**Shape prediction – simulation of dimensional changes in complex steel castings**
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When a casting cools to room temperature, thermal stresses and dimensional changes occur. The magnitude and appearance of the dimensional changes depend on the casting's geometry, temperature and material. These dimensional changes are taken into account during pattern production, to obtain the correct casting geometry after cooling.
Today, the pattern maker often uses experience as a guide to estimate dimensional changes, which in the case of complex geometries can lead to large discrepancies between the desired geometry and the actual result. If the thermal contraction or dimensional changes are simulated by computer before the pattern and casting are designed then any dimensional changes required in the pattern can be taken into account with greater accuracy. This article describes a project between Österby Foundry and the Swedish Foundry Association where the dimensional changes which occur during cooling of a casting were simulated. The component which was studied is a half-ring, which is used in an installation for fusion power. The material is a special steel alloy, and the demands for strength and tolerances are very high.

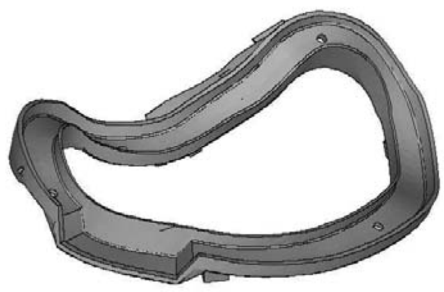

*Figure 1. CAD model of the half ring*

## Problem specification

An important problem with advanced castings is that during cooling they contract non-linearly, and large dimensional changes occur. Many of today's complex cast components have narrow tolerances, which is also a problem. Since the component studied is to be heat treated it is the dimensional changes which occur after heat treatment which are of primary interest. The objective in simulating dimensional changes is to make a pattern with an "incorrect" shape, so that the casting has the correct shape after cooling. For this to be successful the simulation software must be exact, and must be used methodically. With this background the following are relevant questions.

1. Can deformation and dimensional changes in the casting before and after heat treatment be simulated, and how close is the agreement between current simulation software's and reality?

2. Can dimensional changes be transferred from the simulation software's to other computer software's, so that the pattern maker can take these into account?

**Simulation and control of deformation**

Solidification and residual stress simulations were made on the component, both before and after heat treatment. Simulation of the mould filling was not relevant since in this case it has little influence on the result due to a limited thermal effect.
Shrinkage allowance and machining tolerances were added to the original CAD model before simulation was carried out.

The result of the simulation using the software ProCast is shown below in figure 2. The different colours show the deformations in the X and Y dimensions respectively, compared to the original CAD model.

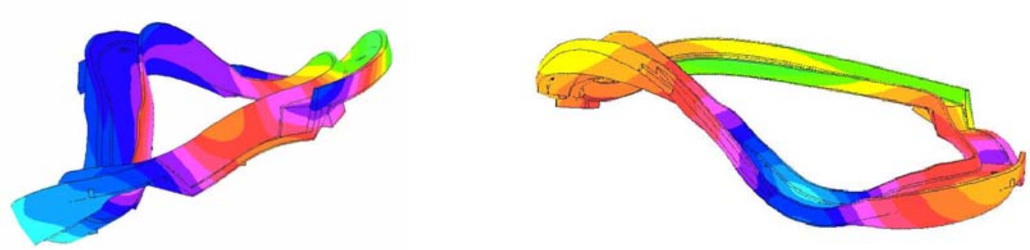

*Figure 2. Simulation of the deformations in the X and Y dimensions respectively*

Figure 3 below shows the simulated Von Mises stresses in the component at room temperature. The left figure shows the time when the casting begins to solidify, and the right figure the casting at 20 °C.

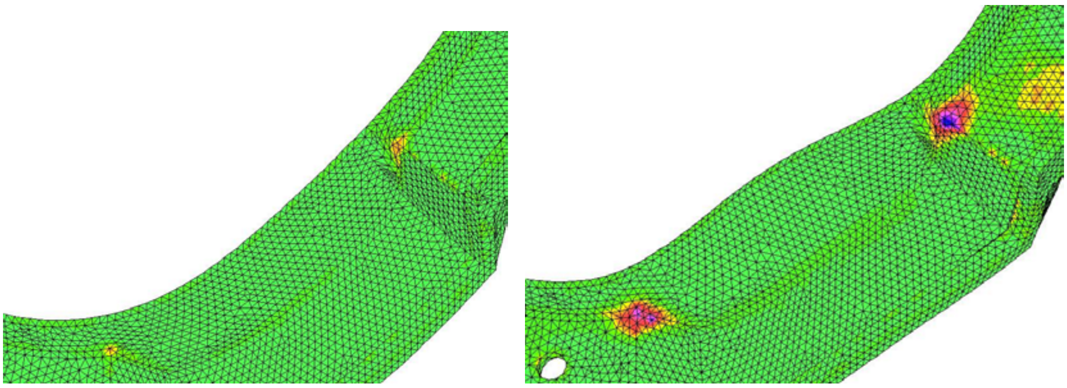

*Figure 3. Simulation of residual stresses*

By overlapping the models in the simulation software it is easy to see how much the casting deforms (figure 4). The black model is the original and the green model the simulation, i.e. the deformed one. For ease of comparison the dimension changes are magnified about ten times in this illustration.

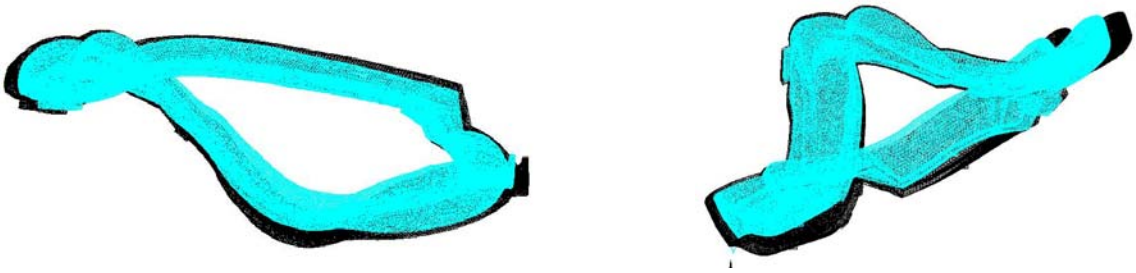

*Figure 4. Comparison between the simulation and the original model*

To validate the simulation against the actual result advanced laser measurements were made on the casting before and after heat treatment. The laser measurements were made using a camera-like nozzle, which one passes over the casting. The laser measures thousands of points on the casting, which are registered in a special software; "Metris CADcompare." From these points, the software can build up a CAD model of the casting. By comparing this with the original CAD model, any differences were identified. The figure below shows these in different colours.

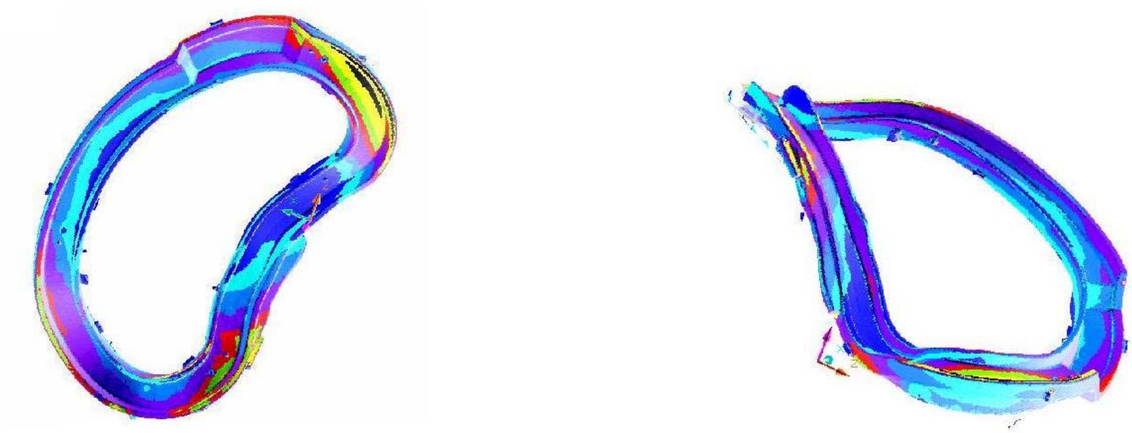

*Figure 5. Comparison between the actual result and the original model in "Matris CADcompare."*

From these differences various parameters in the simulation software could be adjusted, to obtain a good agreement with the actual result. Parameters which influence the result are for example material data, particularly for the mould and core.

**Transfer of the simulation results**

The next problem was to investigate how results from the simulation software can be imported to a conventional CAD software. It is of course possible to estimate dimensional changes with the aid of coloured pictures from the simulation results, and then manually adjust the model. However, with advanced castings such as the current component this is complicated, and it is advantageous to be able to automatically import the dimensional changes into a CAD programme.

So that the pattern maker can adjust the pattern so that the casting geometry is correct after casting and heat treatment, the dimensional changes must be inverted. Using the simulation software Procast an inverted model was produced automatically. The inverted dimensional changes in the x, y and z dimensions for each node (mesh) were fetched as a text file, and then read into Metric CADcompare, which was used to create a new CAD geometry for the simulated deformations. This CAD geometry was then used by the pattern maker.

## Summary

This article describes the possibilities to simulate stresses and deformation in castings, which can then be imported to a CAD software. This makes it easy to visualise dimensional changes and deformations which can arise in a casting during cooling to room temperature. If this becomes practically applicable, and the pattern maker dares to make a pattern with the “wrong” shape then the casting industry can save a great deal of money.

## Swedish Foundy Association

The Swedish Foundry Association (Svenska Gjuteriföreningen) is the research, trade and educational organization of the Swedish foundries. The foundry members represent more than 99% of the total production. Suppliers, casting buyers and other Scandinavian companies are also members of the Association.

The Association is helping the foundries in all aspects of their work. For example casting design, work environment, logistics, metallurgy, production-simulation, production-technique and engineering. The Association has extensive cooperation world wide.
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