Developing the largest size pump in dredging industry

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ABSTRACT

As the demand for larger dredgers rises, there is a growing need for developing bigger dredge pumps that can reach up to 1,800 mm diameter.

At its locations in the Netherlands and UAE, Dredge Yard is developing dredge pumps that will be among the biggest in the industry, with suction diameter up to 1800 mm in diameter. Given their sizes, this development requires a new approach to design and test. The white paper explains some of the challenges encountered when developing such pumps, along with the analysis process used to meet those challenges.

INTRODUCTION

The dredge pump is one of the main components of the dredger, and it is critical for achieving production. Dredge pumps also have the biggest power consumption during operation so efforts to reduce the pump's power needs through smarter design are critical.

Engineering Challenges of Dredge Pumps

Dredge pumps involve more complex engineering challenge than water pumps. They deal with pumping water and also mixture of several types of soils like mud, fine sand, coarse sand, gravel, stones, and debris. The mixture of those materials with pumped water doesn't behave as homogenous fluid as the soil tends to settle down and slide on the pipe bed depending on the flow speed.
Another challenge is that those materials wear out the pump parts very quickly and change the characteristics of a dredge pump in very short time. Clogging of the impeller and breaking vanes are other problems that have to be dealt with.

THE PUMP DESIGN

In 2011, Dredge Yard started its program of developing a new range of dredge pumps ranging from 200mm to 1400mm, the later currently being the biggest size in the dredging industry.

Figure 1. Example of the dredge pump

These pumps, with their robust design and thick wear-resistant materials, are designed to the counter wear problems inherent in dredge pumps. Impellers are designed in multiple categories of 3, 4 and 5 vanes. To resist wear, the pump parts are made from high chromium iron having a hardness of 60HRC. Unfortunately those types of materials don't have high elongation properties and are not impact resistant. For this reason, some dredge pumps are built with an outer casing, the so called double walled pumps.

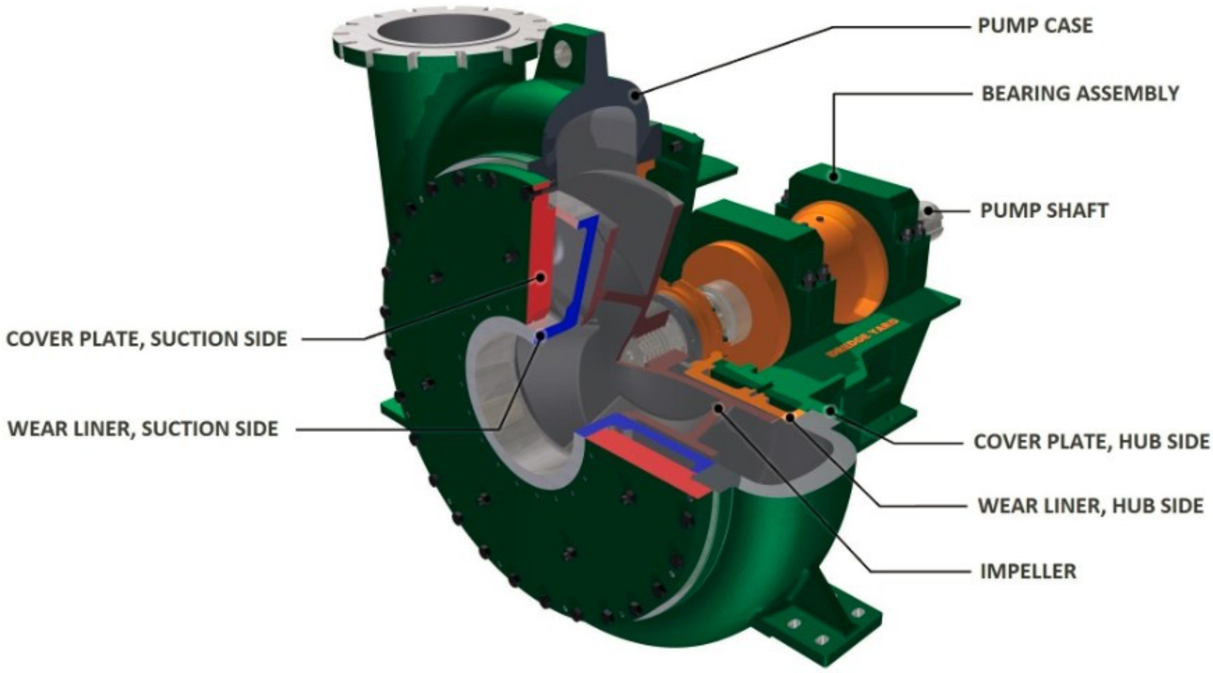

Figure 2. A sectional view of the dredge pump

Some of the big pumps are connected in series, reaching a final pressure at the 3rd pump of 30 bars. The big pumps are very heavy in weight, often weighing more than 100 tons for one complete assembly including wet parts, outer casing, plates, shaft, bearing assembly and pedestal.
All those factors create a heavy challenge for the design and production of dredge pumps; however recently there is a demand for even bigger dredgers in the market.

Dredgers need to have bigger suction pipes and dredge pumps to fill the dredgers in better than 2 hours on average. Hence, there is a need to increase the dredge pump size from 1400mm to 1600mm and even 1800mm. To adapt to the market efficiently, a completely new design method is required. Pumps need to be tested and analyzed for their efficiency and performance. Moreover, for the production like casting and machining of pump cases, foundries with casting capacity of 50 tons are required and heavy steel CNC machinery of a diameter of 6 meters is needed.

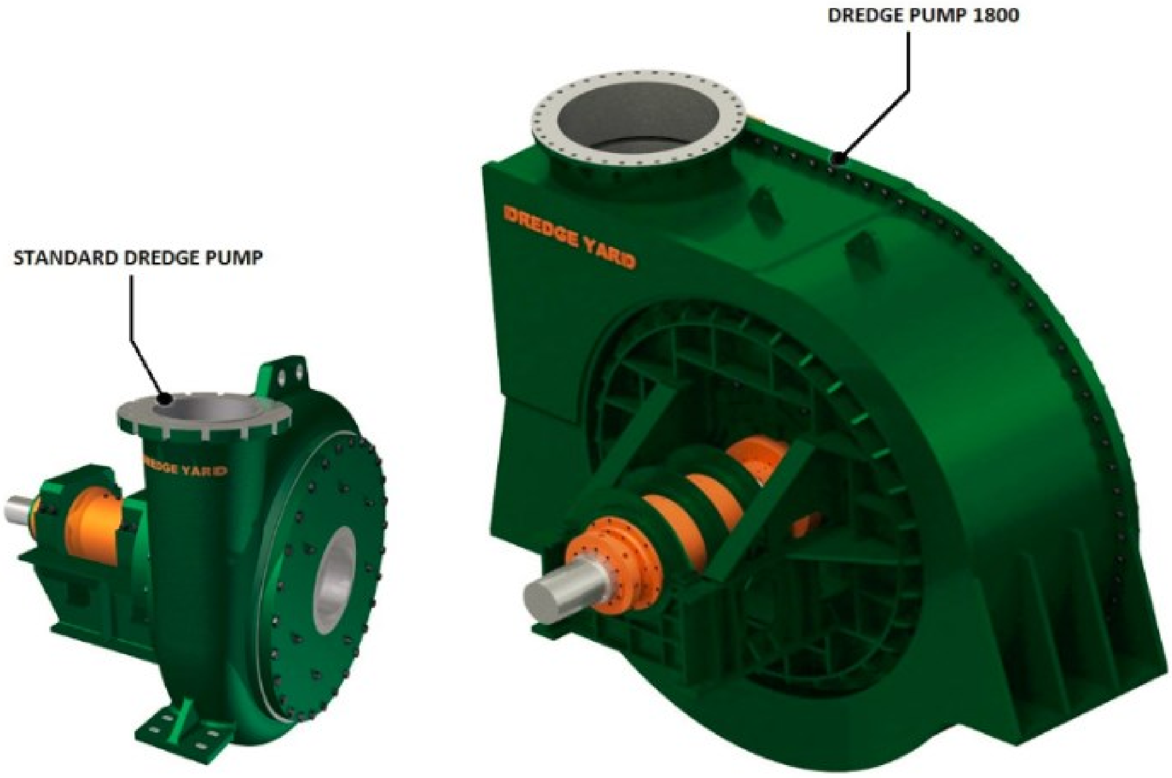

Figure 3. Comparison of a standard dredge pump and dredge pump 1800

Performance analysis of a dredge pump

For testing and analysis, it is impossible to find a laboratory or build a test laboratory for such a huge dredge pump. Dredge Yard has to design and manufacture the pump as a prototype and deliver the prototype for the use in the dredger without prior testing and performance check. All performance will be tested in the dredger when it starts working; however there is no time and possibility for correcting errors for such a massive pump. The design has to be flawless, performance oriented and reliable before its production.
To be able to tackle this challenge Dredge Yard is using several design tools and co-operating with the best software suppliers and specialists. To begin with, Dredge Yard engineers the hydraulic design and then tests its performance using computational fluid dynamics (CFD) instead of physical testing. The tool selected for this task in the software package SimericsMP, which was developed specifically for

pump simulation and includes among the strongest support in the industry. SimericsMP is able to calculate and simulate the pump performance like flow rate, aeration, cavitation, pumping head, efficiency, power required, and net positive suction head. Prior to relying on SimericsMP we first ran simulations in SimericsMP for three past pump designs: Dredge 500, Dredge 900 and Dredge 1100, and made comparisons with existing test data. In both the simulation and test, the working fluid is water at room temperature.

TABLE 1. FLUID PROPERTIES

Fluid	Water
Temperature	20°C
Density	998 kg/m^3
Viscosity	0.001 Pa s
Vapor Pressure	3610 Pa
Vapor Density	0.0245 kg/m^3
Air Contents	2.3x10^{-5} mass fraction
Bulk Modulus	2.15x10^9 Pa

As with other CFD codes, SimericsMP can provide steady state (SS) simulation, also known as multi-frame reference (MRF) simulation or "frozen blade" simulation, which put the impeller in a reference frame that rotates at the pump speed, while solving for the rest of the pump in the stationary lab frame. The MRF approximation can give a quick estimate of pump performance, however, it will fail when transient effects like cavitation/aeration, pressure ripples, or other pulsation are significant. SimericsMP can also provide a more accurate transient simulation of all the fluid passages, including features like small gaps and clearances. Generally transient simulations will take longer than steady state simulations but are more accurate. Due to its speed, SimericsMP can perform this simulation in a reasonably fast time frame. Figure 4 shows an example of the 3D CFD model of the Dredge 1100 pump. The mesh size for each of the Dredge 500, Dredge 900 and Dredge 1100 pumps is about 0.7 million grid cells. Each transient simulation took no longer than 4 hours to finish. Table 2 below shows the comparison between SimericsMP predictions and the test data.

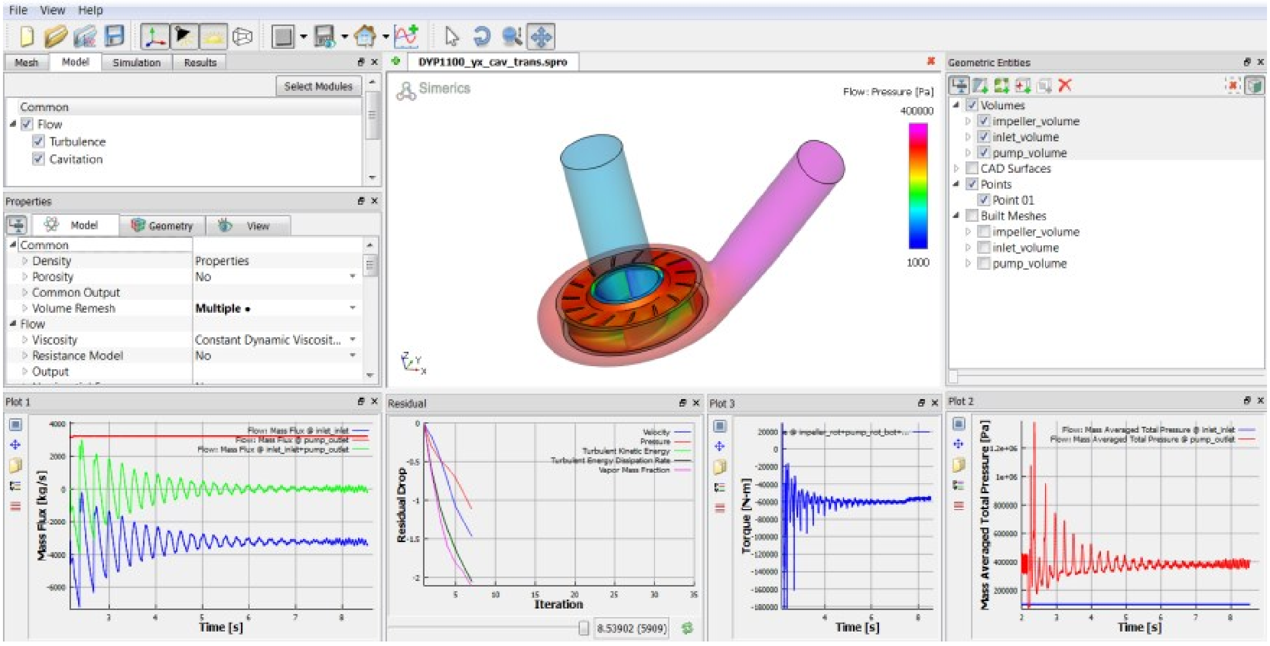

Figure 4. CFD model of Dredge 1100 (surface pressures and x-y data plots)

TABLE 2. COMPARISON BETWEEN Simerics MP AND TEST

Model Name	Pump Speed (rpm)	Flow Rate (m^3/s)	Head by SimericsMP SS Simulation (m)		Head by SimericsMP Transient Simulation(m)		Head by Test (m)
Dredge 500	450	2.1	47.6	6.5%	46	9.6%	50.9
Dredge 900	300	0.75	70	20.5%	84	4.5%	88
Dredge 1100	173	3.25	25.3	15.7%	29	3.3%	30

The transient predictions by Simerics MP are within 10 percent of the test results for all three cases, and within 4.5 and 3.3 percent respectively for the larger pumps, as shown in Fig. 5. This level of accuracy, especially for the larger pumps, provides the confidence of replacing physical testing with the "virtual" test provided by SimericsMP. It is import to note that the steady state simulation were not as accurate, emphasizing the critical importance of including transient effects when modeling these pumps.

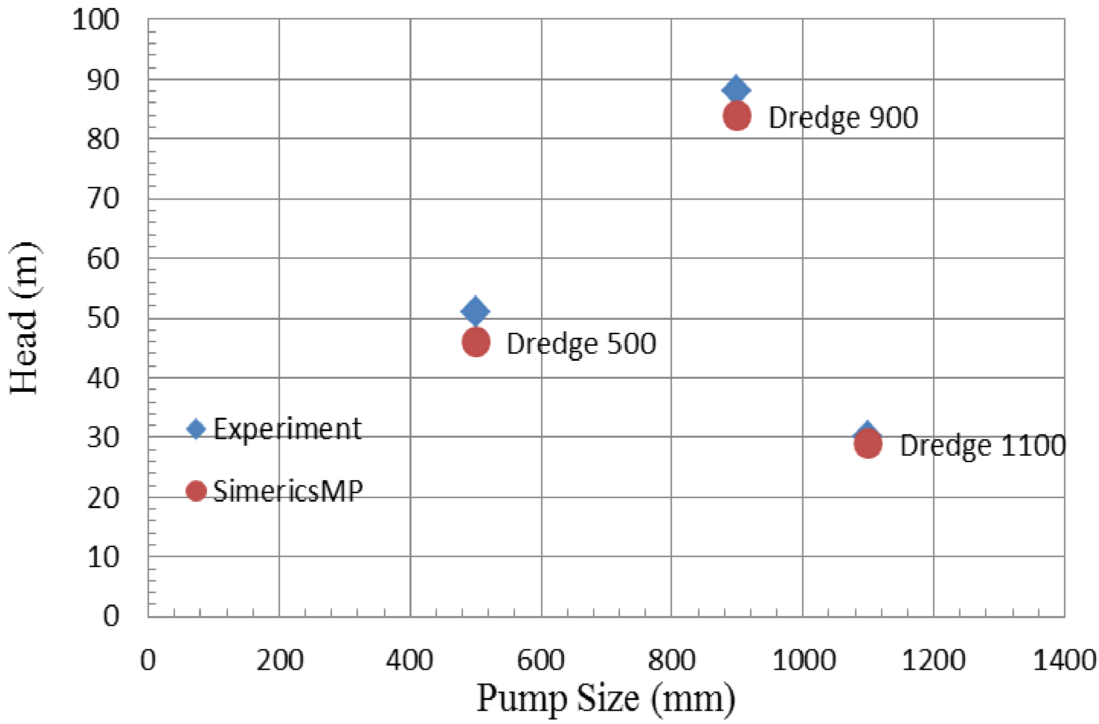

Figure 5. Comparison of the head predicted by SimericsMP transient simulations and the tests for three Dredge Yard pumps of different sizes: Dredge 500, Dredge900, and Dredge 1100, under the same operating conditions respectively for each pump.

After achieving the hydraulic design, a basic pump model is made in Autodesk Inventor using its 3D capabilities. Once the basic design is completed Dredge Yard runs several trials on major FEA calculations on the model to ensure getting the right stiffness and strength of the pump. This model incorporates pressures output from the CFD analysis to determine the wall loadings, as illustrated in Fig. 6. For a dredge pump, a stiff design is of high importance in order to limit the deformation of the pump casing. Any deformation might lead to lower performance.

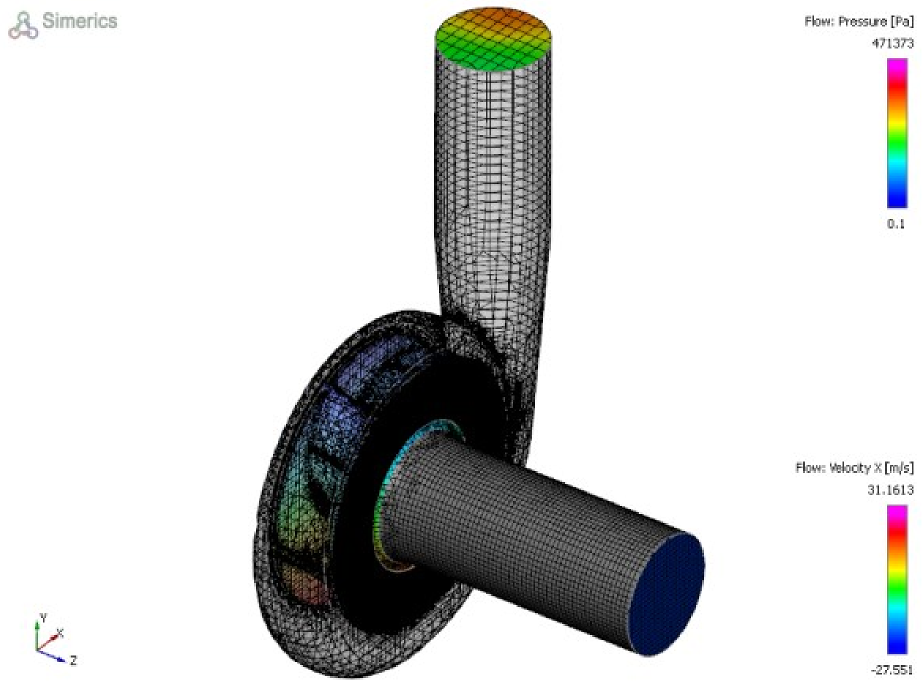

Figure 6. An illustration of the output of the pressure and velocity field from SimericsMP

One of the examples of a geometric tolerance that needs to be tightly controlled is the gap between the impeller and the front plate. If there is a deformation in that area and the gap widens, the efficiency will drop significantly. Besides the impeller gap effect, the stiffening of the pump structure will assure a symmetrical tension on the pump case and plates. As the pump case is of a volute shape and pressure is not evenly spread, deformation could be asymmetric which is not desirable in pump structures.

Figure 7. An illustration of the assembly of a Dredge Yard pump

This process of modeling and FEA is repeated as needed to ensure the highest safety margin and the lowest weight. Keeping in mind that the weight of the dredge pump 1800mm is approximately 200 tons, any saving in the weight by FEA calculation might be very significant.

CONCLUSION

The design work on the 1800mm dredge pump is ongoing and Dredge Yard aims to finalize this development in 2015 and build these pumps for the dredging and mining market.

FOR MORE INFORMATION REGARDING TECHNICAL SPECIFICATIONS AND PERFORMANCE CURVES, IT IS ADVISED TO CONTACT DREDGE YARD.

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