Early Optimization of Large Water Transport Pump Casing

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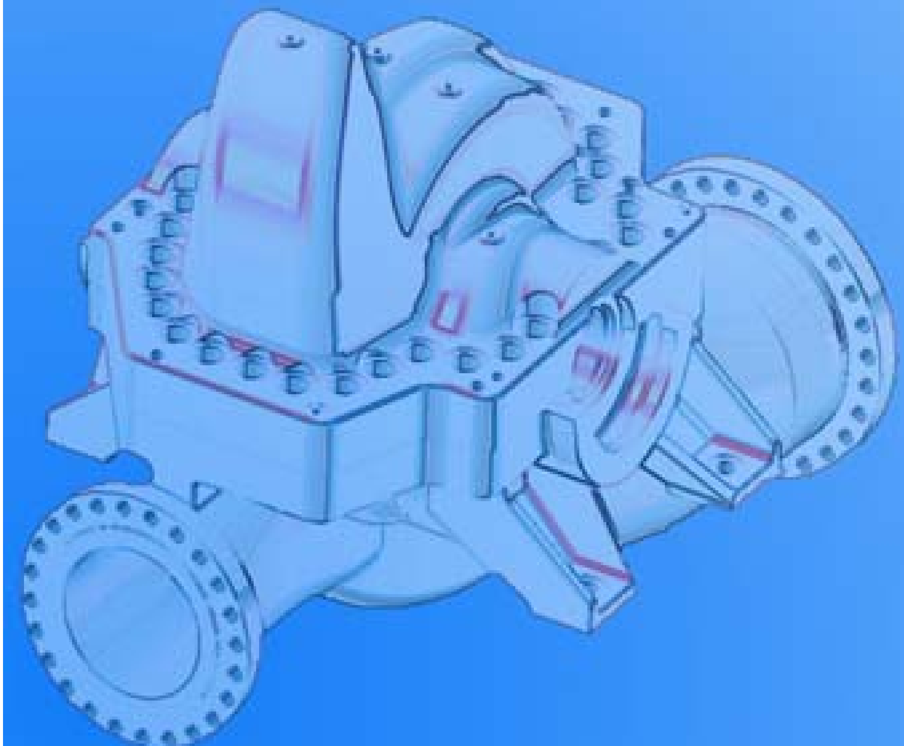
For the irrigation and drinking water supply in the dry regions of the earth, water must be pumped over long distances and, in some cases, large differences in altitude must be overcome. Sulzer HPDM pumps are specifically designed for these tasks, with large volumes up to more than 100 m^3/min and pressures up to 60 bar. The casings are designed and optimized on the computer with computer-aided design (CAD). Through the application of Finite-Element calculations, tests for leakage and deformation can be performed at an early stage. Compared to pressure testing after the manufacture of the pump, this option translates into considerable costs savings and reliable delivery dates for the customers.



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The HPDM 600-940-s+s/30 pump produces approximately 9 MW in power. The finished casing weighs 26 tons and consists of a horizontally divided casing that is held together by studs (Fig. 1). In a typical two-stage pump of this kind, the two impellers are arranged back-to-back, which minimizes the axial thrust on the shaft. During the design phase, particular attention is paid to the adaptation of the casing to the internal pressure.

Hydraulic Design

The design of the pump begins with the hydraulics. After the impellers are designed, the flow channels in the casing are laid out on the basis of the computational fluid dynamics (CFD) calculations so that the power loss will be reduced as much as possible. The modeling of this geometry takes place in a 3D CAD system.

Construction of Pump Cases

The design department imports this geometry and draws up a 3D CAD model of the casings from it (Fig. 2). After the preliminary design of the casing, in which the wall thickness and the thickness of the separation flanges are designed, the number and diameter of the studs that clamp together the two halves of the casing are determined. Next, the material is modeled around the flow channels in the calculated wall thicknesses in the 3D model; the hydraulic model thereby serves as a negative pattern.

The through holes for the studs in the upper casing are positioned as evenly as possible along the hydraulic contour in the design; the separation (wall thickness) between the bores and the hydraulics in the upper and lower parts of the casing is checked. The three-dimensional modeling is very helpful in the positioning of the studs: The distance between a bore and the neighboring hydraulic surfaces can be measured very quickly in three-dimensional space. After the positioning, the outer contour of the separation flange is determined with a defined separation from the “hole run.”

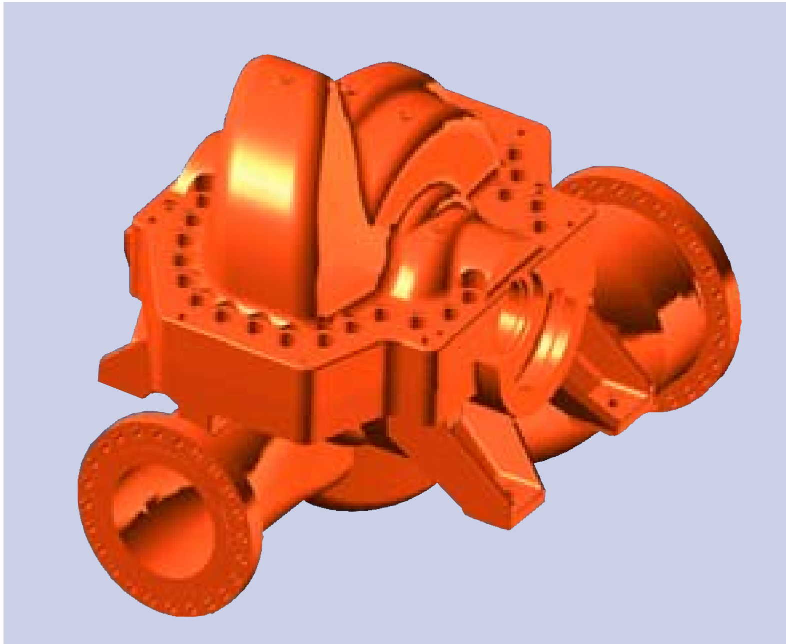
The three-dimensional CAD model of the casing can be used for the subsequent casing calculation. The adaptation of the model takes place in a close discussion between the design department and calculation groups. Moreover, the three-dimensional CAD model can also be used for the modeling of the casting process.

Early Problem Detection Using the Finite-Element Method

In order to avoid leakages, the casing is optimized on the computer, which is more cost-effective than a possible adaptation during the test phase of the pump. With the Finite-Element method (FEM), the mechanical behavior, i.e., the deformations and the internal tensions derived from these changes, can be calculated for any arrangement of components and modules and their loads. Through these calculations, problems can be identified and corrected already during the development phase.

1 The HPDM 600-940-s+s/30 pump produces around 9 MW of power. The finished casing weighs 26 tons, and consists of a horizontally divided casing that is held together with studs.

2 Completed CAD model of the casing of the HPDM 600-940-s+s/30 pump. This geometry will be transferred to the FEM system.

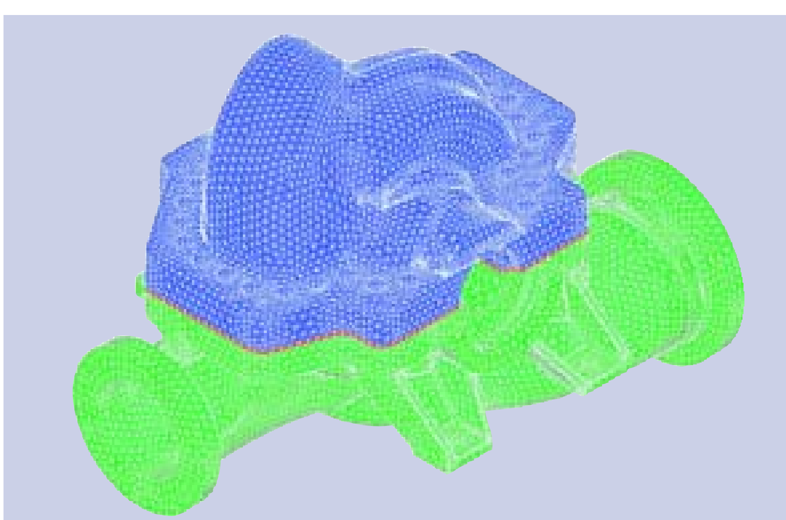


The modified geometry is passed on to a FEM program in the three-dimensional format of the CAD system. The goals of the Finite-Element calculation are to:

- check the leak tightness between the upper and lower halves of the casing
- examine the leak tightness at the bores of the shaft seal
- determine stresses and deformations in the casing
- establish the stud loadings

The correction of a seal leakage detected by this analysis during the development phase can be accomplished much more easily rather than performing later modifications on the test bench. If the pump has already been built, the arrangement of the studs, for example, can no longer be changed. The use of the FEM analysis saves money despite the cost of the calculation.

3 FE model of the pump casing. Here, the model will be supplemented with the flat gasket. Afterwards, the calculation grid shown is fitted onto the 3D model.



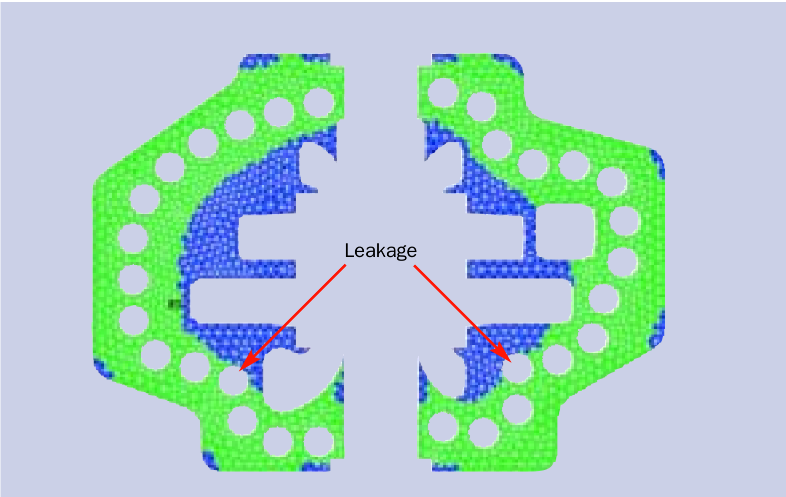
Furthermore, early detection also avoids the delays in delivery that could arise if the pump spends a long time on the test bench and has to be modified so that it can pass the required pressure test. The customer benefits from cost savings and on-schedule deliveries.

Correction of Deformations

The casing geometry is supplemented by the flat seal in the FEM program before the grid generation necessary for the calculation takes place (Fig. 3). The volume of the casing is thereby divided into a very large number of simple geometrical elements (called tetrahedrons), each of which can be calculated individually. The deformations of the complete casing result from the deformations of each individual element. Finally, the studs are inserted as bar elements and the calculation of the load cases "design" and "test pressure" takes place.

In one instance, the calculation showed that the casing would not remain leak-tight under the test pressure (Fig. 4). Water would penetrate into the stud bores. As a result, the following design modifications were carried out step-by-step, and were checked on the computer:

- The flanges both above and below were thickened. The stiffer flange makes a more even loading of the seal possible.
- The bore arrangement for the casing bolts was changed. The studs that were located toward the inside of the contour were shifted outwards so that they would be less exposed to the pressure area.
- The upper and lower halves of the casing were stiffened in or-



4 For a certain HPDM pump, the calculation showed that the casing would not remain sealed under test pressure (blue areas). Water would penetrate, particularly at the two studs that intrude into the hydraulic contour.

der to achieve a more even seal loading. The other areas of the upper half are more rigid by their nature, due to the overflow channels.

The modifications were then transferred to the CAD model, and were later checked with a hydro test (Fig. 5). This loop between design and calculation can be repeated as often as desired until a satisfactory solution is found.

Early Detection Saves Money

Correcting a leakage after the pressure trial is very complicated and time-consuming; it is therefore a very expensive undertaking. The consistent design process using three-dimensional design and calculation tools and numerical casing analysis in this process saves money. In addition, the test phase can be successfully completed and the pump delivered on schedule. ◀

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5 Here, the casing deformation at test pressure is shown before (left) and after (right) modifications. The changes in the sealing are then imported into the CAD model.