PARALLEL ENGINEERING SIMULATIONS BASED ON FORMING SIMULATION OF A HEAT EXCHANGER PLATE

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ABSTRACT

Normally, simulation regarding computational fluid dynamics (CDF), structural mechanics and heat transfer simulations in sheet metal applications are made without a forming simulated part. Instead the simulation is based on especially constructed parts, with some kind of nominal geometry, only for the specific simulation.

This paper presents the use of sheet metal forming simulation of an advanced thin sheet metal part as input to other simulations. Here forming simulation provides input data for different parallel simulations: simulation of computational fluid dynamics (CFD), simulation of structural mechanics and thermal heat transfer simulations. From the forming simulation output e.g. pressed part geometry, it should be possible to use sheet metal thinning, residual stress and strain as input in other simulations later on. However, today it is not trivial to export and use the result from LS-DYNA to the desired application.

We have developed a method for carrying a correct geometry into parallel simulations with input from forming simulated section. A special heat exchanger plate, with intensive and sharp patterns, was developed to study the influence of variations in geometry of the pressing tool. The sheet metal forming simulation was performed with LS-DYNA. A C++ program was developed to calculate new nodes in the surface of forming simulated section. This to be able to created a geometrically correct solid model as input in parallel simulations. A simulation of computational fluid dynamics was performed with forming simulated section of a heat exchanger plate as input to verify method.

Result achieved from forming simulation regarding thickness variation and material inflow were compared with real pressing results for stainless steel material. The comparison showed good agreement between the simulations and the measured parameters on a processed heat exchange plate. Previously the design engineer could actually make real test tools and press metal sheets in the workshop. This is very expensive and even more important; it takes a lot of time. Here the forming simulation is a very powerful tool. Geometrically correct model achieved with described method and forming simulation is possible to use as input in simulation of computational fluid dynamics (CFD). In a similar manner the simulation of structural mechanics and thermal heat transfer are possible to perform with thickness variations instead of nominal geometry.

The sheet metal simulation is nowadays used for a number of different purposes. The main purpose is to detect problems with the tools. The second aspect is to be able to make other useful simulations with the geometry of the simulated heat exchanger plate and it is necessary to be well established in this IT-area to be a competitive manufacturer of heat exchanger plates in future.

KEYWORDS: Forming simulation, simulations, sheet metal forming, parallel simulations, engineering, fluid dynamics

INTRODUCTION

Everybody who works with product design and development knows that it is very important to understand the whole manufacturing process as well as the product itself to be able to design a new product in the best possible way. One of the main processes in engineering design is to be able to forecast the consequences of chosen approaches early on the design stage. If one takes measures early in the design process it is much more cost effective than to make changes late, which could be very costly. Modern simulation techniques provide the possibility to evaluate and predict many different process and product characteristics. These predictions can be made with very good accuracy. These simulation techniques are a powerful resource and a good complement to other IT-based product design tools. Using the simulation tools, the design engineer is able to create user-friendly solutions and also generate cost-effective products.

Even though more industries are discussing possibilities using simulation results from earlier simulations as input for further simulations, there are still many problems concerning this technique. Using residual stresses, strain and thickness variations from simulations of sheet metal forming as input regarding e.g. simulation of computational fluid dynamics (CFD), simulation of structural mechanics and thermal heat transfer analysis in software from different suppliers is not very established today. The importance of optimising an engineering process at an early stage in the design to reduce total cost have been shown in different papers e.g. [1].

In this paper we present the use of forming simulation of an advanced thin sheet metal part as input to other parallel simulations.

FORMING SIMULATION OF A HEAT EXCHANGER PLATE

The design of forming tools for pressing heat exchange plates with are in many ways special. The patterns are intensive with a lot of small designs that are often repeated up to several hundred times. Pressing depth is only a couple of millimetres even if the outer dimension of a heat exchanger plate can have a length of 2-3 m and a width of up to 1,5 m. Typical tool radiuses in these designs are one or a few millimetres. This makes it very demanding regarding computer capacity already at the meshing of elements of the tool. A special experimental heat exchanger plate was designed for comparing simulations with real situations and testing simulation methods. Se figure 1.

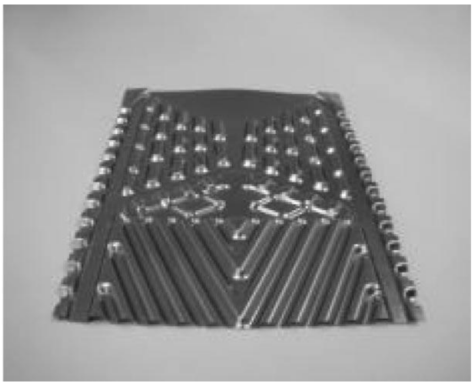

Figure 1: Special heat exchanger plate in stainless steel

This test heat exchanger plate represents only some chosen parts from a real heat exchanger plate and is not a complete commercial heat exchanger plate. Sheet material used in forming operation was stainless steel with a nominal thickness 0,5 mm.

Tool designs are created in Pro/Engineer and thereafter exported from Pro/E in IGES-format. One experience that we observed at an early stage and regarding the meshing of the tool was that maximum numbers of elements was limited in DYNAFORM pre-processor. However, the maximum number of elements is increased in the current release and thanks to this the meshing of the tool is now possible. Pre processing is made within DYNAFORM and as a result from the pre-processing an LS-DYNA input file is generated. The sheet metal forming simulation was performed with LS-DYNA and the results achieved from forming simulation regarding thickness variation and material inflow were compared with real pressing results for stainless steel material. The forming simulation of the complete heat exchanger plate requires so much calculation capacity that it is preferably to dived the product into smaller sections. Each section can then be calculated separately. In calculation we used Belytschko-Tsay element [2] with five integration points through the thickness. Small tool radius also means very small elements locally. In the situation with locally small radius the adaptive method within LS-DYNA was used to decide element sizes. Typical dimensions of the elements used locally are 0,15-0,3 mm. See figure 2.

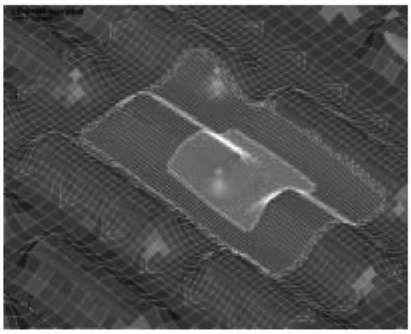

Figure 2: Different element sizes tested

INPUT TO OTHER PARALELL SIMULATIONS

From the forming simulation output e.g. pressed part geometry, it should be possible to use sheet metal thinning, residual stress and strain as input in other simulations later on. With help from the simulation it is possible to receive a pressed heat exchanger plate with these parameters. However, today it is not trivial to export and use the result from LS-DYNA to the desired application. To develop and test our method a section from simulated test heat exchanger plate was selected as input for different parallel simulations. The section is shown in figure 3.

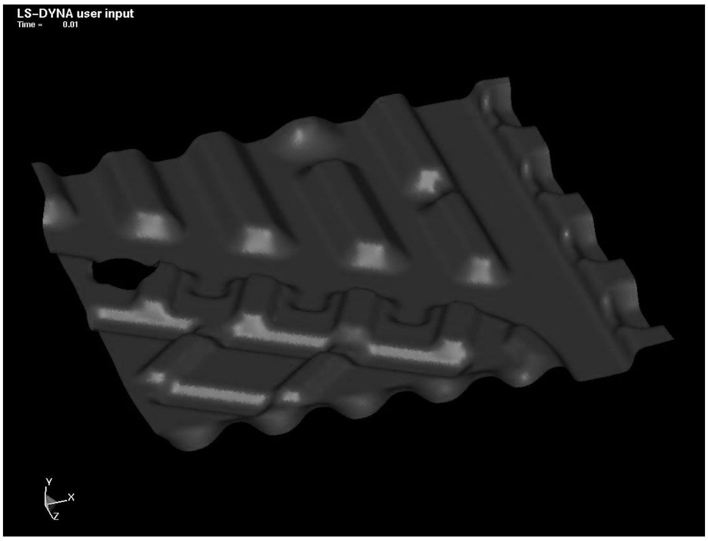

Figure 3: Section of simulated test heat exchanger plate created as input for different parallel simulations

Normally, simulation regarding computational fluid dynamics (CDF), structural mechanics and heat transfer simulations in sheet metal applications are made without a forming simulated part. Instead the simulation is based on virgin material and in many cases also especially constructed parts only for the specific simulation. This means that it takes a lot of time to create the input.

In this work we have developed a method for carrying a correct geometry into parallel simulations with input from forming simulated section [3][4]. LS-DYNA uses shell element when processing the model of the blank. Information regarding cross section of formed sheet metal plate is described as a line in middle of sheet with a thickness value in every node. The thickness value in every node depends on the behaviour in the forming process. To produce outlines out of this information, centre line and thickness value in every node, a new node is created at half thickness value from and perpendicular to the centre line. Curving of the sheet has to be taken in to consideration. See figure 4 and 5.

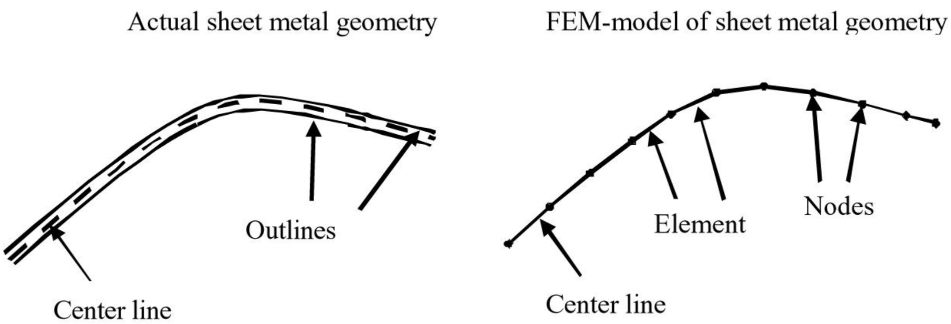

Figure 4: Actual sheet metal geometry and FEM-model of the same

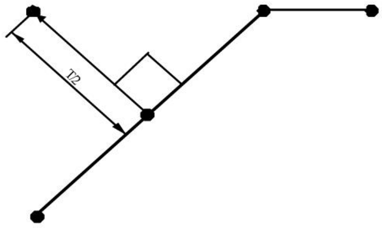

Figure 5: A new node is created at half thickness from original node perpendicular to centre line

A C++ program was developed to calculate all the new nodes in the surface of the solid model. See figure 6. Different methods used to calculate the direction of thickness vector were tested. Using the edges of an element and cross product seemed to be the best possible way to define the direction of the normal to the element and out of these position nodes in the actual surface of the sheet. See figure 7.

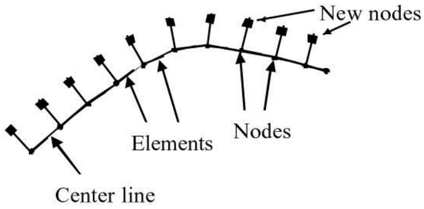

Figure 6: New nodes are creating the outer surface

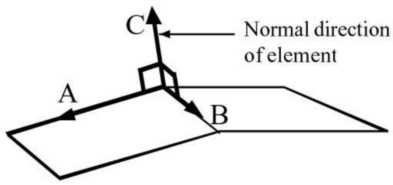

Figure 7: The normal to a element C is calculated from edges A and B

A typical output from developed surface node generation program is shown in figure 8.

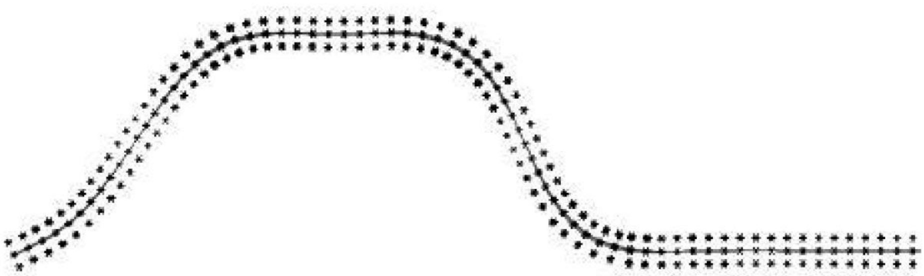

Figure 8: Over, middle and under surface for a thin sheet metal part

A solid model is created from surface nodes and used as input in parallel simulations. Generated upper surface, see figure 9.

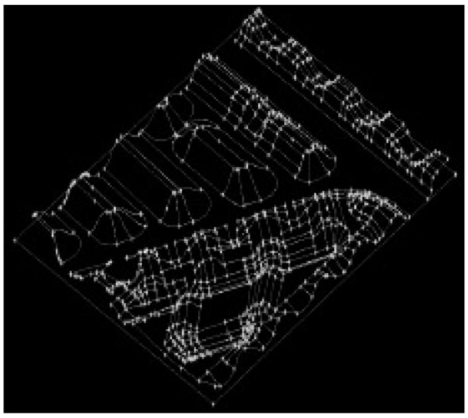

Figure 9: Generated upper surface for input in parallel simulations

RESULT

The forming of a special test heat exchanger plate was made both by simulation with LS-DYNA and by forming in real pressing tool. Results achieved from forming simulation regarding thickness variation and material inflow were compared with real pressing result. The comparison showed good agreement between the simulations and the measured parameters on a processed heat exchange plate. See figure 10.

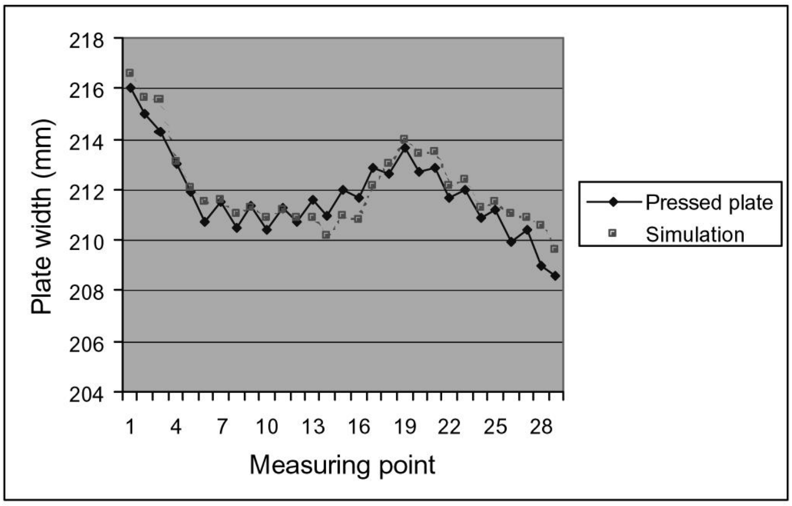

Figure 10: Comparison of outer dimension for pressed heat exchanger plate and simulated heat exchanger plate.

Previously simulation regarding computational fluid dynamics (CDF) analysis in sheet metal applications is made without a forming simulated part. Using a forming simulated part as input to fluid dynamics analysis gives a more exact geometry and it is not necessary to construct a special part only for a specific simulation.

The result shows that it is possible to use the created geometrically correct solid model as input in a parallel simulation. The solid model was in this case created from surface nodes generated from LS-DYNA forming simulation. Surface nodes were generated with a developed C++-program. The result from simulation of computational fluid dynamics performed on a part of the forming simulated section of a heat exchanger plate is shown in picture 11.

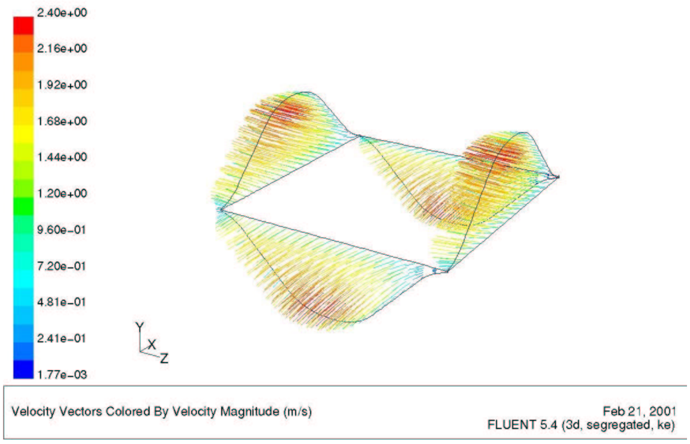

Figure 11: Result from simulation of computational fluid dynamics performed on forming simulated section of a heat exchanger plate

In a similar manner the simulation of structural mechanics and thermal heat transfer are possible to perform with thickness variations instead of nominal geometry and therefore the results could be more authentic than before. So far, the residual stresses and strains have not been taken into account.

DISCUSSION AND CONCLUSIONS

Today engineers use software for simulating the forming of a heat exchanger plate. The main purpose is to detect problems with the pressing tool at an early stage. The second aspect is to be able to make other useful simulations with the geometry of the simulated heat exchanger plate.

In this paper we have investigated how forming simulation of an advanced thin sheet metal part can be used as input to other parallel simulations. A solid geometry was created out of result from forming simulation for use as input in parallel simulations. Account was taken regarding the solid geometry and thickness reduction. Future models will include information regarding residual stresses and strain.

- Forming simulation of heat exchanger plate in stainless steel sheet material is possible with LS-DYNA. However, a very small tool radius and complicated and intense patterns makes it very demanding regarding computer capacity

- Comparison shows good agreement between the simulations and measured parameters on a processed special test heat exchange plate

- Parallel engineering simulations based on forming simulation of a heat exchanger plate is possible

- It is possible to use results from forming simulation as input in simulation of computational fluid dynamics (CFD)

- The communication, interface and possibility to export and import necessary data between different simulation systems has to be improved to avoid the need of a special program

Designing and testing part or complete heat exchangers in a virtual world will be more and more usual. This to be able to create fully optimised heat exchangers for every single customer oriented task. It is necessary to be well established in this IT-area to be a competitive manufacturer of heat exchanger plates in future.

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