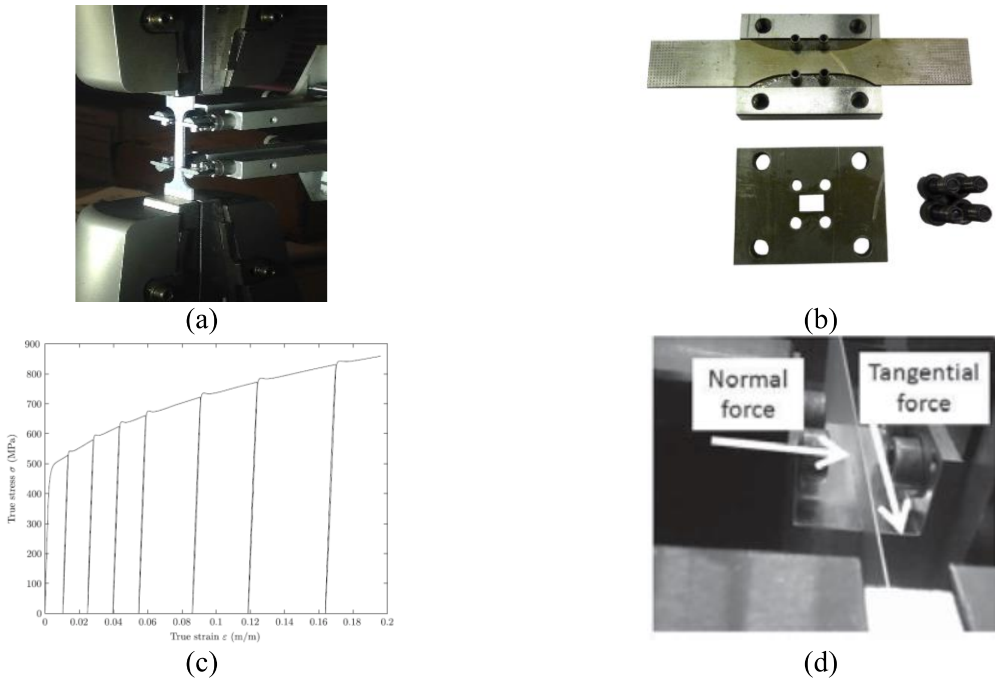


**Figure 1.** Material advanced characterization: a) r values measurement with DIC, b) tension compression tests, c) loading-unloading test and d) Strip drawing test.

Table 1 shows the anisotropy values and the yielding stresses (Rp02) of the analysed AC600 material. It should be noted that the elastic modulus decrease and the anisotropic hardening have been taken from the software database.

**Table 1.** AC600 material anisotropy values.

| Sample | RD | 45D | TD |
|---|---|---|---|
| Yield stress Rp02 | 152 MPa | 144 MPa | 150 MPa |
| r value | 0.636 | 0.344 | 0.802 |

The Strip Drawing test shows an average coefficient of 0.22 in contrast to the 0.14 proposed by the aluminium supplier.

## 3. Roof panel simulation

Figure 2 shows the roof panel simulation conducted on this work in a single action press and with blankholder and drawbeads.

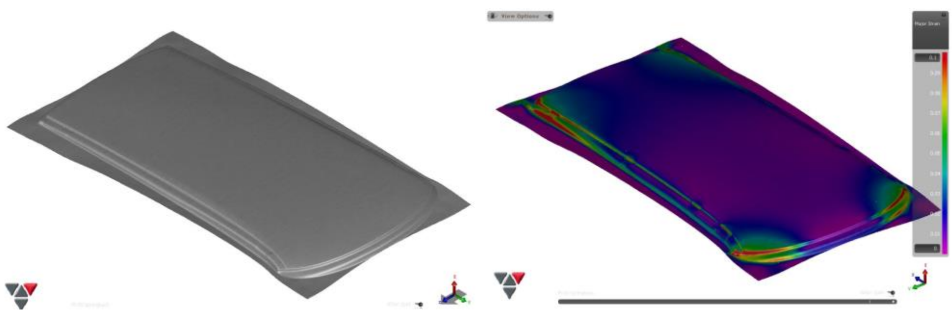

**Figure 2.** Uncoiling process simulation where the residual stresses profile can be monitored.

Different simulations have been conducted in this study. First, isotropic hardening (IH) and mixed isotropic-kinematic hardening (IKH) have been compared. Next, the yielding definition has been analysed from a Barlat 1989 model supposing 0.6 of anisotropy coefficients (Barlat*) to a Barlat 1989 using the real coefficients of Table 1 to a BBC model where all yielding stresses and anisotropy coefficients are used on the definition. Then, the elastic modulus (constant or variable) has been analysed and finally the influence of the correct definition of the friction coefficient.

**Table 2.** Sensitivity analysis model definition

| Model | Hardening | | Yielding | | | Elastic modulus | | Friction | |
|---|---|---|---|---|---|---|---|---|---|
| | IH | IKH | Barlat* | Barlat | BBC | CT | Variable | 0.14 | 0.22 |
| 1 | X | | | X | | X | | X | |
| 2 | X | | X | | | X | | X | |
| 3 | X | | | | X | X | | X | |
| 4 | | X | | X | | X | | X | |
| 5 | X | | | X | | | X | X | |
| 6 | X | | | X | | X | | | X |

## 4. Results and discussion

Figure 3 shows the transverse springback profile in a XZ plane for the models shown in Table 2.

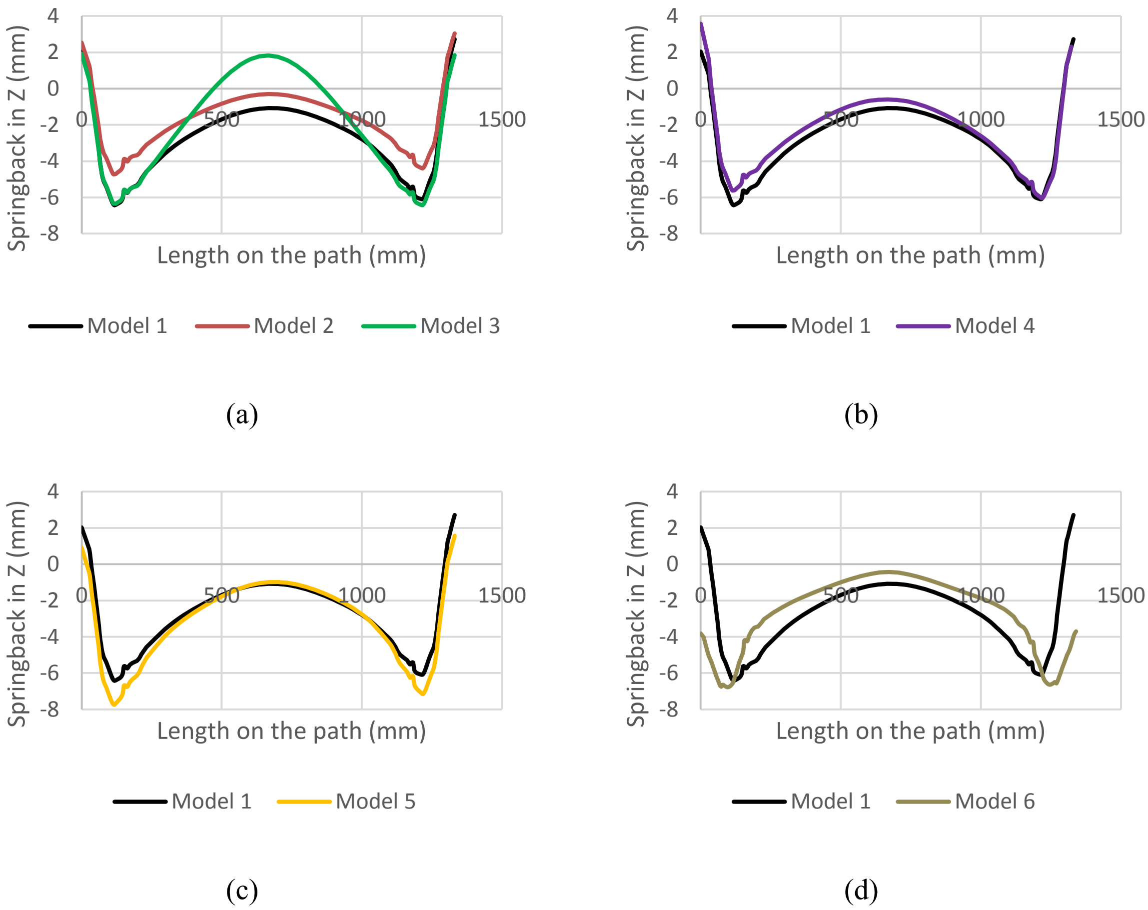


**Figure 3.** Sensitivity of the springback results to the different material inputs: a) Yield function definition, b) Hardening definition, c) Elastic behaviour definition and d) Friction coefficient

Figure 4 shows the forming limit diagram of the different models.

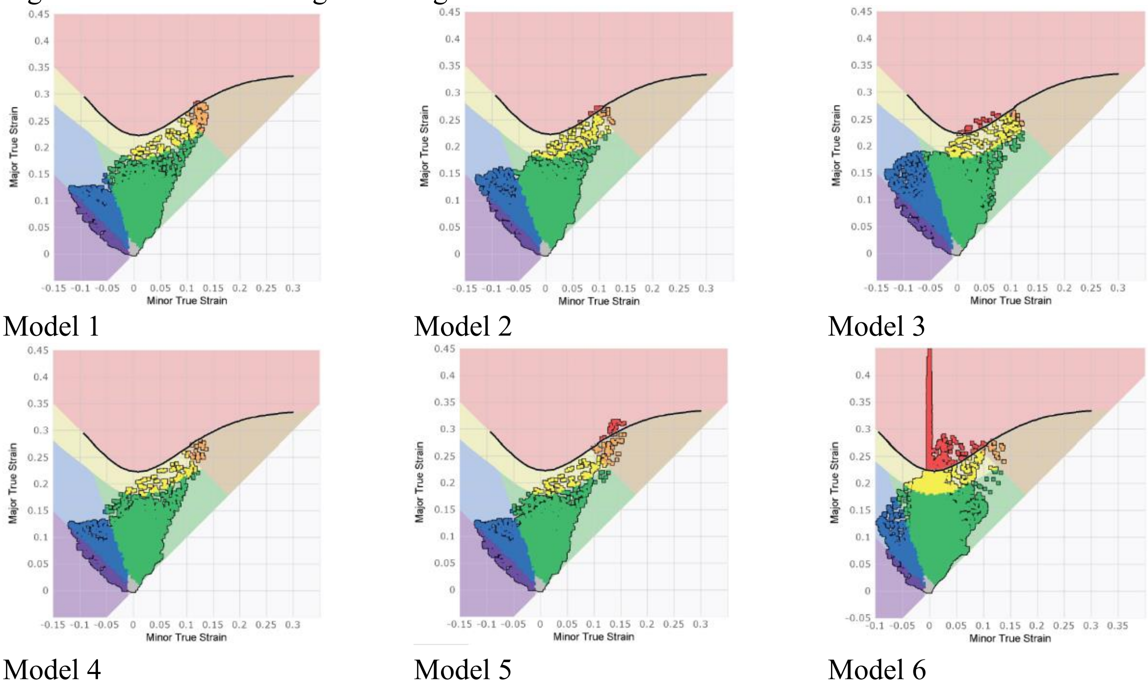


**Figure 4.** Formability results of the different models.

## 5. Conclusions

From the present study it can be shown that for the actual component the yield criteria definition and the friction coefficient are the critical parameters in terms of springback and formability respectively. Differences of almost 4 mm have been found between the use of the Barlat 1989 model and the BBC model while differences of 2 mm have been derived from the correct definition of the anisotropy coefficients. In the case of this component, small influence of the elastic behaviour definition and hardening definition has been found. The friction coefficient on the other hand shows a critical impact on formability where increasing the coefficient the sheet is stretched and therefore the formability reduced.

It has to be noted that these are particular results for this specific component and that a different component could show a different trend.

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