Exit Report

Project Title	Modelling of Sheet Metal Forming
Project Number	ME97033
Cluster	Modelling of Forming of Metal and Laminate Products
Author	A. Selman University of Twente Netherlands Institute *for* Metals Research
Project Leaders	J. Huetink & A.H. van den Boogaard

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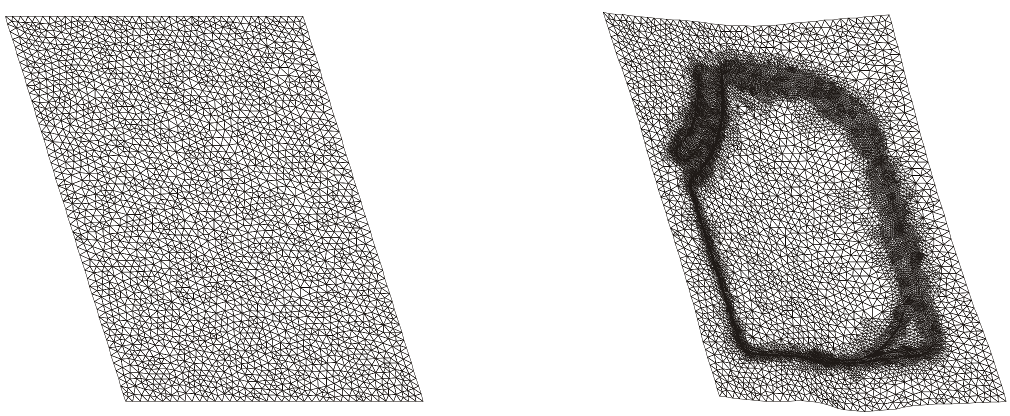
I have been working for the NIMR (Netherlands Institute *for* Metals Research) for the last 3 years under the leadership of Prof. J. Huetink and A.H. van den Boogaard at the University of Twente.

My work has been dedicated to the improvement of numerical simulation in thin sheet metal forming processes in terms of accuracy, reduction of the computational cost and addition of new features.

With this objective, in the first part of my work a discretisation error estimation routine has been developed to better approximate the thickness distribution as well as the geometry of the formed products, as these play major roles in numerical simulations of forming processes. The routine was subsequently linked to an adaptive mesh refinement process.

Consequently, the numerical simulation of the forming of complex products that could not be carried out to a desired accuracy (at a reasonable computational cost) such as the Audi front door panel (benchmark NUMISHEET '99) presented in Figure 1 can now be easily examined. Figure 1 shows the initial (coarse) mesh and the final (adapted) mesh for the forming process of this product.

It should be noted that in the absence of adaptive mesh refinement, a uniform mesh of approximately 90000 Elements would be necessary to achieve the same order of accuracy in the results as that obtained with adaptive mesh refinement which necessitates 26400 Elements only in the final mesh.



Initial Mesh 5550 Elts

Final Mesh 26400 Elts

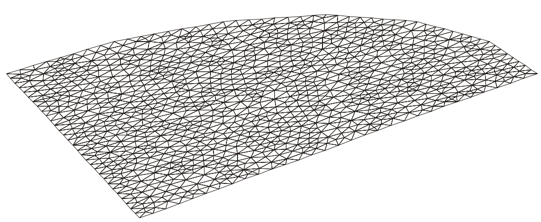
Figure 1 – Adaptive Mesh Refinement (AUDI front door panel - benchmark Numisheet '99)

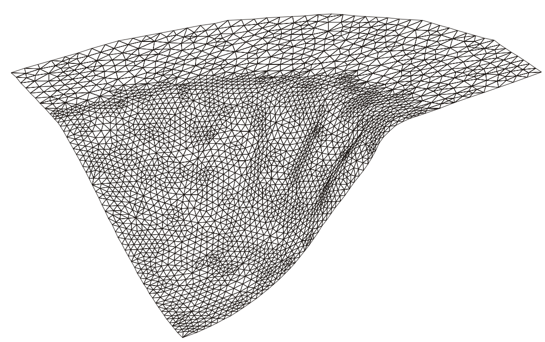
The next subject that has been considered was wrinkling as this phenomenon is becoming one of the most troublesome modes of failure in sheet metals during stamping and other forming operations mainly because of the trend towards thinner, high-strength sheet metals.

The methods used in the past to predict wrinkling failures in sheet metals have been mostly empirical and have, unfortunately, proved to be inadequate for predicting observed trends.

In a numerical simulation, wrinkles can be detected by a visual inspection of the deformed mesh, provided that the finite element discretisation is fine enough to allow a proper capture of the wrinkles. This, in general, makes it cumbersome to proceed with the analysis. Rather, it is desirable to proceed with a selective refinement to keep the computational cost low (acceptable). In this context, adaptive mesh refinement plays an essential role. However, this implies that some kind of wrinkling indicators are used to direct the refinement process.

We first considered the analysis of Hutchinson and Neale, which consists of formulating the problem within the context of plastic bifurcation theory for thin shell elements and its extension by Neale to account for more general constitutive models to develop a wrinkling indicator. Henceforth the indicator was implemented in our DiekA code and, again, linked to the adaptive mesh refinement process.
Figure 2 shows an application to the numerical simulation of the deep drawing of a hemispherical product whereby a high blank holder force is used to avoid wrinkling under the blank holder.



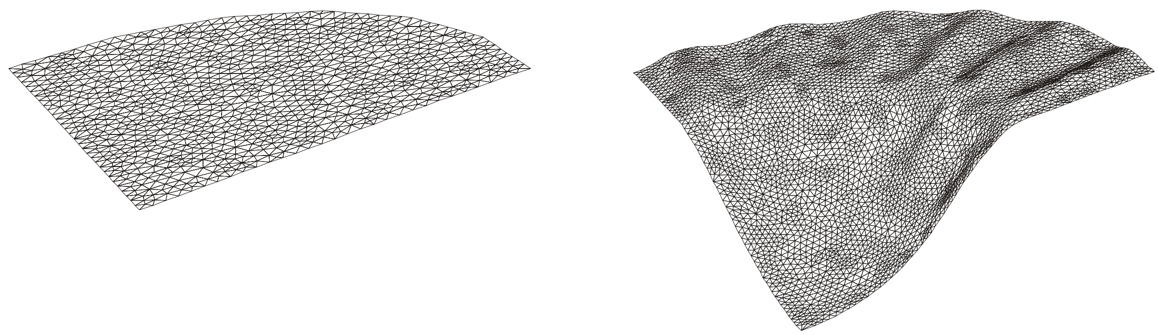


Initial Mesh 2050 Elts

Final Mesh 5400 Elts

Hutchinson analysis is, unfortunately, limited to regions of the sheet that are free of any contact. When contact is taken into account the problem is further complicated. Furthermore, given that numerical simulations of complex sheet metal forming involve large scale models, it is obvious that global wrinkling indicators found in the literature - mostly based on eigen value analysis of the global tangent stiffness matrix - should not be used because of their high computational cost. This is to avoid over-loading the already time consuming deep drawing simulations.
Per Nordlund wrinkling indicator was first considered. When implemented and tested it appeared that this indicator gives good indication only in situations where large rotations under compressive stresses take place. Consequently, an indicator based on the local change of curvatures has been developed, implemented in DiekA and linked to the adaptive mesh refinement process. Figure 3 shows an application of his indicator to the numerical simulation of the deep drawing of a hemispherical product under a low blank

holder force. As can be seen, the wrinkling (with contact) under the blank holder has been spotted by the wrinkling indicator and a mesh refinement is ensued.



Initial Mesh 2050 Elts   Final Mesh 8150 Elts

Figure 3 – Wrinkling with contact predication with Adaptive Mesh Refinement.

We have been asked on a number of occasions on how do our numerical simulations compare with experimental testing. To answer this question and to conclude this work, we have asked our industrial partners at CORUS to perform some experimental testing on the hemispherical product.
A good agreement has been observed between the numerical and experimental results in terms of location, onset and modes of wrinkling. However, it is also found that the numerical analysis tends to overestimate the real amplitudes of the wrinkles.

A number of reports, journal papers and conference contributions have been written in the subjects treated in my work of which a list is given in the next page.

Publications

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Submitted to Int. J. of Forming Processes, 2001.

A. Selman, T. Meinders, J. Huetink and A.H. van den Boogaard
Comprehensive approach to wrinkling prediction analysis in thin sheet metal forming processes
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On Adaptive Mesh Refinement in Wrinkling Prediction Analysis
Extended abstract sent to ESAFORM2002.

A. Selman**,** T. Meinders, J. Huetink and A.H. van den Boogaard
Comprehensive Adaptive Mesh Refinement in Wrinkling Prediction Analysis
Extended abstract sent to NUMESHEET 2002.

A Selman, E. Atzema, T. Meiders, A.H. van den Boogaard and J. Huetink
Wrinkling in sheet metal forming : Experimental testing vs. numerical analysis
To be submitted to Int. J. of Forming Processes, 2002.

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