

Friction and lubrication in sheet metal forming simulations: Application to the Renault Talisman trunk lid inner part

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Abstract. More and more automotive companies realize that controlling the tribological conditions in stamping production enables prevention of production issues, increasing overall production stability, and therewith achieving higher quality parts. Therefore, increasing effort is spent in accurately accounting for friction and lubrication conditions in sheet metal forming simulations. In this work, a selection of results for a Groupe Renault case is presented whereby forming simulations are utilized to simulate issues, including splits and wrinkles, observed in stamping production for the Renault Talisman trunk lid inner part. A comparison between simulation results and experimental measurements on parts taken from production is made. This comparison shows that the respective issues can only be simulated accurately when accounting for the actual tribological conditions in stamping production. By doing so, simulation accuracy is increased, now enabling Renault to improve part quality by controlling, adjusting and optimizing the tribological conditions in both in simulations and production.

1. Introduction

The quality of sheet metal formed parts is strongly dependent upon friction and lubrication (tribological) conditions in stamping production, which in turn may cause forming operations either to succeed or fail. Therefore, accurately accounting for friction and lubrication conditions in sheet metal forming simulations is a hot item in the automotive industry today. In fact, recent robustness studies on industrial parts show that the effect of friction conditions is one of the most influential factors in stamping production. See [1] for a study demonstrating that friction conditions can be more influential than the variation of sheet material properties or stamping process settings.

The current industrial standard is to use a constant value for the friction coefficient in metal forming simulations. This limits the overall simulation accuracy, as in reality the frictional conditions between the stamping tools and the sheet material varies locally and in time. That is, the conditions depend on the local pressure distribution, forming velocity, interface temperature, plastic strain of the sheet material, the type and amount of lubrication and the surface topography of both the sheet and the stamping tool.

This paper describes a selection of results of a cooperation between Groupe Renault, Tata Steel, AutoForm and TriboForm, examining production issues including splits and wrinkles observed in stamping production for the Renault Talisman trunk lid inner part. Figure 1 shows the all new Renault Talisman. The respective part and stamping process is described in detail in Section 2. The simulation approach followed to solve these production issues is described in Section 3. In Section 4, a comparison between simulation results and experimental measurements on parts taken from production is made. Finally, a conclusion and points of future work are given in Section 5.



Figure 1. The all new Renault Talisman

2. Stamping process of the Renault Talisman tail-gate inner part

2.1. Tribology system: sheet material, lubricant and die material

An impression of the considered trunk lid inner part is given in Figure 2. The combination of the utilized sheet material, lubricant type and die material is referred to as the tribology system. The sheet material used is a mild steel, VDA239 CR3 GI50/50-E (abbreviated CR3-GI), supplied by Tata Steel. The surface properties of the blanks were determined using 3D confocal microscopy measurements. A sheet surface roughness of $R_a = 1.4 \mu\text{m}$ was observed. The sheet material is pre-lubricated with Quaker N6130. An average pre-applied lubrication amount of 1.0 g/m^2 was observed. The utilized tooling material is GGG70L. The die surfaces are polished and hardened. Die surface replicas were taken in the Renault tool room in Douai to determine the tooling roughness. An average tooling roughness of $S_a = 0.4 \mu\text{m}$ was observed.

2.2. Stamping process and observed production issues

The stamping process of this highly complex part takes place in the Renault press shop in Douai, France using a single action process. An impression of considered trunk lid inner part is given in Figure 2, whereby the critical regions are indicated in the dashed boxes. The regions where splitting or critical thinning might occur in the production part are indicated in red. These locations are visible in the final product and are unacceptable. In addition, wrinkling of the part occurs on the left and right side of the part indicated in blue. Although these effects will not be visible in the final part, they are unacceptable as they may damage the tool surfaces locally.

3. Stamping simulations

3.1. Sheet metal forming simulations approach

This section described the simulation approach followed in this work, as visualized in Figure 3. The sheet metal forming simulations in this study were all performed with AutoForm^{plus} R7.0.3. The material models used in this study are a temperature and strain rate sensitivity hardening curve, with the Vegter yield locus and forming limit curve provided by Tata Steel and as readily available in AutoForm. The material parameters are determined according to the method described in [2] and [3]. All tools in production were digitalized and imported in AutoForm. As significant differences were

observed between the CAD tooling geometry and the digitalized tooling geometry, it was decided to use the latter in the forming simulations.



Figure 2. Impression of the trunk lid inner part after the forming operation with critical regions showing splits or critical thinning (red) and wrinkles (blue)

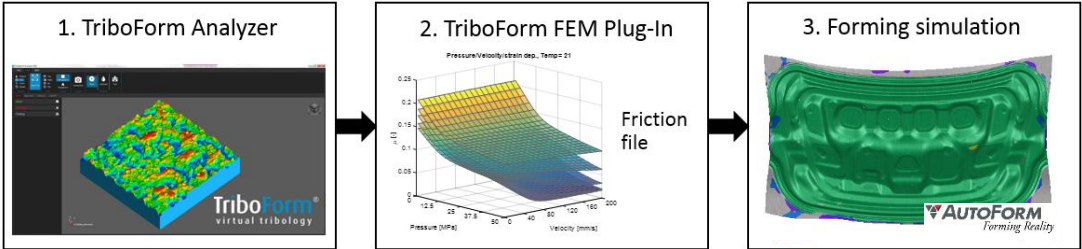


Figure 3. Followed simulation approach for friction and lubrication modelling in sheet metal forming simulations.

3.2. Simulation of friction and lubrication conditions

Currently, a constant Coulomb coefficient of friction of $\mu = 0.16$ is used by Groupe Renault for steels. To more accurately account for friction and lubrication conditions in sheet metal forming simulations, the TriboForm software is used. See Figure 3. The TriboForm software allows for multi-scale modeling of a time and locally varying friction coefficient under a wide range of process conditions. The tribology system information as described in Section 2.1, combined with viscosity data of the lubricant used, enables the creation of a TriboForm Library which includes the friction conditions for the considered tribology system according to the procedure described in [4]. The resulting TriboForm friction models are a function of local contact pressure, straining of the sheet material, relative sliding velocity and interface temperature. The friction model can be imported in the AutoForm software using a FEM Plug-In, replacing the constant coefficient of friction. A more detailed description of this simulation approach can be found in [5].

4. Results and discussion

In this section, a comparison is made between measurements of draw-in, strain and wrinkles made using parts from production with simulation results. AutoForm simulations are performed using a constant coefficient of friction and the TriboForm friction model, referred to as Coulomb and TriboForm friction respectively.

4.1. Production vs. simulation results: draw-in

Figure 4 shows a comparison between draw-in measurements performed on production parts with simulation results for the bottom right corner of the part. The black line in both images represents the draw-in measured for the production part. The red line represents the simulated underpredicted draw-in, and the green line represent the simulated overpredicted draw-in. The simulation results using Coulomb friction are shown in the top image, whereas the simulation results using TriboForm friction are shown in the bottom image. The simulation using Coulomb friction overpredicts the draw-in compared to the production part. Using TriboForm friction improves the draw-in prediction, showing an improved agreement with the draw-in of the production part.

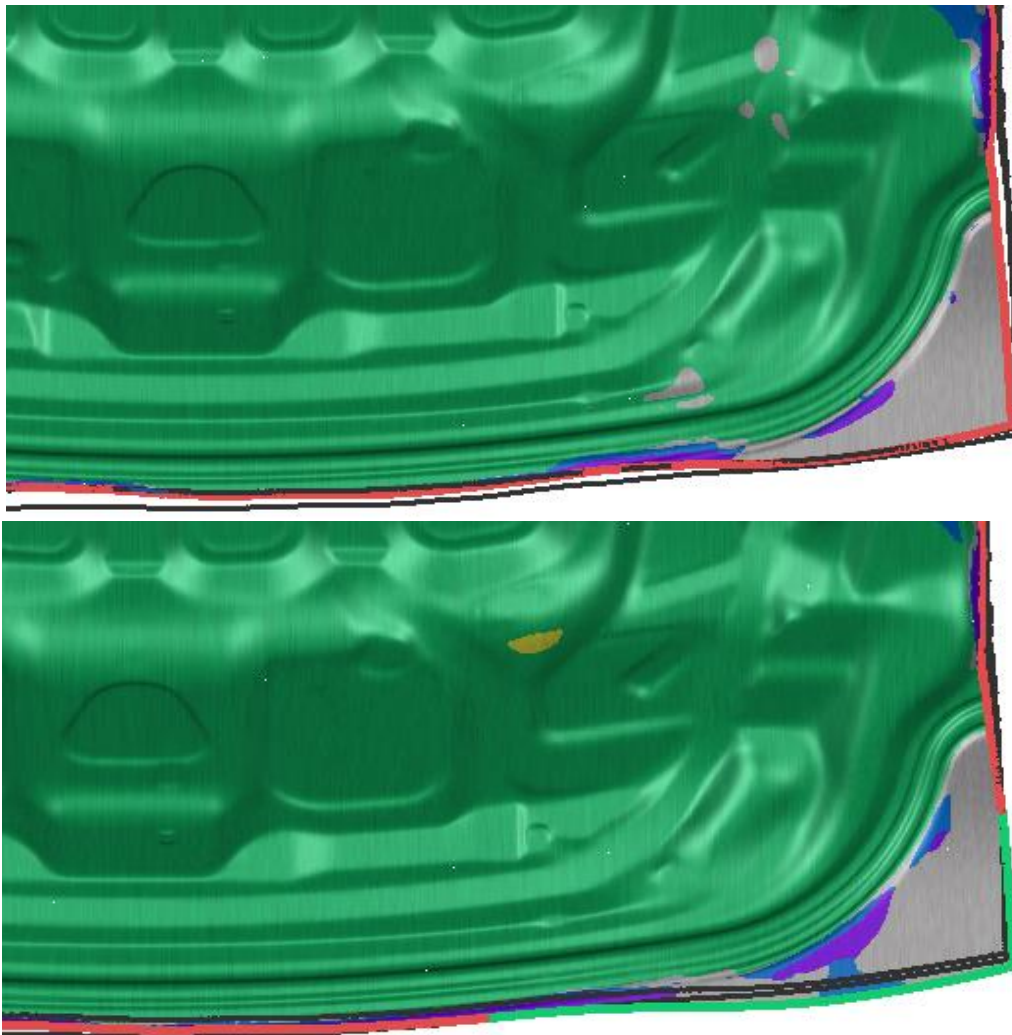


Figure 4. Draw-in measurements performed on production parts (black line) and compared with simulation results (red line for underpredicted draw-in, and green line for overpredicted draw-in) using Coulomb friction (top image) and TriboForm friction (bottom image)

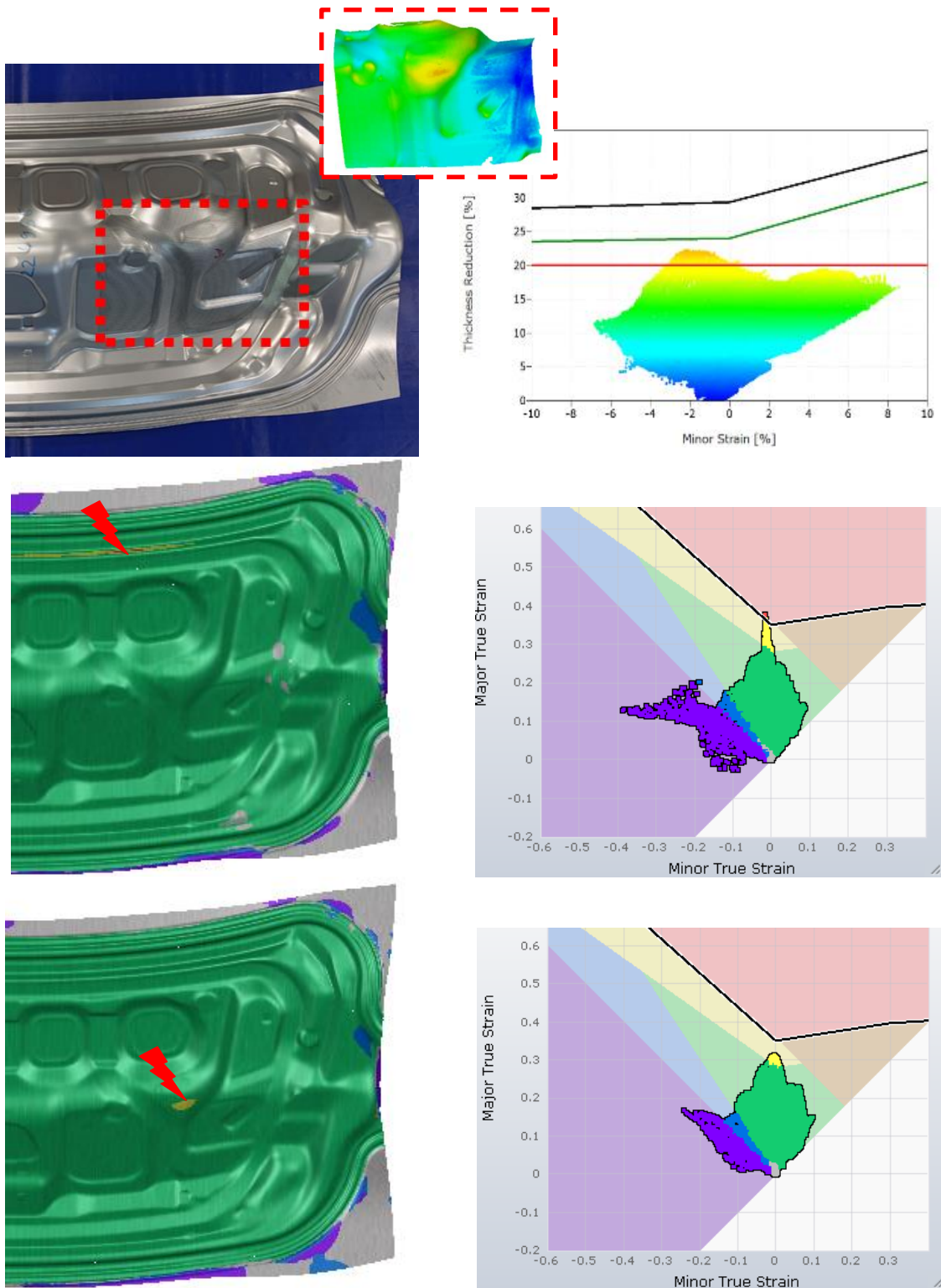


Figure 5. Strain measurements performed on a production part (top images) and compared with simulation results using Coulomb friction (center images) and TriboForm friction (bottom images)

4.2. Production vs. simulation results: thickness and strain

Strain measurements performed on parts from production are shown in the top image in Figure 5. These measurements are performed where the critical strain levels were observed in an area of approximately 300 mm x 400 mm, i.e. the red dotted boxes. The strain results from the forming simulations using Coulomb friction and TriboForm friction are displayed in Figure 5 center images and bottom images respectively. Note that these are the strain clouds representing the entire panel, including the critical area measured on the production part.

The simulation results using Coulomb friction do show critical strain levels. However, the location does not correspond to the critical locations in the production parts. On the other hand, the simulation results using TriboForm friction show the critical strain levels and predict these levels at the locations corresponding to the production parts. That is, the best qualitative correspondence in terms of the location of the critical area between simulations and production part is found using TriboForm friction.

4.3. Production vs. simulation results: wrinkles

Finally, a visual comparison is made between the wrinkles observed in the production part and the simulation results. The top images in Figure 6 shows the wrinkles observed on the left and right side of the production parts. The forming simulation results using Coulomb friction and TriboForm friction are displayed in Figure 6 center images and bottom images respectively. Based on these images, it can be visually observed that the simulations using both Coulomb friction and TriboForm friction can predict the wrinkles observed in production, although the wrinkles in the production part are more severe than numerically observed. Based on a visual evaluation of the results, it seems that the TriboForm friction predicts slightly more severe wrinkling than Coulomb friction, corresponding better the wrinkles on both sides of the production parts.

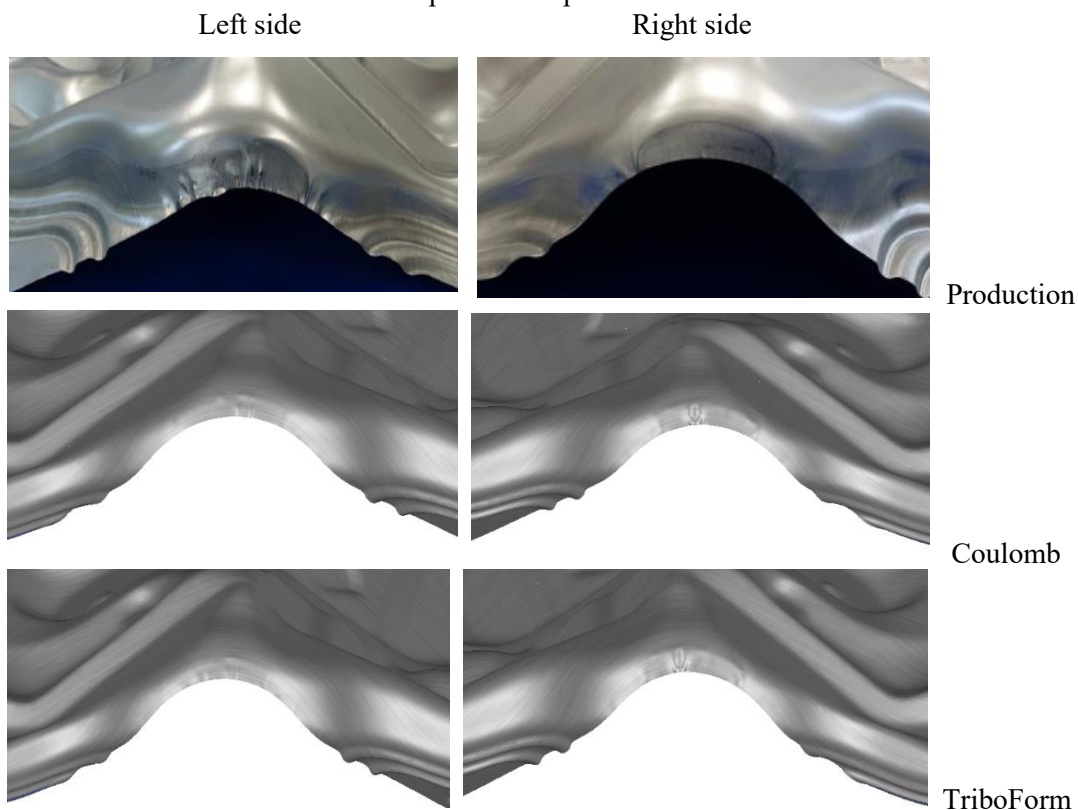


Figure 6. A comparison between wrinkles observed in production (top images) and compared with simulation results using Coulomb friction (center images) and TriboForm friction (bottom images)

5. Conclusion and future work

This work clearly demonstrates the strong influence of friction and lubrication on the part quality of the Renault Talisman trunk lid inner part. More importantly, it was demonstrated that the observed production issues, including splits and wrinkles in the part, could be simulated accurately by accounting for friction and lubrication conditions in sheet metal forming simulations. This subsequently enables Renault to first virtually and subsequently improve it to a safe part. This can now be done by controlling, adjusting and optimizing the tribological conditions both in simulations and production.

Future work of the consortium, led by Groupe Renault, will focus on continuing the implementation of TriboForm advanced friction and lubrication modeling technology into the AutoForm sheet metal forming simulations to further enhance prediction accuracy and finally improve stamping part quality. Specifically, the use of such advanced tribological models for aluminum parts will be considered, as this is considered as indispensable for virtual design of lightweight car bodies.

References

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