Rotating Machinery Services, Inc.

VANED VS. VANELESS DIFFUSOR IN COMPRESSOR STAGES

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When designing a centrifugal compressor stage the choice in diffusor design must be considered in clean sheet designs and rerate cases. In general, these diffusors fall into two categories: vaned and vaneless.

The job of the diffusor section of a stage is to convert the dynamic pressure (velocity head) coming out of the impeller into static pressure. The velocity will be reduced going into the crossover bend, or volute depending on the stage, reducing the amount of loss taken going into the final sections of the stage. The diffusion done in a vaneless space is primarily done through area increase as the flow goes radially outward. For a given diffusor width, as the radius increases so will the area. A vaned diffusor can achieve diffusion in two ways; through the increase in area as radius increases and through use of diffusion over the vane. The vane acts as a diffusing agent itself through the pressure field created on the airfoil surface.

Diffusors can also be designed to aid in surge avoidance. As the flow in a stage decreases, the area increase in a vaneless space becomes more of a hindrance than a benefit; and as the flow angle decreases below a stable value the flow in the diffuser can reverse and surge can occur. Vaneless diffusors can be "pinched", meaning the diffusor width decreases with radius, in order to attempt to avoid this. The issue with this is of course that the area increase that the diffusor depends on may not exist depending on the severity of the pinch required. Vaned diffusors can tune diffusor angles to turn the flow for increasing angle to avoid surge. In this way the vaned spaces still get the diffusion of the area increase and vane diffusion, all while helping to create head margin to surge. Figure 1 shows a vaned and vaneless diffusor tuned to create similar curve shape and head margin to surge, these diffusors follow identical impellers. In this case the vaneless diffusor is pinched to create the same head margin as the vaned diffusor. Notice how the static pressure is higher at the exit of the vaned diffusor where adequate diffusion has taken place.

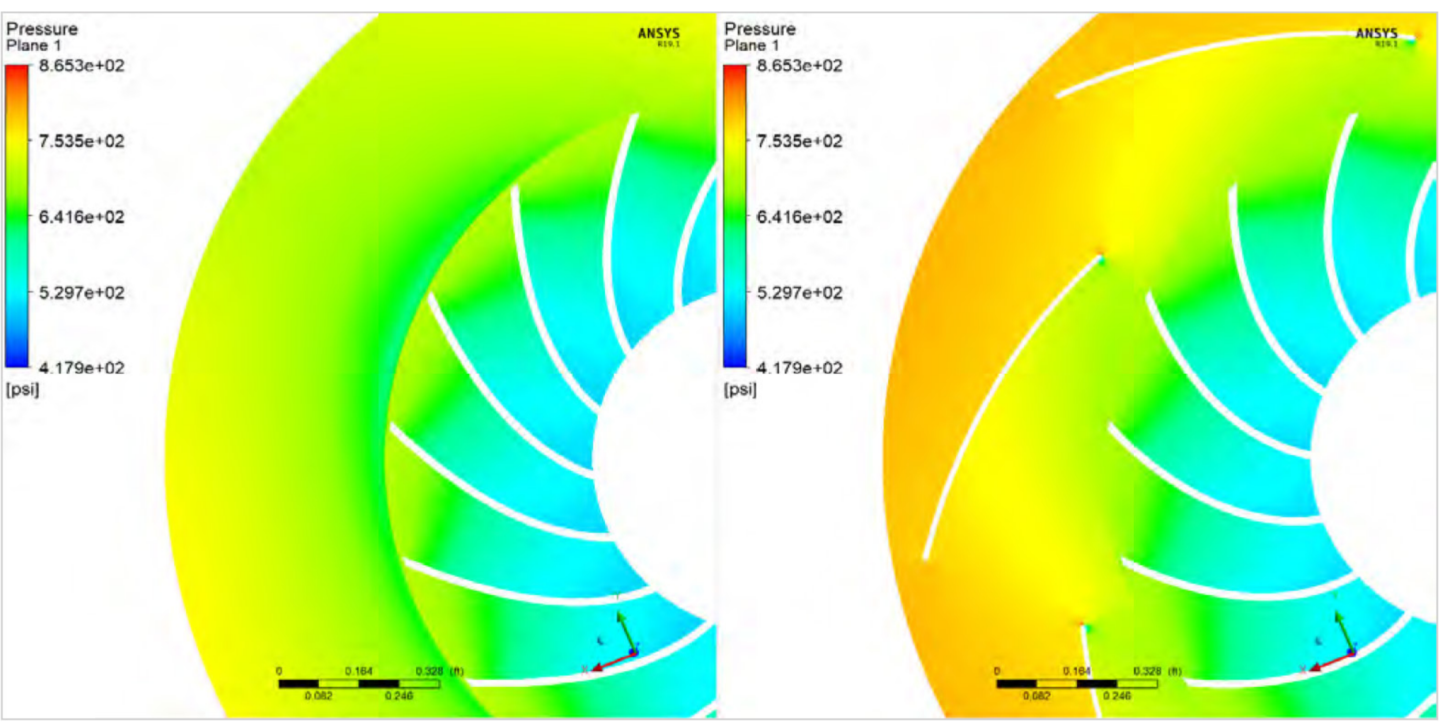

Figure 1: Pressure distributions determined by CFD results for vaned (right) and vaneless (left) diffusors designed for similar impellers/stages

Both vaned and vaneless diffusor designs have benefits and drawbacks to their implementation.

Vaneless Diffusor

- Better flow range
- Better performance off design
- Reduces aeroacoustic effects of pressure pulsations from impeller

Vaned Diffusor

- Better performance near design point
- Lower velocity going into discharge volute
- Higher efficiency

Figure 2 illustrates this by directly comparing head and efficiency curves for similar stages with both vaned and vaneless diffusors. As anticipated, the vaneless diffusor curve is slightly less efficient near the design point, but the compressor has a greater operating range and has more sustained performance off-design. The vaned by comparison has shorter range, but is more efficient at the design point. This makes vaned diffusors a better choice where the user anticipates narrow flow ranges during operation, where the compressor can be kept near the design point and can leverage these efficiency benefits of the vaned diffusor.

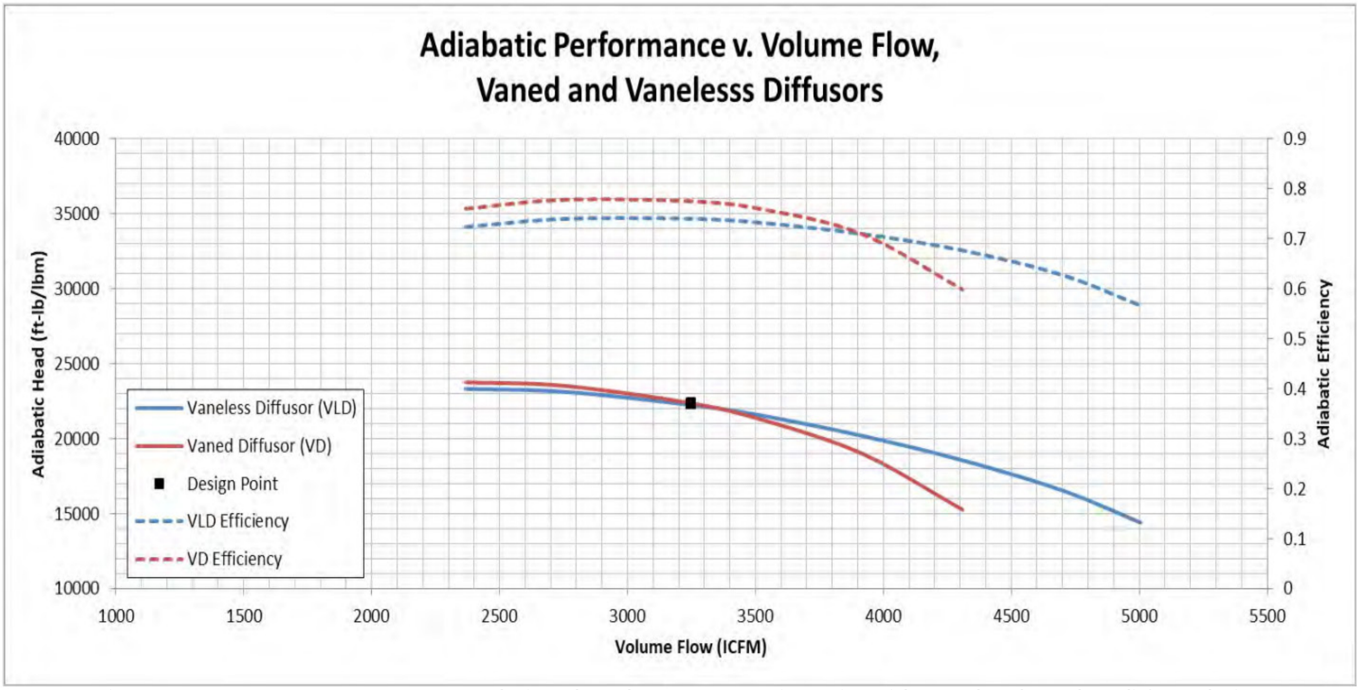

Figure 2: Performance curves for stages designed for the same operating point with vaned and vaneless diffusor designs

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