Precise Production for Large Impellers

The pump impeller is one of the most important parts with regard to pump efficiency. Impellers have to be produced with the highest geometrical accuracy. Even small geometrical deviations can impair the efficiency and, furthermore, cause the risk of a hydraulic imbalance during operation. Sulzer tested several new manufacturing methods to meet the highest quality standards for impeller production.

1 Finished impeller.

Sulzer offers different types of pump product lines: standardized, pre-engineered, and engineered pumps. Standardized pumps are developed with a defined configuration, produced, and delivered directly from the Sulzer warehouse to customers. Engineered pumps are individually designed, developed, and manufactured for customers according to their specific requirements. These engineered pumps are used mainly for oil and gas production, power plants, and major water projects. For an important project, Sulzer examined new methods of improving the quality and reducing lead times for individually manufactured pump impellers (Fig. 1).

Casting — the traditional manufacturing method

The common — and often most cost-effective — method to produce large steel parts of engineered pumps is to cast them in one piece. But for open impellers, a general, intrinsic problem of the casting process becomes apparent. Casting areas with thick walls cool down slowly, whereas sections with thin walls lose heat much faster. This difference results in material stresses between impeller sections with different wall thicknesses. In the worst case, it leads to significant geometric distortions or even visible cracks in the material. For impellers, this effect is observed mainly at the transition from the relatively thick impeller hub to the relatively thin blades.

2 SJT/SJM cooling water pump.

3 Impeller (marked blue).

Large vertical pumps

Engineered pumps are designed according to customers' requests. The engineered SJT/SJM cooling water pumps (Fig. 2) are single-stage, mixed-flow vertical pumps with semi-open impellers. They are available in sizes starting from 750 mm (30") up to 1 800 mm (72") impeller diameter (Fig 3).

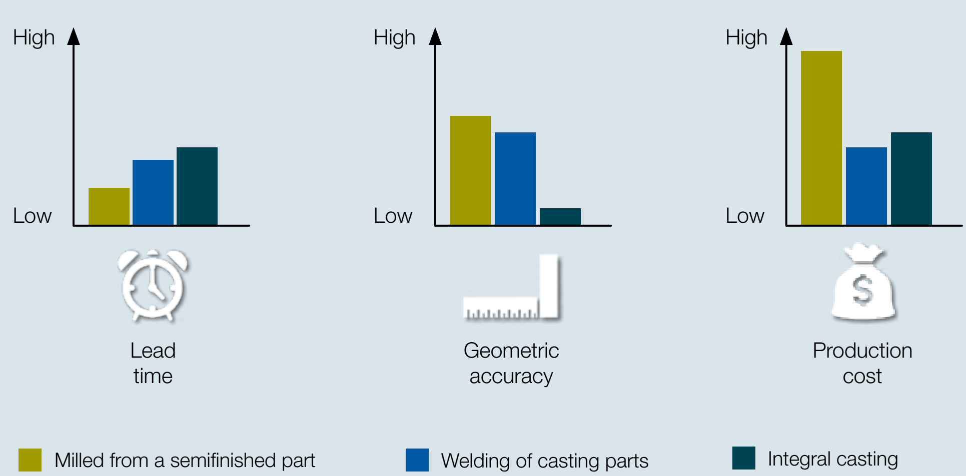
They are used for water supply, such as cooling water pumps for power applications, irrigation, drainage, or desalination. The pump length and the impeller sizes are always adapted to the on-site measurements and the required pump curve. The capacities of those pumps can reach up to 80 000 m^3/h (349 000 USgpm).

Evaluation of alternative manufacturing methods

In the search for the best method, Sulzer engineers analyzed six possible manufacturing processes. The first assessment ruled out three possibilities. In the final, detailed decision round, three manufacturing processes were checked and compared in detail. The traditional method of casting a single-piece impeller was compared with two new alternatives. Would it be better to mill the impeller from a wrought semifinished part? Or would welding separately cast blades onto a hub be the better way for a precise and fast result?

Comparing subtractive manufacturing with the traditional method of casting, the milled variant, of course, yields the best quality and is the fastest. However, this manufacturing route is significantly more expensive than producing a cast part because of the high amount of material that has to be removed.

The method of welding single blades to a hub received only a slightly lower score for accuracy and lead time than subtractive manufacturing. Because it is far more cost-effective and feasible, this method was chosen as the solution to be tested and realized (Fig. 4).



4 Comparison of three manufacturing methods for large vertical impellers.

Strength analysis of welding connections

The impeller inside an engineered water pump — such as an SJT or SJM cooling water pump — has to withstand all applied loads in different working conditions. The weld seams between blade and hub represent the most critical areas to fulfill this requirement. When building up a very large weld seam consisting of multiple layers, there is a certain risk of incomplete fusion, even with highly skilled welders. The Sulzer engineers performed a finite element analysis (FEA) on a weld seam with induced defects. The calculation showed that even with a void along the whole length of a blade, the whole impeller is durable. The defined weld seam is able to bear all static and all fatigue loads that occur within the entire operating range of the impeller (Fig. 5).

Weld qualification with a model

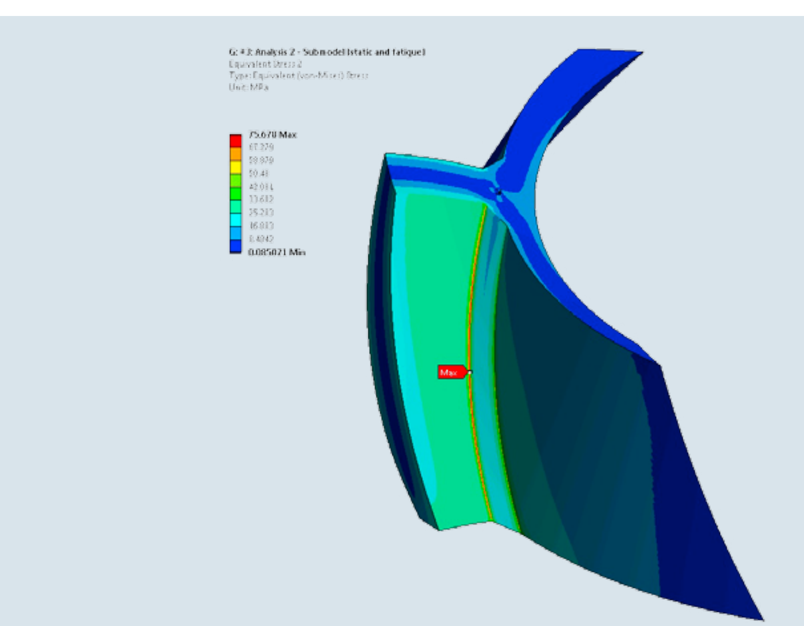
So that the engineers could qualify the planned welding operation, a model part was produced and welded at a designated weld supplier. The model part (Fig. 6) was designed so that it had the same measurements as the original impeller: weld preparation geometry, weld geometry, and distances between impeller blades. This way, it reflected all difficulties that were present at the real impeller. The specific shape of the impeller allows only restricted accessibility during the welding process.

Depending on their end use, pump impellers of the SJT or SJM cooling water pumps can be produced from bronze, chrome steel, stainless austenitic steel, duplex, or super duplex stainless steel. For corrosive liquids like seawater, the use of duplex or super duplex components is often required. Usually, for super duplex stainless steel, the only reasonable heat treatment is a full-solution annealing with subsequent water quenching. But that heat treatment can result in extensive part distortions. To avoid such heat treatments, the welding operator has to set the parameters very narrowly. Therefore, it is challenging to achieve superior welding quality, and only extremely reliable welding suppliers meet the demands for this task.

After it had successfully completed liquid penetrant testing, the model part had to undergo several destructive tests: corrosion tests, phase content determinations, tensile tests, and hardness tests. Macrosections were cut from the welding area to be judged later under the microscope. After all these tests, the Sulzer engineers were sure the welding zone itself and the heat-affected zone had been produced in the quality needed.

Prototype production and tests

After the positive test results, a prototype of a super duplex stainless steel impeller was manufactured. This prototype showed that the chosen welding supplier was qualified to produce such weldings — even ones with difficult geometric arrangements. The hub part and the four single blades were produced as a cast as



5 Finite element analysis of weld seam to check the feasibility.

6 Welding model to test the weld quality and check the geometry.

A leading manufacturing process portfolio

"As shown with the study above, all new methods are analyzed, assessed, and tested thoroughly, before they are used in full-scale production. At Sulzer Pumps Equipment 14 material specialists investigate and check materials, coatings, and material treatments to improve our products and production processes" informs Thomas Kraenzler, Head of Global Core Technology Materials of Sulzer. "Sulzer has a broad experience in many different manufacturing processes and uses a wide variety of them. Furthermore new production methods are being developed. Our production and material engineers constantly research which production method is the most suitable to achieve the best quality and faster lead times.

Sulzer uses, e.g. traditional and innovative casting technologies, forging, hot isostatic pressing (HIPing), state-of-the-art milling and turning, and electrical discharge machining (EDM). For the joining of materials, we use all kinds of conventional welding technologies but also laser welding processes. Product quality is frequently determined not only by the base material but also by post-processes, like heat treatment, and surface modifications. Particularly the huge variety of coating technologies for defined surface properties is very important for us." Kraenzler adds.

a first step. The blades were manufactured at a very high geometric accuracy on the first try. A precise prediction of the blade distortion during the cooldown of the melt was possible because the wall thickness over the blade was all the same. The dimensions of all parts were checked by 3D measurements before the welding process. All requirements for the castings were according to the quality specifications.

The second production step — the welding — was carried out subsequently according to the parameters that have been evaluated with the model part. The biggest challenge in keeping the high geometric accuracy

7 Positioning template for the blades used during the welding process.

was the correct positioning of the blades on the hub. Sulzer engineers created several templates to adjust the blades. The templates support the welding operator during this challenging process (Fig. 7). After technicians had finished grinding the weld seams, final machining, and balancing, the prototype was ready to be used and compared with the traditionally manufactured impeller.

Process evaluation

With the new manufacturing method, the major goal — to improve the geometric accuracy — had been fulfilled. All 3D measurements confirmed that — even compared with the very best conventionally cast impellers — distortions could be reduced by 40%. Indirect benefits of the improved geometric accuracy are significantly reduced machining, grinding, and balancing efforts. Impellers up to a size of 2.5 m can be produced with the new process.

In terms of cost, the welding process increases the production costs. On the other hand, the patterns for the casting process are much easier to produce and thus more cost-efficient. The reduced final machining and balancing effort saves costs and ultimately leads to a reduction of the total production cost. The lead time follows the same logic as the costs. Welding adds time but pattern manufacturing for casting is easier and, thus, faster. Final machining and balancing is much faster, which leads to a shorter overall lead time.

Author: Robin Rettberg
sulzertechnicalreview@sulzer.com