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INCREASED ACCURACY IN FORMING SIMULATION OF COMPLEX RENAULT PART THROUGH CORUS-VEGTER MATERIAL MODEL

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Summary. *The accuracy of forming simulations is dependent on the accuracy of the material model used. In this paper, forming simulations of a complex automotive part using different material models are compared to measurements on a pre-production part. The part chosen was the tailgate inner of the Renault Modus. The results show that the Corus-Vegter material model predicted the rupture risk, thinning, strain distribution and draw-in significantly more accurately than the standard Hill'48 and Hill'90 models.*

1 INTRODUCTION

The automotive industry uses PAM-STAMP for formability analyses to reduce the cost and lead time of new vehicle programmes. It can also help to optimise manufacturing processes. Nevertheless, accurate analyses of the feasibility and processing of an automotive part can only be made if the material is modelled accurately. Experience shows[1,2] that for a wide selection of materials the standard plasticity models (e.g. Hill'48 and Hill'90) rarely agree completely with measurements. Therefore, a new material model was developed at Corus Research Development & Technology to increase the accuracy of forming simulations: the Corus-Vegter material model[3]. This model consists of an improved yield locus description and an improved strain hardening description. Together with ESI this model has been integrated into PAM-STAMP as an option of AUTOSTAMP.

The Corus-Vegter material model was first successfully validated in laboratory conditions for cup drawing and stretch forming. A joint Renault, Corus, ESI study was agreed in order to validate the Corus-Vegter material model for an industrial application. The part chosen was the tailgate inner of the Renault Modus. The validation study was done during the tooling development phase preceding pilot production. This paper describes the results of this study.

2 THE CORUS-VEGTER MATERIAL MODEL

The plasticity models that are usually used for stamping simulations, Hill'48 or Hill'90, rarely agree completely with measurements. The Hill'48 yield locus is based on the R-values obtained from tensile tests in three directions: 0°, 45° and 90° to the rolling direction. The

Hill'90 yield locus mathematics permits one additional parameter besides the R-values, often the stress at the equibiaxial point is used.

The Vegter model is based on 4 reference stress points that are measured in three directions: 0°, 45° and 90° to the rolling direction. The four points are: the uniaxial tensile, plane strain, pure shear and equibiaxial stress points. Besides the stress values, the strain vectors (i.e. slope of the yield locus) at these points are also taken into account. A Bezier interpolation function is used between the points to describe the yield locus. As the Vegter yield locus uses all the measured yield locus points, it is the most accurate representation of the real yield behaviour of the material.

In figure 1, the Hill'48, Hill'90 and Corus-Vegter yield loci are compared. These yield loci are used in the simulations described in this paper. Clear differences between the Hill'48 and the Corus-Vegter locus can be seen at the equibiaxial point. But also significant differences occur at the uniaxial yield point at 45° to the rolling direction. As the Hill'90 parameters were determined using the R-values and the biaxial point, the Hill'90 yield locus is closer to the Vegter locus than Hill'48. However, Hill'90 is also unable to accurately describe the uniaxial point in the 45° direction.

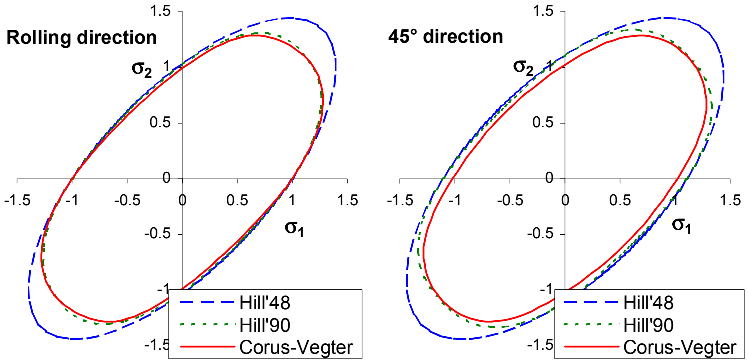

Figure 1. The Hill'48, Hill'90 and Vegter yield loci for DX56D+Z

3 INDUSTRIAL VALIDATION & SIMULATION SET-UP

Renault and Corus chose the rear door inner of the Renault Modus as a test case to evaluate the significance of the increased accuracy of the Corus-Vegter material model on the stamping prediction. The part obtained after the first draw is shown in figure 2. The validation trials were performed in Valladolid, Spain, during the pre-production tooling development for this part. Therefore the results shown in this paper are not indicative of the final production components. The strains resulting from the first draw were measured using the PHAST™ strain measurement system.

Since the intention was to compare simulations with the actual pre-production stampings, Corus used a laser scanner on-site at Renault to obtain the actual geometry of the tools at the time of the stamping trials, rather than the original CAD data for tool cutting. The actual press forces and tooling features such as drawbead geometries, spacers and blank positioning were measured and incorporated in the PAM-STAMP simulation in order to simulate the actual process as accurately as possible. The simulations were performed using Hill'48, Hill'90 and Vegter yield loci in order to compare each model with measurements.

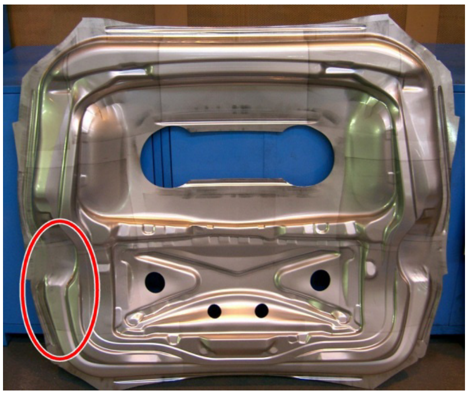

Figure 2. The tailgate inner of the Renault Modus after the first draw. The circle indicates the most critical area

4 RESULTS

Using the PHAST™ strain measurement system large areas of the part were measured. The area of the pre-production part that was found to be the most critical is indicated by the circle in figure 2. In figure 3 the measured and calculated risk of rupture (i.e. distance to the FLC) is shown for this area. The measurements were imported into PAM-STAMP to be able to set the contour colours exactly the same as for the simulations. From the contours it can be seen that the rupture risk is underestimated by the Hill'48 model while it is overestimated by the Hill'90 model. The Corus-Vegter model is closer to the measurements. The values of the maximum thinning in this area make the difference even clearer. The maximum thinning measured in this area was 25%. Hill'48 and Hill'90 predicted a maximum thinning of 18.5% and 31.1% respectively, while the Vegter model predicted 26.5% thinning.

Correlation of calculated and measured strain distributions is made in figure 4 using the forming limit diagram (FLD). In order to make this figure clearer, the outline of the FLD points of the simulations are shown instead of the points themselves. For the plane strain region (coloured yellow) the results of the Vegter model coincides almost exactly with the measurements. Hill'48 shows a skewed strain distribution, while Hill'90 over-estimates the strains.

The simulated FLD's show more points in the pure shear region (deep drawing conditions) than the measured FLD. All of the simulations predict more material draw-in than was seen in reality. This is confirmed by the position of the edge of the blank relative to the drawbead in figure 3. The error for material draw is larger with Hill'48 than with Hill'90 or Vegter. The differences in draw-in between the simulations and reality could be caused by the tooling spacers. The spacers make it very difficult to accurately model contact with the blankholder.

Increased accuracy usually comes with a penalty of increased CPU time. For the simulations of this part, the Corus-Vegter model used only 5% more CPU time than the Hill'48 model, and only 1% more than the Hill'90 model. (Note: the differences in CPU time may vary from case to case.)

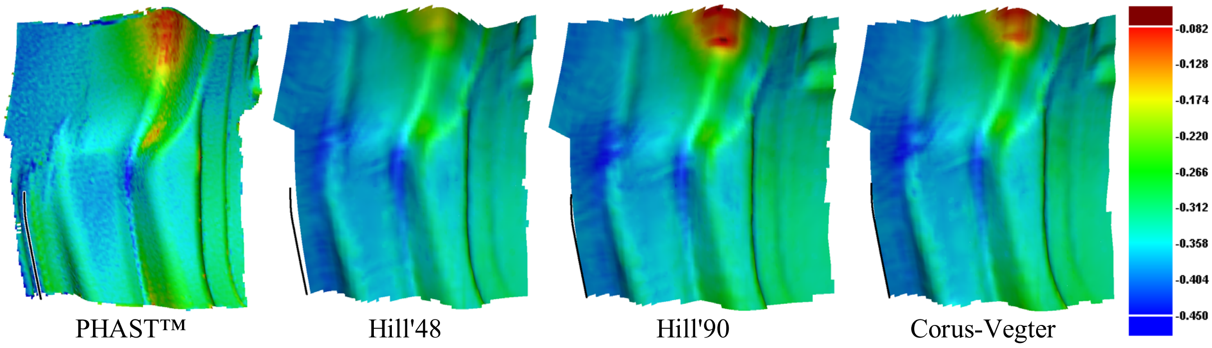

Figure 3. Rupture risk contour of the most critical area. The black line indicates the position of the drawbead.

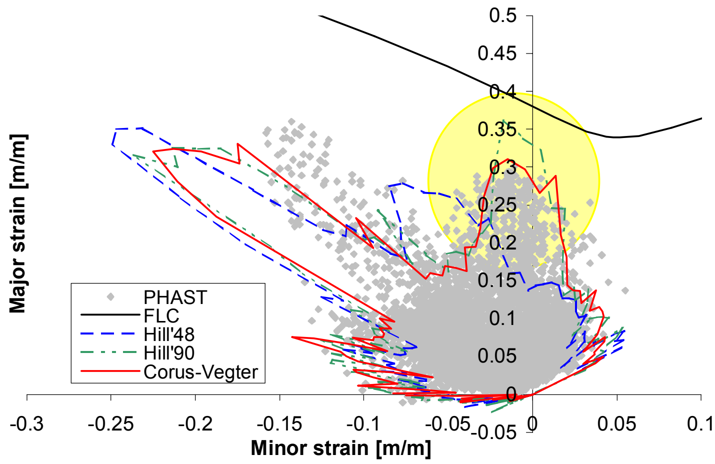

Figure 4. A comparison of the forming limit diagram for the simulations and reality for the most critical area.

5 CONCLUSIONS

- For the Renault Modus tailgate inner, the Corus-Vegter material model predicted the rupture risk, thinning, strain distribution and draw-in significantly more accurately than the Hill'48 and Hill'90 models.
- The increased simulation accuracy is obtained at a very modest increase in CPU time.
- The increased simulation accuracy can reduce the cost and time needed to check the feasibility of automotive parts and to design and modify the tooling.

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