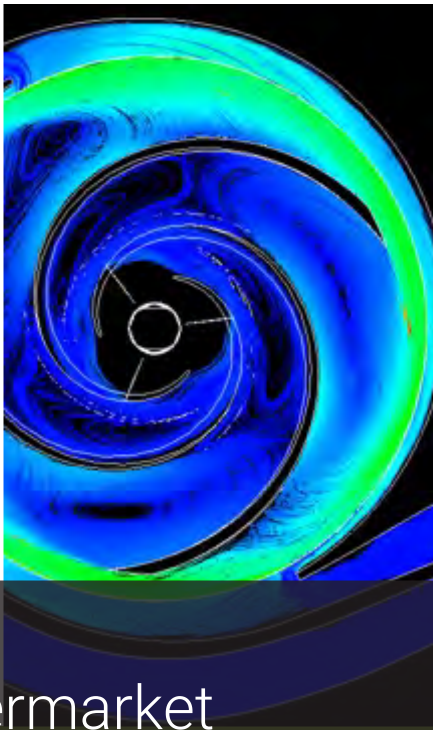
By Dr. Gary Dyson | Hydro, Inc.



Performance Prediction:
A Unique Approach for the Aftermarket

Hydro's software has allowed us to improve the optimize the performance of equipment and its fit to its system to make dramatic efficiency and reliability improvements for our customers.

Pumps at first glance appear to be very simple machines. To the layman, they are a number of castings and turned parts bolted together that move liquid around.

The truth is far different. Pumps are at the heart of many processes and are vital to our everyday lives. They are one of the most popular machines on the planet and are expected to survive and thrive in the most challenging environments.

Pumps are responsible for consuming a lot of power as they are driven to move around the fluids that enhance our lives. This presents a unique opportunity for end users and Hydro's pump design experts to help the environment by reducing this power consumption and thus reducing both the cost of operation and the emissions generated by the equipment.

Hydro has a unique place in this word of pump design that supports a deeper understanding of pump performance. Hydro's skills and tools are not focused on designing new equipment; all the engineering resources and systems within Hydro are turned to solving problems that occur in the field on equipment that is operating. Understanding at a deep level how pumping equipment performs is in Hydro's DNA.

In many cases, sophisticated and complex engineering skills are needed to solve the problems of operating pump equipment. The design cycle times are often critical, as they must match scheduled outages. New designs are frequently installed without the luxury of a testbed verification process- they have to be right the first time. This requires the use of enhanced analytical tools and an understanding of what factors affect reliability and performance.

Hydro's unique process involves several significant steps that come together to provide a comprehensive approach to understanding and modifying hydraulic performance. This process allows pumping equipment to function exactly as required by the system that it fits within.

Analysis of Reverse Engineered Components

The first step of this analytical approach involves integrating reverse engineered data for hydraulic components directly into an advanced suite of tools. The ability to import the hydraulic geometry obtained through reverse engineering supports seamlessly analyzing components to verify performance and modifying components to update performance.

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A key customer approached Hydro with an issue on a critical service water pump, which was not performing per the original curve provided. This mismatch resulted in a performance that was not optimized for the plant. Hydro scanned the existing impeller and bowls and assessed the principles of the hydraulic design to determine the link between the components and the deficit in performance.

Using our advanced analytics and a unique approach, which contains a subfeature for re-engineering tasks, we were able to quickly establish the deviations. The analytical software quickly gave us the key component design parameters, profiles, and trends, which were provided to an experienced engineer to develop a picture of how well-designed the components were.

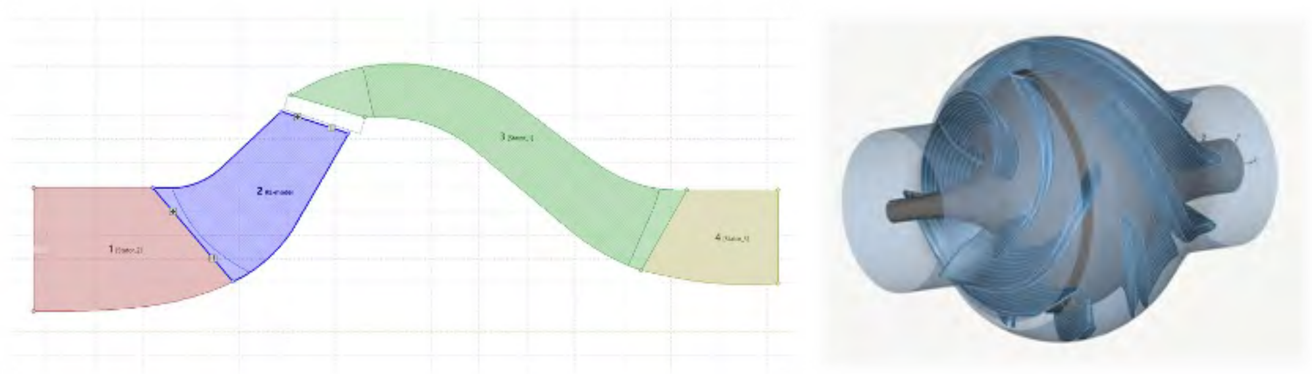

Fig 1: Existing impeller and bowl design analysis

Hydro has used this process on hundreds of components, enabling our customers to improve the reliability of machines through optimized system matching and verify components as part of a complex reverse engineering process. This unique adaptation of these analytical tools to end user's needs combined with extensive engineering capability across manufacturers and models has made Hydro a leader in the fields of hydraulic verification and redesign for operating pumps.

Complex Off Design Analysis

Hydro has been able to uses its advanced analytical capabilities to assess and understand the complex nature of fluid flow within a machine when it runs at low flows. There are many empirical methods available to predict the inlet backflow inception point, but these only give a crude estimation of where inlet backflow occurs. Using the exact hydraulic geometry gives a refined picture of the fluid flow paths and allows evaluation of the consequences to equipment performance.

What Is Inlet Backflow and Its Effects?

Inlet backflow is a phenomenon that is present within all pumps operating at partial capacity. Running in this flow region always contributes significantly to vibration levels, as the flow from the impeller eye turns inward and exits back into the suction channel.

When this occurs, high energy liquid is expelled from the impeller eye in streams. This expelled liquid dominates the suction passage, occupying the 2/3 of the flow area from the pipe outer diameter downwards towards the channel centerline (Fig 3 & 4). The extent that the expelled liquid fills the suction channel remains unchanged with distance from the impeller. This flow spirals helically down the periphery of the suction pipe.

Each impeller blade generates individual streams. The tangential velocity imposed on the regime by the impeller dominates the flow, causing the helical spiral angle to be approximately equal to the blade inlet angle, as seen in the relative frame. This angular flow stream does not diminish with distance from the impeller, implying that both the tangential and axial components of the velocity decay proportionally to maintain this angle.

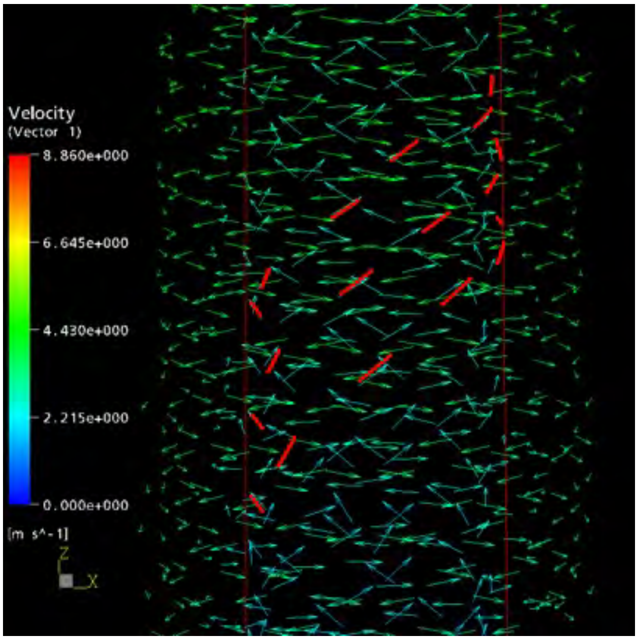

Figure 3. Internal Core of Spiralling Fluid in Suction Channel

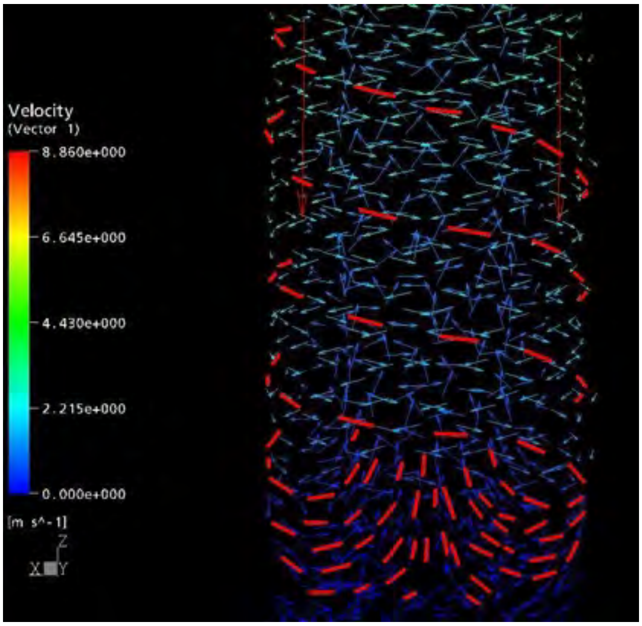

Figure 4. Helical Spiraling Inlet Backflow at Suction Duct Periphery

The inner 1/3 of the suction channel area contains a spiralling core of slower moving fluid. Viscous effects transmit tangential energy from the high-energy peripheral flow and drive this core in a helical spiral counter to the direction of pump rotation. Flow is dominated by the axial component of the velocity and tangential forces exerted by the peripheral flow cause the inner helical flow angle to be approximately double the outer angle. Again, the helical spiral angle remains constant.

Whilst these velocity streams are not responsible in the computational analysis for a vibration component, this cannot be said in a real situation. Pump suction and piping designs contain discontinuities, such as splitters, elbows and reducers. The velocity streams impacting on these features contribute to high vane pass frequency vibration.
How pumps experience the onset of this backflow is dependent on the design of the impeller. Both the inlet tip speed and the inlet blade design have been shown by both Fraser and Palgrave, in their empirical methods, to greatly influence the flow at which backflow commences. However, these empirical methods do not predict the inception as accurately Hydro's analytical method does- they only predict the flow at which the regime starts to have a negative consequence on the pump performance.

By keeping the image of these high energy streams exiting the impeller in the mind, it reinforces the mental image of the damage that can be done to a pump running at low flow. These streams impact on the downstream inlet piping and the suction nozzles; excess vane pass vibration is inevitable.

The other phenomenon to understand when a pump operates at or around inlet backflow is how it affects the NPSHR levels. These are commonly misrepresented on curve data as the 3% differential head drop, and the selection of the flows at which the points are measured during testing commonly masks the NPSHR values.

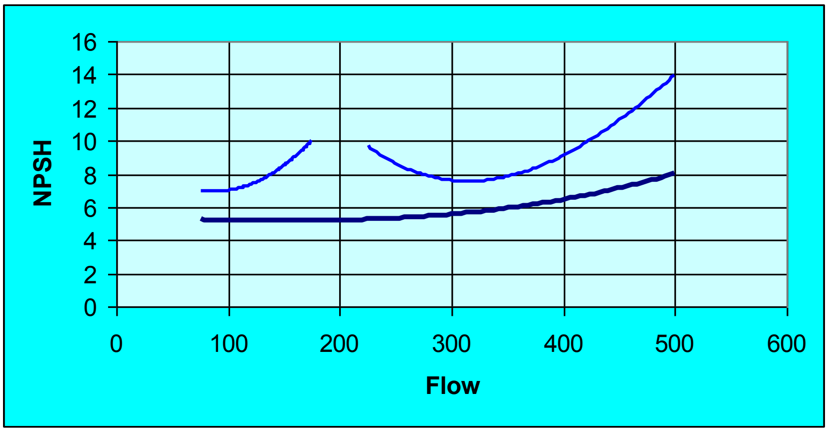

Figure 5. NPSHR at inlet backflow

Fig 5 Depicts the 3% head drop against a 0.5% head drop, and the NPSHR values are startling different.

What Does the Flow Look Like When Operating Back From Best Efficiency Point?

Operating centrifugal pumps at low flows is known to cause pump failure. There are a number of known phenomena from flow physics that contribute to rapid heating of the process liquid and increased vibration and noise levels.

When a pump operates at low flow the impeller and volute become stalled with bound liquid within the machine. This liquid is continually driven by the impeller blades, as demonstrated by Fig.6. Areas at 'A' and 'D' contain captured fluid that experiences rapid heating. On high power machines, this phenomenon is particularly profound and can lead to contact between the rotating and stationary wear parts.

The rapid heating that occurs within the impeller also quickly transmits to the surrounding bound liquid within the volute, as shown in Fig. 7, and a machine can quickly become thermally unstable as the heat generated is unable to be dissipated to the atmosphere. Again, machine failure can easily occur.

Holding this mental image in your mind when you see a pump running at low flow helps engineers to visualize what is occurring within the hidden passages of the machine. It is easy to imagine how the process fluid can heat up rapidly at low flows when all the energy is diverted into the bound liquid in the volute.

Navigating Low Flow Operation

Pump design and analytics have a valuable place in improving the performance of pumps, but the design is seldom just about the Best Efficiency Point. Pumps are often expected to run at low flows and on many occasions can spend their entire operating lives there. It is important to understand the complex behavior of fluid and how that affects performance and reliability so that modifications can be made to achieve optimal performance at these challenging conditions.

Hydro has developed a unique understanding of operating equipment at these low flows and has pioneered techniques to both predict and redesign impellers so that the damaging inlet backflow flow regimes are either eliminated or their impact is mitigated and reduced. This optimization of the pump design and its fit within the system also has the benefit of reducing power consumption, supporting reductions in total cost of ownership and GHG emissions.

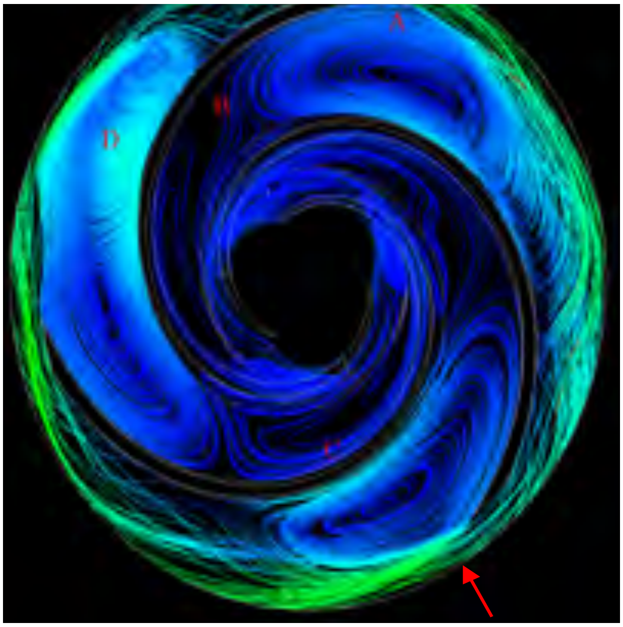

Figure 6. Impeller flow stream at extreme low flow

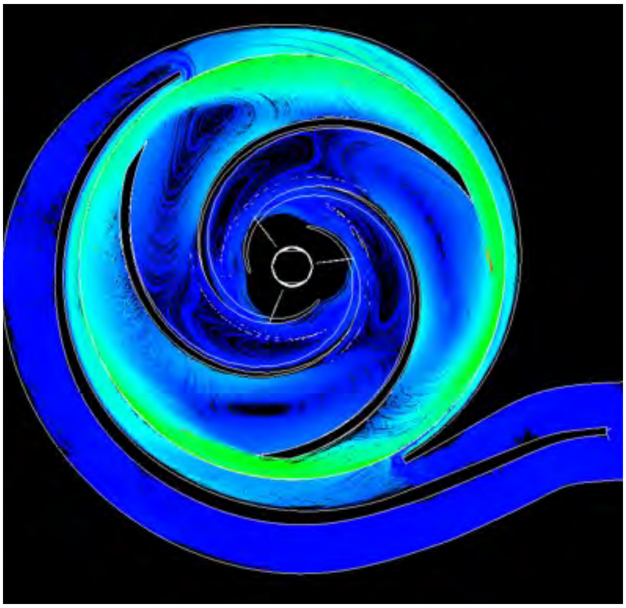

Figure 7. Volute and Impeller at Extreme Low Flow

Dr. Gary Dyson is managing director with Hydro Global Engineering Services. He has a doctorate from Cranfield University and 30 years of experience in senior positions with many pump industry manufacturers.

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