Rotating Machinery Services, Inc.

CENTRIFUGAL COMPRESSORS CONSTRUCTION EXPLAINED

By Robert Huffman

This article will help provide basic understanding of centrifugal compressors. We will start with an overview of what components are within a centrifugal compressor, focusing on the flow path of the machine. Subsequent articles will discuss general compressor performance theory, compressor curves and how each component within the flow path influences the compressor's range, head and efficiency.

The basic compressor stage has an inlet section, an impeller, a diffuser and depending upon the location of the stage within the machine either a return channel or an exit section to the discharge flange. The exit section can either be a volute or a collector. Refer to figures 1 and 2 for cross section views of a typical compressor stage.

Let's start with a typical multistage compressor, we'll first list the typical components and then in future articles come back and talk about each one in some more detail. The first stage in the machine may or may not have an inlet guide vane before the impeller. The next component will be the impeller, followed by the

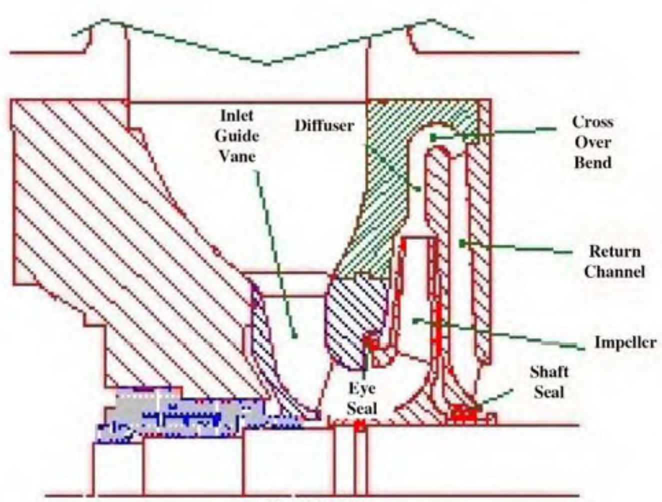

FIGURE 1

diffuser, the cross over bend, and finally the return channel. There is an impeller eye seal and a shaft seal at the back of the impeller. Each stage will follow this component stack up until you get to the last stage within the machine. Typically the last stage impeller exits into a diffuser and from the diffuser the flow passes into either a discharge volute or discharge collector and then on out of the compressor discharge flange. This last stage impeller has an eye seal but instead of a shaft seal behind the impeller, there is a balance piston seal. Now let's go back and talk about the specific purpose of each components.

Inlet Guide Vane: Regardless of its location within the compressor, the inlet guide vane (IGV) is there as the name suggests, guiding the flow into the inlet of the next component. Specifically what it does is to ensure that a prescribed velocity profile is presently going into

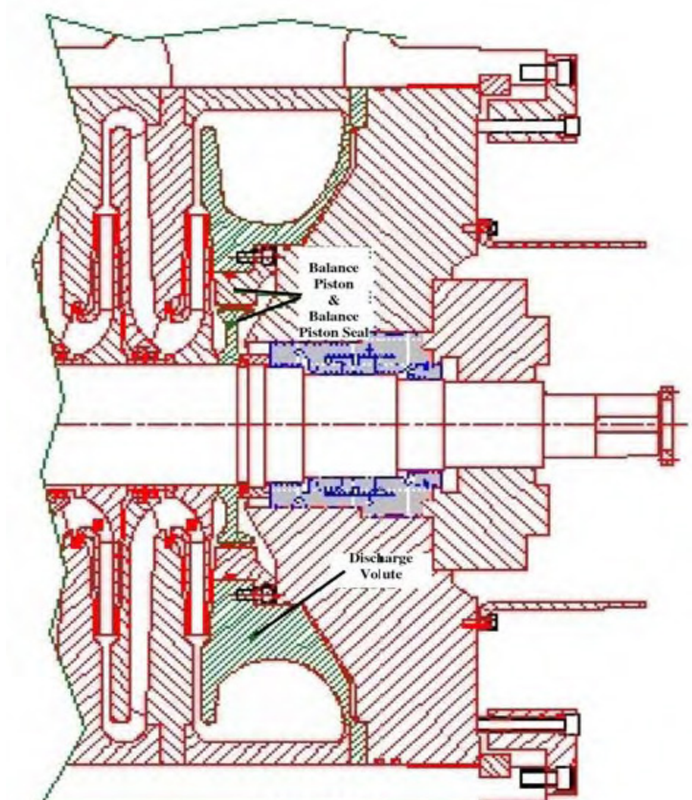

FIGURE 2

the next component. In another article we will come back to this subject in more detail to discuss the Euler Turbomachinery equation, but in short the work input to a gas from a compressor stage is a function of the change in tangential velocity from the inlet to the outlet. It is important for the compressor designer to ensure that the inlet velocity profile is known to ensure that the stage design meets the target output. The IGV acts to ensure that the velocity profile is known. Most machines are designed to have a tangential velocity component of zero magnitude, but some designers have used the IGV to impart tangential velocity into the flow. There are also machines that have variable IGV's, that is the IGV can be rotated while the machine is in operation.

This is typically only seen at the first stage of the compressor due to mechanical constraints and complexity of using variable IGV's at stages other than the first stage. Variable IGV's are also typically found on fixed speed compressors vs. variable speed compressors. Speed changes have a greater effect on compressor output than IGV rotation changes. Further discussion of this will occur in future articles, but the key takeaway is that the IGV is there to ensure a known velocity profile going into the impeller.

Impeller: There are various designs of impellers; open, closed, radial, mixed flow, 2D and 3D.

Depending upon the specific gas being handled, the flow rate, target pressure ratio of the compressor, the number of stages present, and cost vs. efficiency goals will determine the type of impeller required. Further details of these areas will be in the future but for now the takeaway is that the impeller imparts work into the gas to increase the gas kinetic energy. The things that affect the work input, or energy added to the gas, include the impeller blade exit diameter, impeller blade mean inlet diameter, the impeller blade exit angle, the inlet flow tangential velocity and the shaft speed. Most industrial multistage impellers will be a covered impeller of either 2D or 3D blade design. The flow leaving the impeller will have a large velocity component in the tangential direction. Open impellers are typically not used in multistage compressors where the impellers are mounted on a single shaft. There are a few multistage machine types where the first stage is of an open wheel design but they are not that common. It is not uncommon for integrally geared compressors to have open impellers for all stages. Open impellers are typically used when higher pressure ratio's per stage are needed; the impeller can with stand a higher tip speed than a closed impeller. Without the cover, the stresses are reduced significantly so the impeller can be spun faster before the same stress limits of a closed impeller are met. Impeller discharge pressure is a direct function of the tip speed of the impeller, so the faster I can spin an impeller the more pressure I can develop. Open impeller stage efficiency is in part governed by the leakage of the gas over the top of the impeller blade; therefore control of this clearance is critical to maintaining good stage efficiency. With a multistage compressor with all the impellers on a single shaft, it has proven difficult in practice to ensure all stages are at the correct clearance during rotor installation due to tolerance stack up and to control hot running clearances in operation. Closed impellers do not suffer from the shroud tip leakage loss and so in general typically achieve better efficiency but at lower discharge pressure when compared to an open impeller of the same diameter. The next newsletter article will continue on with discussion of the diffuser, cross over and return channel sections of the compressor.

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