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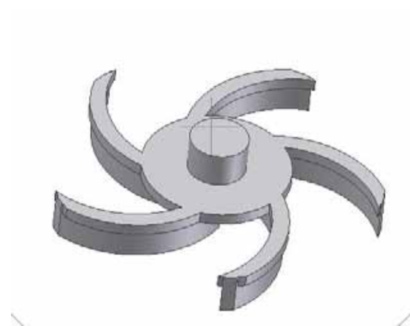
The August 2004 issue of Run Times discussed pump specific speed (Ns) and its influence on impeller geometry. For any given Ns there are a variety of impeller styles available that provide specific mechanical or application benefits. Choosing a pump with an impeller style that is most compatible with the application is an important part in pump selection. In this issue, we discuss the three most common impeller styles and their application.

Dale B. Andrews – Editor

Open Impellers

An open impeller is characterized by impeller blades that are supported almost entirely by the impeller hub. This is the simplest impeller style and it is primarily applied to clean, non-abrasive, low horsepower applications. An open impeller is lighter in weight than its shrouded counterpart. Less impeller weight reduces shaft deflection and enables the use of a smaller diameter shaft, at a lower cost, than an equivalent shrouded impeller.



An open impeller typically operates at a higher efficiency than a shrouded impeller of the same specific speed. The largest contributor to efficiency loss in an enclosed radial impeller is disc friction caused by the front and back impeller shrouds turning in close proximity to the stationary casing walls. (See the Sept 2004 newsletter on efficiency). Removing the shrouds eliminates the disc friction.

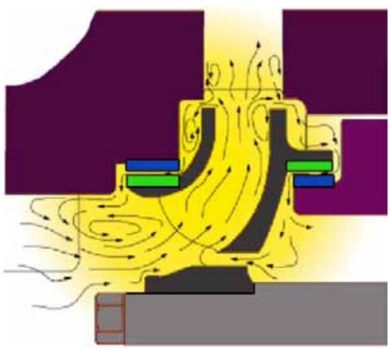
One drawback of the open impeller is that it is more susceptible to abrasive wear than a shrouded impeller. High velocity fluid on the impeller blades in close proximity to the casing walls establishes rotating vortices that accelerate wear when abrasives are present.

A tight clearance between the impeller and the front and back casing walls is necessary to maximize efficiency. As the impeller wears, these clearances open and efficiency drops rapidly. The tight operating clearances required on both sides of an open impeller for efficient operation precludes adjustment of the impeller axial position to compensate for wear.

Enclosed Impellers

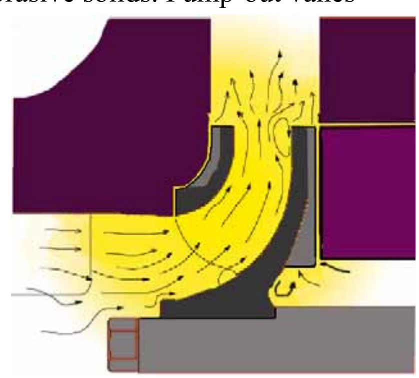
An enclosed impeller incorporates a full front and back shroud. Fluid flows through the internal impeller passages without hydraulic interaction with the stationary casing walls. In a well designed enclosed impeller, the relative velocity between the impeller and the fluid at any given radius is quite small. This results in less wear than other impeller styles.

A portion of the fluid exiting an enclosed impeller leaks back to the pump suction by traveling through the gap between the front impeller shroud and the casing. An enclosed impeller typically has wear rings or radial pump-out vanes to control this leakage. A centrifugal pump with an enclosed impeller is usually not dependent on tight axial clearances to manage leakage. Therefore an enclosed impeller pump can tolerate moderate wear with little adverse effect on overall performance and efficiency.



Wear rings provide an adequate solution for applications that occasionally handle light solids and for the practical design and manufacture of multi-stage pumps where liberal axial clearance precludes tolerance stack-up problems during assembly. Wear rings control recirculation through flow restriction, and are used in conjunction with impeller balance holes to control axial thrust. The flow restriction created by the tight clearances between the stationary and rotating wear ring faces causes very high local velocities and high hence a high wear rate. Wear rings, because they are subject to a very high flow velocity, will have an unacceptably short life span in an abrasive environment, even when hard materials or treated surfaces are used.

Pump-out vanes offer a better alternative for handling abrasive solids. Pump-out vanes control both leakage and axial thrust through a pumping action. Local flow velocities with pump-out vanes are much lower and spread over a greater area. The lower local velocity results in a much lower wear rate. It is not uncommon for pump-out vane life to equal or exceed the life of the main impeller blades.



The disadvantage of pump-out vanes is that they consume power while controlling leakage and thrust. When new, a pump impeller equipped with pump-out vanes will likely have a lower efficiency than its wear ring counterpart. However, it will come close to maintaining its “as installed” efficiency throughout its operational life.

An impeller with wear rings loses efficiency rapidly as the rings wear. If ring wear is severe, the high velocity zone can shift from the wear rings to the impeller thrust balance holes resulting in an expensive and premature repair or replacement of the impeller. It is not uncommon to have several outages to replace wear rings over the life of a single impeller when wear rings are used in an aggressive solids application.

A disadvantage of enclosed impellers is that the front and back shrouds, rotating in close proximity to the casing walls, generate disc friction that lowers the efficiency of the pump relative to that found in open impeller designs. Another disadvantage is that the enclosed impeller is more easily plugged. Large solids that might otherwise be broken up by the grinding action generated by a rotating open impeller and the stationary casing wall, can easily become lodged in the eye of an enclosed impeller. This may create a mechanical or hydraulic imbalance that has the potential to damage the pump, or at the least causes a pre-mature outage to remove the blockage.

Semi-Open Impellers

A semi-open impeller is a compromise between an open and an enclosed impeller. It incorporates a single shroud, usually located on the back of the impeller. A semi-open impeller has a solids passing capability similar to that found in an open impeller. With only a single shroud a semi-open impeller is easy to manufacture and completely accessible for applying surface hardening treatments. For moderately abrasive slurries, especially if plugging is a concern, a semi-open impeller is a good choice.

A semi-open impeller operates more efficiently than an enclosed impeller because of lower disc friction and tighter axial clearances. It has an advantage over an open impeller in that it can be adjusted axially to compensate for casing wear.

High axial thrust is the primary drawback of a semi-open impeller design. Axial thrust balance is manageable through design for both open and enclosed impellers. On a semi-open impeller, the entire backside surface of the shroud is subject to the full impeller discharge pressure. The front side of the shroud is at suction pressure at the eye of the impeller and increases along the impeller radius due to centrifugal action. The differential between the pressure profiles along the two sides of the shroud creates the axial thrust imbalance. This can be managed somewhat through the use of pump-out vanes on the back side of the shroud, but the vanes will start to lose effectiveness if the impeller is moved forward in the casing to compensate for wear. Some manufacturers have integrated an adjustable wear-plate into the casing design so that clearance adjustments can be made. Combined with hard materials or surface hardening treatments, this option provides a good design in lightly to moderately abrasive applications.

An obvious question is why use a semi-open impeller in a solids application if an open impeller with an adjustable wear plate could be used instead? It might seem logical that an open impeller of hard metal construction, used in conjunction with an adjustable wear liner, would combine good solids handling characteristics, with low thrust imbalance, light weight, and adjustability for wear. Unfortunately, true open impellers lack the structural support to prevent blade collapse or deformation under the demands of most industrial applications. A semi-open impeller is well suited for handling solids in applications where the blades might encounter high impact loads from rocks and the like, or in higher power applications. In both situations the shroud provides additional structural support and reinforcement to protect against blade collapse or deformation. One improvement that has been made to the semi-open impeller is the use of a partial shroud. Most of the pressure developed by the impeller, and most of the shroud surface area, is in the outer diameter region of the impeller. Elimination of the shroud in this area reduces the axial thrust in a semi-open impeller without compromise to the structure support provided by the full back shroud.

Open, enclosed, and semi-open impellers are available in pumps that span a broad range of N_s and should be chosen based upon the characteristics of the application. Next month, in part two of this series, we'll discuss several special purpose impellers such as the recessed, screw centrifugal, and multi-disc impellers.