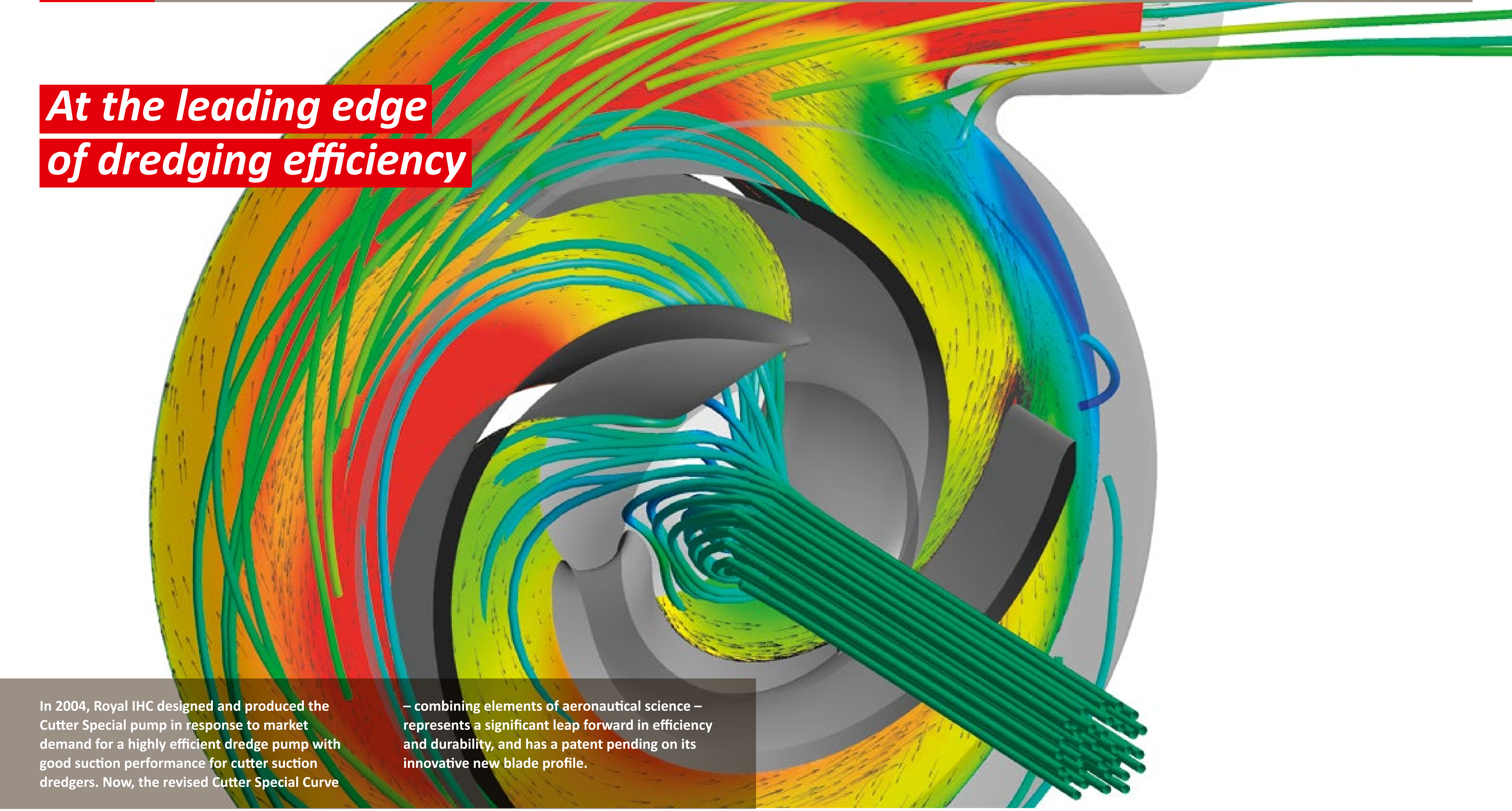
At the leading edge of dredging efficiency

In 2004, Royal IHC designed and produced the Cutter Special pump in response to market demand for a highly efficient dredge pump with good suction performance for cutter suction dredgers. Now, the revised Cutter Special Curve – combining elements of aeronautical science – represents a significant leap forward in efficiency and durability, and has a patent pending on its innovative new blade profile.



The performance of any dredging vessel is heavily reliant on the efficiency of its pump. This is especially true for medium and large cutter suction dredger (CSD) vessels, which frequently operate across a wide variety of challenging environments working with material ranging from clay and sand to gravel and hard rocks.

Key to the efficiency of a dredging vessel is the spherical passage of the dredge pump. This is defined as the space through which the material (of spherical shape) is able to pass in relation to the suction diameter of the pump. A larger spherical passage can prove incredibly beneficial, especially when a blockage in the pump can lead to expensive downtime.

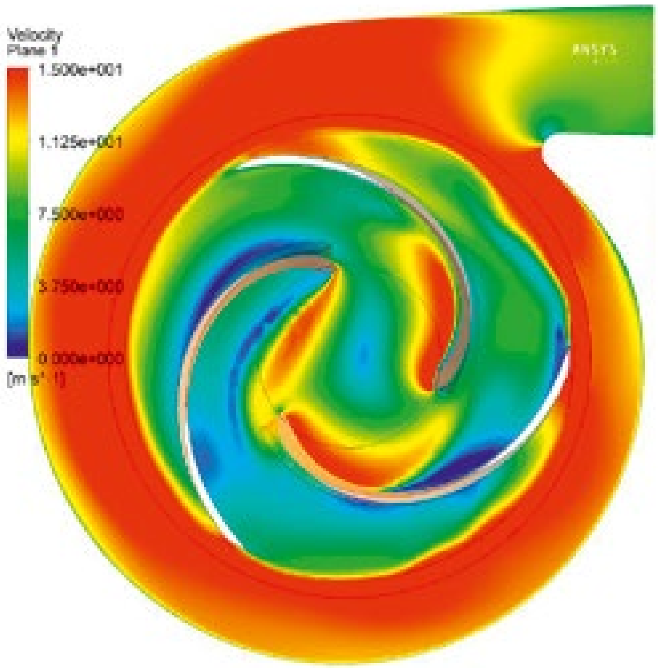
The unique selling point of the original Cutter Special (CS) was its larger spherical passage – 50%, meaning rocks half the size of the inlet opening will pass through the pump without causing an obstruction.

"The CS pump proved to be very successful, with a wide range of vessels benefiting from its productive design and innovative capabilities," says Hasan Bugdayci, Royal IHC's Product Manager for Dredge Pumps. "But three years ago, in response to customer feedback, coupled with technological advancements we have made in-house, we decided that the system could be improved even further."

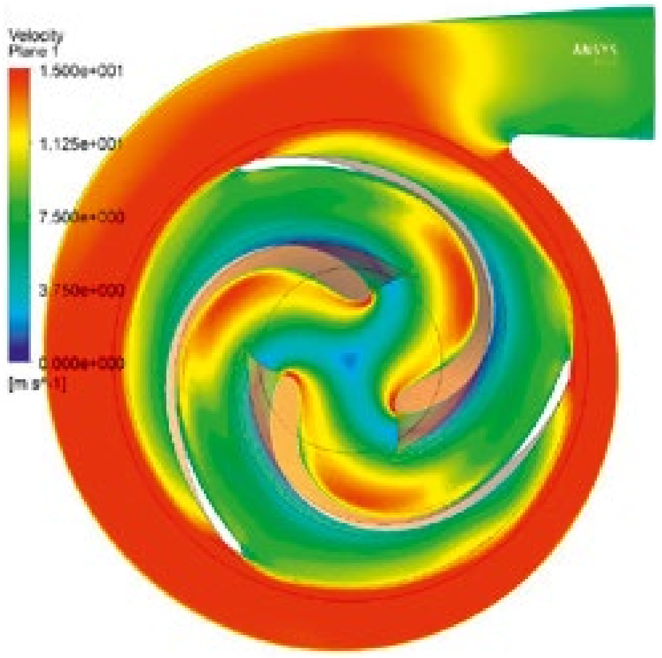
Hasan's team initially carried out measurements in both the field and the lab to determine exactly where improvements could be made. Following this research, IHC began designing a new version of the Cutter Special with two overall aims – to increase the pump's efficiency and to improve its wear resistance.

Design criteria

A number of performance criteria were identified for the new and improved Cutter Special pump – now named the Cutter Special Curve (CS Curve). Specifically, the goal was to revise some of the pump's characteristics without having an adverse impact on others. "We wanted to improve the efficiency and wear characteristics without losing pressure and without reducing the size of the spherical passage," says Hasan. "It was ultimately decided that only the blades and the volute would be modified, with the front and rear shrouds remaining the same as the CS."



Flow field analysis of CS pump. The spectrum represents the magnitude of the flow's velocity within the impeller



Flow visualisation inside CS Curve pump. The flow remains attached to the blade surfaces

Improving performance

The first step in the redesign process was to analyse the flow field in the original model in order to assess the pump's performance. Edwin Munts, Research Engineer at MTI Holland, uses computational fluid dynamics (CFD) in order to achieve this. CFD employs complex mathematical models and algorithms in order to simulate the fluid flow inside a pump.

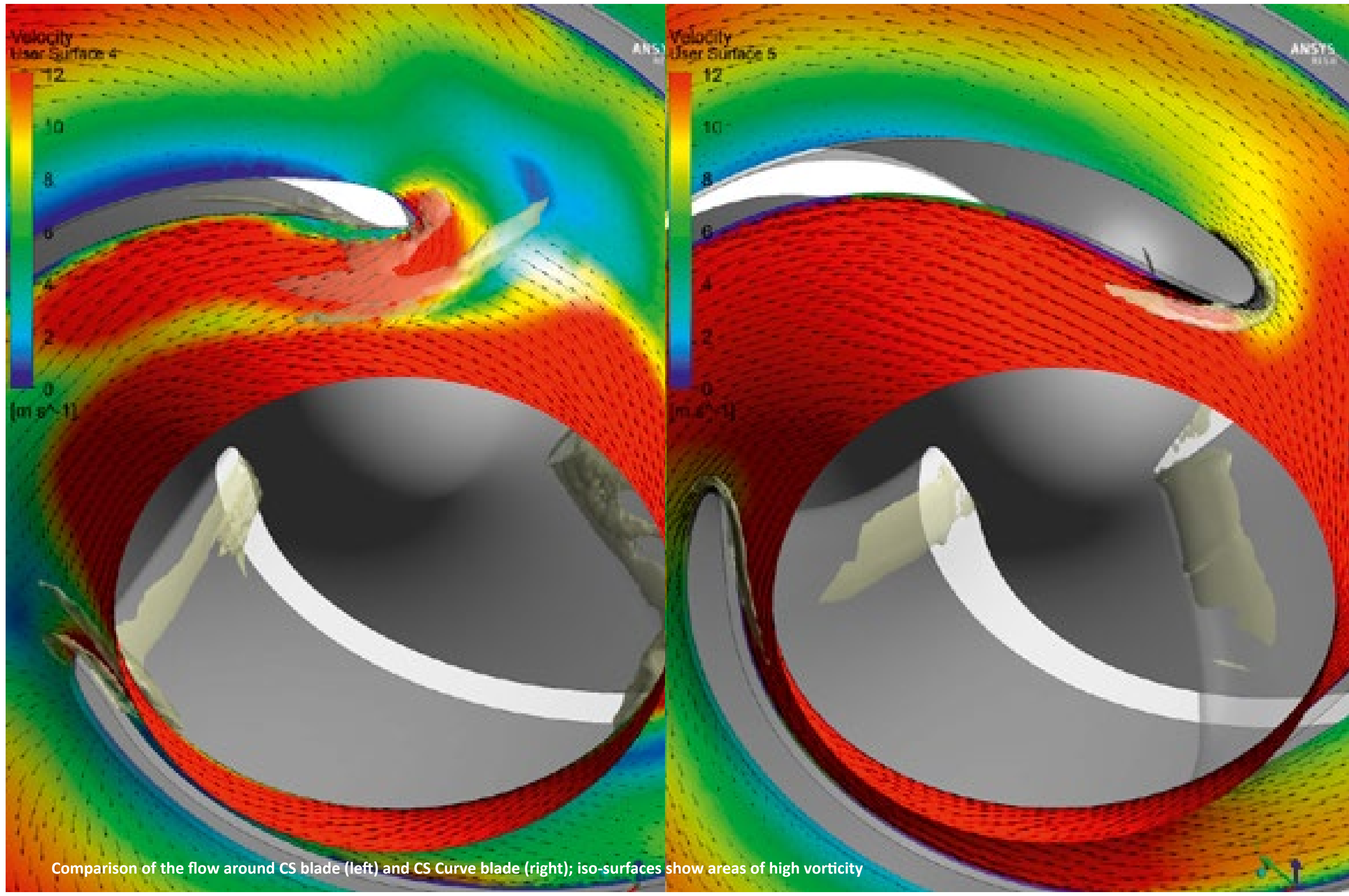
"This technique provides key information, such as pressure and required power, from which we are able to calculate efficiency," explains Edwin. "Moreover, CFD provides a detailed flow field visualisation, which can be used to identify potential problem areas.

"This type of approach has its limitations, but over the years we have built up a significant amount of experience using the correct models. Our calculations are quite accurate, and very close to actual live measurement data."

Ideally, the results of an analysis would demonstrate that the direction of the flow within the pump follows the contours of the blades. "But that's not what we see in the first Cutter Special pump," says Hasan. "In each channel the pattern is somewhat inconsistent, with varying velocities in chaotic directions."

When the inward flow is not properly aligned with the blade, it separates from its surface at the leading edge and a low velocity region, or 'separation bubble', is generated. This separation bubble acts as an obstacle, causing a chain reaction in the flow over the other blades.

"These separation bubbles consume energy from the flow within the pump," says Edwin. "As energy inside the pump is reduced, there is less energy to increase the pressure of the flow. We ultimately found that flow separation was responsible for the



Comparison of the flow around CS blade (left) and CS Curve blade (right); iso-surfaces show areas of high vorticity

observed reduction in efficiency."

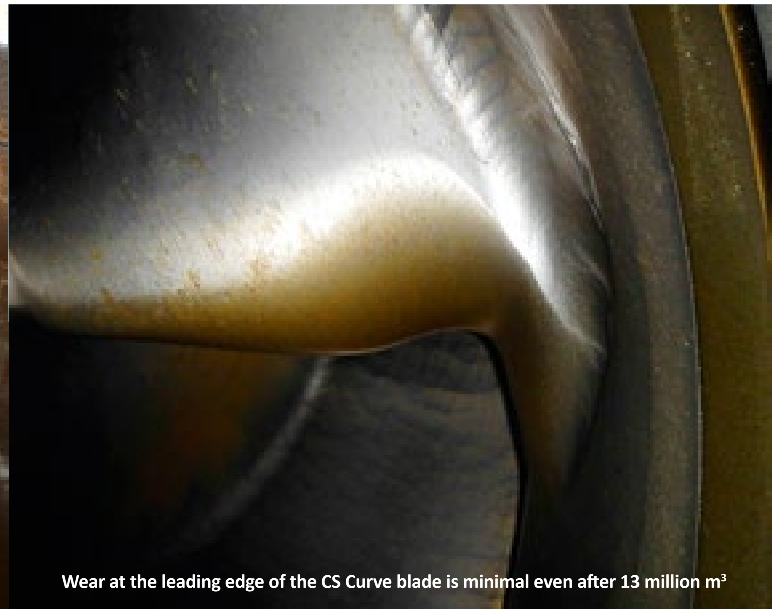
Having discovered how efficiency can be reduced through analysis of the flow field, the team knew how they could make improvements to the pump. "We had to design a new blade that wouldn't cause the flow to separate," says Hasan. "This required a modification to the blade profile to ensure it is optimally aligned with incoming flow across a number of different working conditions."

Aeronautical science

Historically, dredge pump blades have been designed to be uniformly thick across their entire length. The new IHC design changed this common component, presenting a blade that is much thicker at the leading edge and thinner towards the trailing end.

"The new design is very similar to a NASA space shuttle profile," says Hasan with a smile. "So there is actually some rocket science in the new pump!"

Wear at the leading edge of the CS blade is clearly visible after 15 million m³



Wear at the leading edge of the CS Curve blade is minimal even after 13 million m³

3D sand printed CS Curve impeller model, ready for casting

View of CS impeller suction opening

View of CS Curve impeller suction opening

The modification means that the flow now remains attached to the blade surface. This results in stronger symmetrical flow field between the different impeller blades and, because it is not disturbed from its intended path, it doesn't disturb the flow around the other blades either. The desired result had been achieved. "We assessed the new design using CFD, and calculated a 5.5% increase in efficiency compared to the previous pump," explains Hasan. "But when we came to measure it in the lab, we found it to be 1% more efficient than CFD calculations indicated! Therefore, the actual efficiency difference between the CS and the CS Curve is 6.5%."

Beneficial side effects

Along with increased efficiency, the team's goal for the CS Curve was to improve the pump's wear characteristics. Specifically, to reduce local wear occurrences on the blade-shroud connection and the volute cutwater.

As the newly designed blades are thicker at the leading edge, there's already an additional advantage in relation to this goal. "Wear inside the impeller is often most severe at the leading edge of the blade," says Edwin. "Now that this area is significantly thicker, it simply increases the components lifetime by providing more material – a very beneficial side effect!"

However, a number of other key design modifications were required in order to fully maximise the overall longevity of the new pump. One new feature is the addition of sweep to the blades. This is another innovation appropriated from the aeronautical world, in which the blades are inclined at an angle relative to the incoming flow – similar to a fighter jet's wings.

"In the CS Curve, the leading edge of each blade incorporates a sweep angle," says Hasan. "This decreases the impact velocity of the flow onto the blade, which in turn reduces wear and boosts performance. And by applying sweep, you're also elongating the blade, which again means there is generally more material to wear."

Reducing local wear

In addition, the connection between the blade and the front shield was modified to help solve the problem of local wear phenomena in this area. This wear is caused by so-called 'horseshoe' vortices that occur whenever a flow travelling along a solid surface meets an object in its path.

Virtually no wear at the trailing edge of a CS Curve impeller after 13 million m^3

"The boundary layer of the incoming flow impacts on the leading edge of the blade," says Edwin. "This boundary layer has less energy the closer it is to the blade's surface, and so it is pushed back on itself to create a vortex. Velocities within such a vortex can be very high; eating away at a surface until a hole is formed."

Again, CFD simulations were performed to investigate these ideas before they were implemented. In this scenario, three-dimensional iso-surfaces are analogous of areas where vorticity pressure exceeds the acceptable threshold. Comparisons to the CS design indicated that vorticity strength has been significantly reduced.

Similar conditions along the shrouds of the cutwater in the CS pump also lead to the formation of harmful horseshoe vortices. "In order to avoid this, a modification was made that results in a curvature of the cutwater," says Edwin. "This helps to reduce frontal impact and increases the life span of the component."

Patent pending

The modified blade profile within the CS Curve has proved to be so innovative, a patent has been applied for. 'Impeller blade with asymmetric thickness' is currently pending.

"When we started this process, we had no idea that we would patent the idea," says Edwin. "We have produced a dredge pump that combines a big spherical passage with a high level of efficiency. It has the potential to make other pumps obsolete."

Wear at the trailing edge of a CS impeller blade after 15 million m^3

Horseshoe wear on a CS impeller blade

Another important advantage of the new design is backwards compatibility. "As we only modified the blades and the volute, if a customer is already using a CS pump they can simply change the impeller and benefit from all the latest technology," adds Hasan. "The customer will not need to adjust any of their existing configurations in order to do this."

Although the Cutter Special pumps were primarily designed for CSDs operating in areas with a large presence of particles such as rocks and boulders, they have the potential to outperform in other fields including operations in sand and other mixtures. Consequently, this pump may also prove beneficial to trailing suction hopper dredgers.

Pushing the industry forward

The new CS Curve was officially launched in September 2014, when a number of customers were invited to the IHC premises. A presentation on the revised design was given and visitors were allowed access to the laboratory for a demonstration of the new parts in a live environment.

"Following the launch, we have since delivered new impellers to be installed in CSDs operating in countries including Kuwait and Croatia," says Edwin. "It was important for us to visit these customers to find out first-hand how the new products are performing, and so far we have received excellent feedback."

IHC is able to use this feedback from the field in order to expand upon its knowledge base. The development of advanced in-house tools, such as new CFD models, enables pioneers such as Hasan and Edwin to respond to demands in an increasingly challenging market.

"We have a commitment to our customers to offer them the best possible technology available," says Hasan. "The CS Curve was produced through a combination of IHC's extensive experience in the field, and continuous research and development. It demonstrates our promise to keep pushing the industry forward."