VOLUTE DESIGN AND HOW IT CAN AFFECT STABILITY

By Ryan Montero

The final flowpath section of most centrifugal compressors is the volute; and although it is relatively simple in design compared to other flowpath components, it is always as critical to overall performance. The purpose of a discharge volute is to recover the radial velocity head of the flow exiting the diffusor before exiting the compressor. A well designed volute collects the flow while conserving the angular momentum of the flow. This is done by matching the area progression around the circumference of the volute according to the requirements of the discharge condition of the diffusor section. A volute that is oversized will incur losses due to over diffusion of the flow, and an undersized volute will fail to completely recover the dynamic pressure from the radial component of the flow entering the volute. In some cases these losses can hurt not only your efficiency, but also flow stability. There have even been examples of impeller failure due to poor volute design. Meanline, onedimensional, performance codes have good correlations to predict volute performance based on circumferential area progression and diffusor discharge condition. However, to really capture what is going on in your volute, full 3D CFD is necessary.

In the example shown in Figure 1, the volute is constant area from the cut water through to the discharge pipe. This causes large areas of recirculation to form where the fluid has diffused too quickly. This leads to larger efficiency losses, and can result in loss of surge margin as well. The flow point for the model shown in Figure1 is beyond the expected surge limit line, but small pockets of stall can still be seen in a few impeller blades. A close up of this is given on the right side of Figure 1. This is the direct result of poor volute performance.

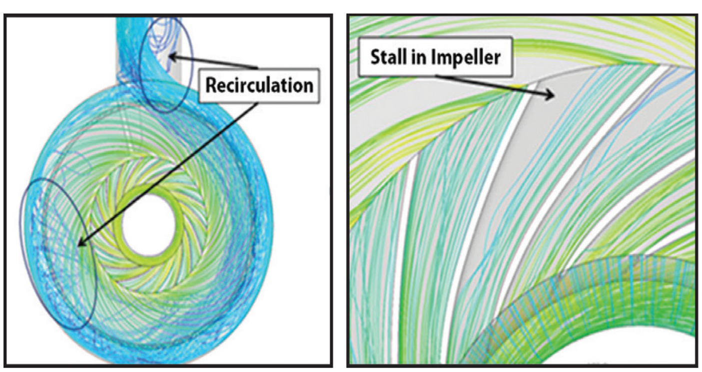

Figure 1: (LEFT) Constant area volute, note large areas of recirculation (RIGHT) Close up of stall in impeller (volute domain hidden) due to poor volute performance

In order to correct this flow instability, a new volute can be designed that properly matches the diffusor discharge conditions. Instead of a constant area along the circumference, it will have a steadily increasing area from the inlet at the cutwater to the discharge pipe. This area progression is essential for volutes which are created for the purpose of recovering velocity head in the flow before entering the next section of the process. In this case, because the volute has a radial exit, there is recirculation in the pipe where the flow turns sharply to exit the volute. This is a common problem with radial volutes and, in some cases, guide vanes are employed to combat this. An updated design is shown below in Figure 2 with the changes mentioned above.

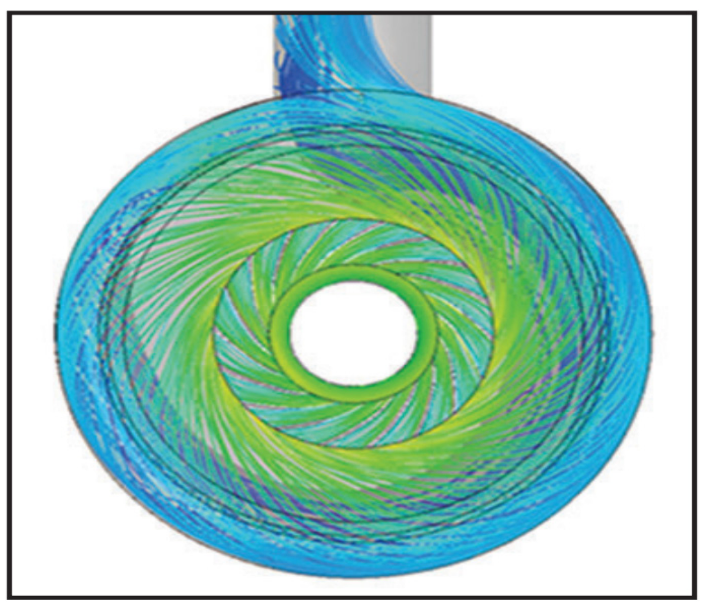

Figure 2: Upgraded volute design with proper flow matching area progression, guide vane at discharge pipe to smooth turning flow.

The flow point in Figure 2 is the same that is shown in Figure 1, but does not have the same large pockets of recirculation. The flow going through the impeller has also been smoothed, and there are no longer signs of stall in the impeller passages. The added turning vane near the radial discharge also smoothed the flow turning into the pipe. Flow stability is restored and surge margin maintained.

Good volute design is essential for high stage efficiency, and it can make or break compressor stability especially when operating near the surge control line.

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