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REDUCING LOCALISATION INDUCED DEFECTS AT BLOW FORMING IN TERMS OF OPTIMAL SHAPE DESIGN

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Summary. *The problem of cracks occurring during blow forming of aluminium evaporators' channel systems has been addressed. Numerical studies indicated that strain localization in the later stage of the process with subsequent tearing of sheet metal at the channel edge is the primary mechanism of defect formation. We focused on the possibility of reducing the risk of crack formation by changing channel geometry around the critical regions. Appropriate numerical procedures have been designed in order to deal with the noisy numerical response, which makes possible application of automatic optimisation techniques to the related problems.*

1 INTRODUCTION

The problem of cracks appearing after the blow forming stage of the production of cooling system evaporators has been studied. These defects cause loss of output and interruptions in the production process, which has a significant impact on the overall production cost.

Detailed numerical analysis of the process was performed in order to identify the causes for defect formation, which is outlined in Section 2. In order to alleviate the complexity of numerical analyses, more detailed study has been performed on a two dimensional model of a straight channel. Strain localisation has been unambiguously identified as the underlying defect mechanism. An automatic optimisation procedure outlined in Section 3 was set up in order to obtain an improved channel geometry with minimised risk of defect. Appropriate algorithms had to be constructed in order to deal with the inherently noisy numerical response.

2 PROCESS DESCRIPTION AND ANALYSIS

The cooling system evaporators consist of a channel system that is produced by a blow forming process. Two aluminium plates are thermally welded together, one of them being coated by a graphite layer in the desired shape of the channels. Air is then blown into the system under pressure, inflating the channels. During this operation, cracks tend to occur at specific locations in the channel system (Figure 1).

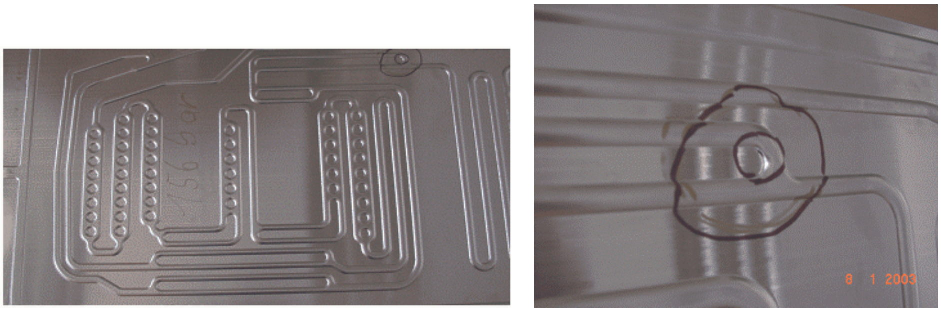

Figure 1: Photograph of a part of the channel system with magnified area around a defect.

In order to investigate the mechanisms of defect formation, the process was numerically simulated (Figure 2) by the finite element method[1] based software Elfen[2]. Three dimensional analyses of details indicated high deformation at locations where cracks tend to occur.

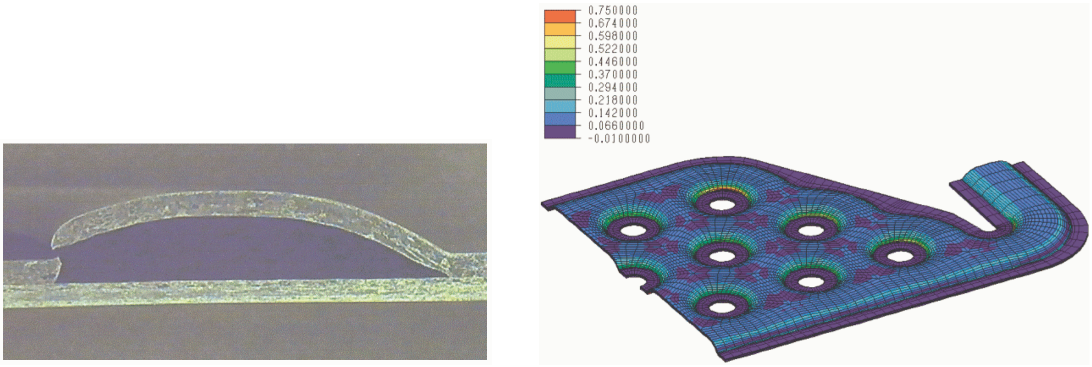

Figure 2: Enlarged channel cross-section showing a defect and numerical analysis of a part of the channel system.

3 PROCESS OPTIMISATION

More detailed numerical study has been performed on a two dimensional model of a straight channel cross-section (Figure 3). Enlarged detail indicates outstanding concentration of deformation around the juncture between lower and upper plate, which is a consequence of cross section geometry. In the later stage, strain localisation makes the process unstable, which leads to tearing of the channel wall.

Strain localisation is manifested by a rapid increase of strain rate, which provides a reliable detection method for the onset of defect formation in the course of numerical analysis. An optimisation[3] problem has been formulated in order to examine the possibility of reducing the risk of crack formation by modifying channel geometry. We have chosen width *d* and maximal height h of the channel as design parameters (Figure 3) and set bound constraints for both parameters in order to prevent large deviations from the original channel geometry, namely $8mm \le d \le 12mm$ and $3mm \le h \le 3.4mm$. We introduced a constraint related to the defect mechanism, requiring that the pressure of onset of localisation $p_l(d,h)$ may not be lower than a prescribed limit value p_0, which was set suitably higher than the final pressure applied in the process. In order to ensure sufficient volume of the channel while satisfying the specified constraints, the objective function was defined as the cross-section area $S(d,h)$ of channel interior attained at the final forming pressure.

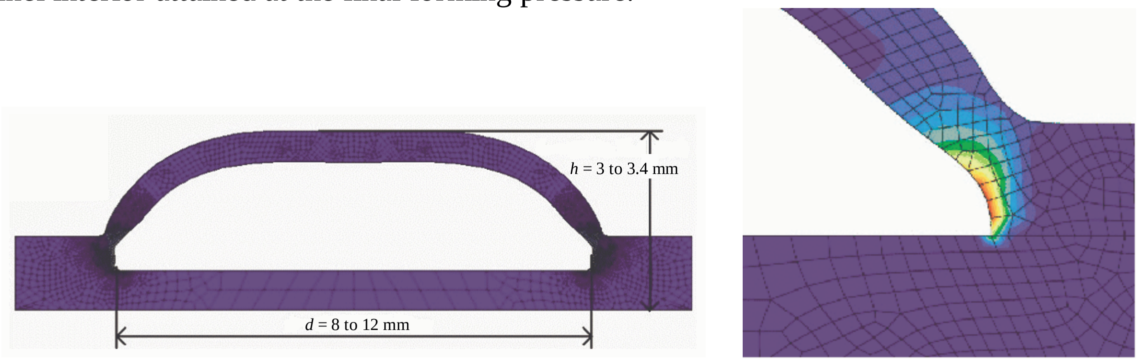

Figure 3: Plain strain simulation of forming of channel cross-section with enlarged region around the juncture between the lower and upper plate.

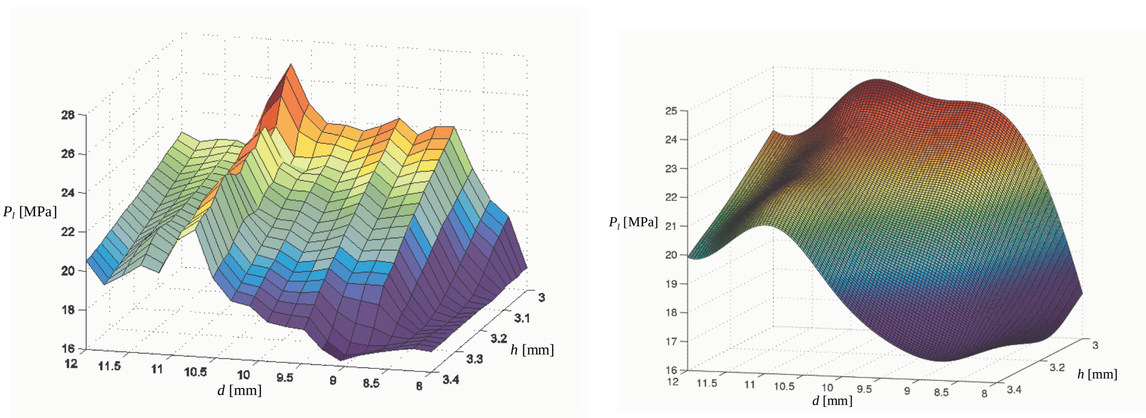

Figure 4: Dependence of the pressure p_l where localization begins on the width d and maximal height h of the channel: sampled on a 20x20 grid (left-hand side) and smoothed response (right-hand side).

A high level of numerical noise represented a major obstacle for efficient accomplishment of optimisation procedure. Smoothing of the response was therefore performed by the moving least squares approximation[4] of the sampled response (Figure 4). The optimisation problem as formulated above, but using the approximated response[5], was then efficiently solved by using the optimisation software *Inverse*[6]-[8] and the FSQP algorithm[10].

Approximations on the basis of sampled data and their visualisation provide a valuable insight into the problem. Beside the response functions mentioned above, some others were simultaneously sampled on the region of interest in the design space, which made possible subsequent examination of different details and eventual reformulation of the optimisation problem in accordance with new findings.

Such approach is not applicable when the design space has higher dimension. A class of perspective optimisation techniques applicable to the described problem is therefore considered, based on combining successive approximation of the minimized function with adaptive sampling, noise filtering and restricted step prototype algorithm. A numerical optimisation library[9],[5] is being constructed as a platform for systematic development and testing of such techniques, with intention to promote exchange of experience and ideas between academic research groups and industrial analysits. The library is currently in the design stage in which basic outline has been set up with some fundamental constituents and testing facilities provided. Short term plans include release of the free open source version of the library and its documentation.

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