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describe the advantages of an integrally geared centrifugal  
compressor for flammable and/or toxic gas applications.*

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# CONTINUING FROM CONVENTIONAL COMPRESSORS

**A**n integrally geared centrifugal compressor has a characteristic in its structure, where one or several impellers are mounted on ends of pinion shafts of a speed increasing gear unit in overhung position, and the casings for each impeller are mounted directly to the gear casing (Figure 1). This type of compressor is much more compact than the conventional single shaft type (Figure 2). For a long time it has been accepted that the integrally geared centrifugal compressors are only applied for air or other non-hazardous gases such as nitrogen service. This is, however, no longer the case because integrally geared machines nowadays can handle almost any kinds of gases including flammable and/or toxic ones. KOBELCO SUPERTURBO, an integrally geared centrifugal compressor has been widely used for such gas service supported by various newly developed technologies.

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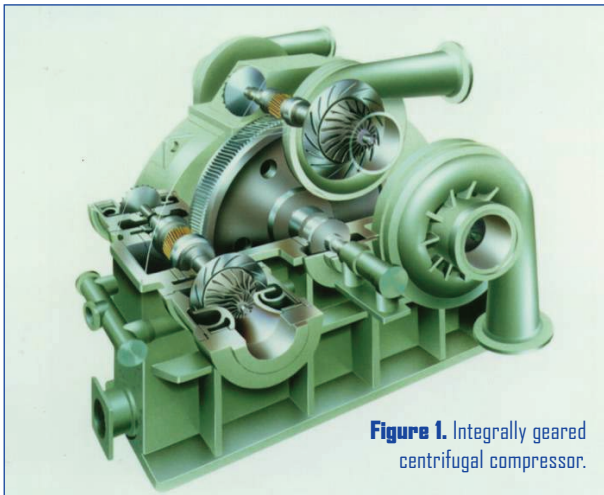


Figure 1. Integrally geared centrifugal compressor.

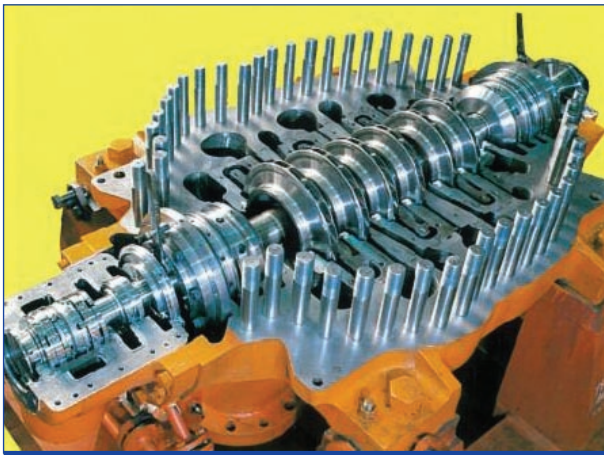


Figure 2. Conventional single shaft centrifugal.

## Technologies

### Aerodynamic performance

Aerodynamic performance is one of the most important factors for the user and the impeller is the most important component for the performance. Various types of impeller can be applied to SUPERTURBO. Open or enclosed, blade types, such as backward, radial, high steep, etc. and materials, such as carbon steel, stainless steel, titanium, etc., suitable combinations of impeller types and materials are selected to match each application and/or requirement. In addition to impellers, various types of casing and diffuser were developed and optimised combination were confirmed. The compressor design including the impeller, casing and/or diffuser is tuned for each compressor/project to enable the best performance.

### Rotor design

A typical rotor configuration of integrally geared centrifugal compressor is shown in Figure 3. Two impellers are attached at both ends of the rotor shaft. Rotor dimension, gear size and bearings are designed with rotor dynamic analysis to ensure ample stability to combat unbalancing forces from high density gas and the longer overhang, due to the application of tandem dry gas seals that have two seals in series. The rotor design is tuned based on both lateral and torsional vibration analysis results. An example of rotor stability analysis for an integrally geared compressor is shown in Figure 4, which shows that the rotor is stable against instability force with tilting pad journal bearing. The stability is improved further more by journal bearings with a squeezed

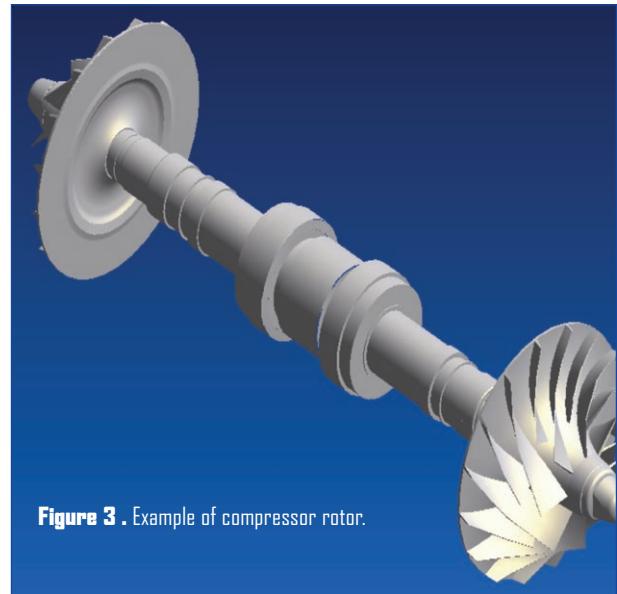


Figure 3. Example of compressor rotor.

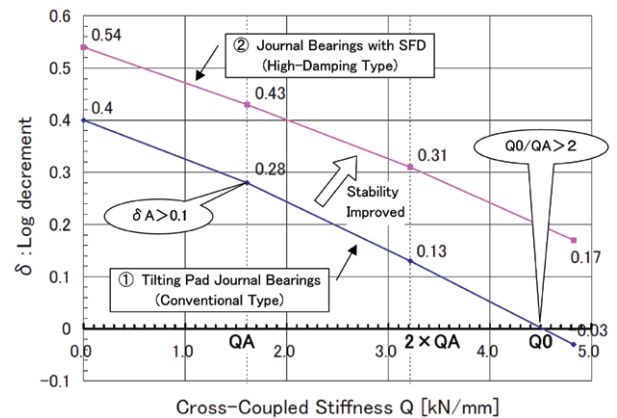


Figure 4. Example of rotor dynamics analysis.

film damper (SFD) for 8 MPa high pressure operating condition. The analysis is performed according to API617 7<sup>th</sup> edition.

### Bearing

Depending on the mechanical requirements to the bearings, suitable journal bearings are selected: FLEXURE PIVOT™ tilt pad bearing and the same option with SFD bearing.

### Shaft seal

Sealing flammable and/or toxic gas to prevent gas leakage and to protect compressor components is also essential for such compressors. A dry gas seal is a device that seals gas with minimal leakage by taking the gas into grooves in a rotating ring (mating ring), thereby maintaining a minute clearance of several microns due to the pressure rise in the groove. This seal is inherently stable because the pressure in the groove becomes larger when the clearance becomes narrower and vice versa. Leakage is negligible, less than several millionths of conventional labyrinth seals. The development of dry gas seals stable up to the high circumferential speed region, that do not require seal oil, have enabled the application of integrally geared centrifugal compressors for gas services. This seal is called a 'dry gas seal' because it is used in a 'dry' gaseous environment as opposed to the oil film seal used in a 'wet' seal oil environment. In cases where dry gas seals cannot be applied, carbon packing or labyrinth seals are used instead.

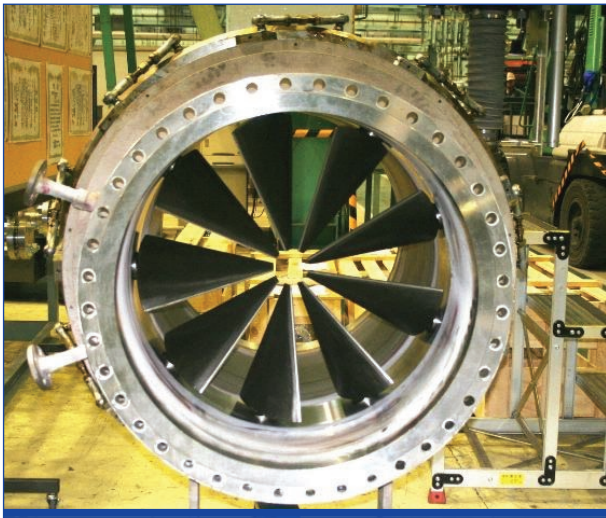


Figure 5. Inlet guide vane.



Figure 6. CO compressor for Taiwan.

## High pressure casings

SUPERTURBO can be applied up to 8 MPa. Barrel type casings are lined up for high pressure services because of their high strength and perfect resistance against leakage.

## Gear

Integrated helical gears, special thrust collars, which transfer gas thrust force from pinion gears to bull gears, are one of the important compressor components according to API613 or API617 7<sup>th</sup> edition.

## Intermediate cooling

One of the merits of integrally geared compressors is easier implementation of intermediate cooler to each compressor stage than in single shaft type compressors. This allows lowering of the necessary shaft driven power and suppression of the gas temperature in the compressor. When the designated service renders too high a discharge temperature, especially when the corrosiveness of the handled gas requires a limitation within a certain temperature during the compression stage, the necessity of intermediate cooling is determined on the basis of gas characteristics.

## Advantages

Incorporating the excellent features of conventional integrally geared compressors, such as simple structure and package design, the SUPERTURBO has the following advantages in comparison with single shaft compressors.

### Reduction in power consumption

Aerodynamic power consumption can be reduced because rotating speed can be optimised for each pinion, optimising the specific speed

even for the higher stages where volumetric flow of the gas is substantially reduced compared with initial ones, and because cooling between each impeller is easy. Fewer bearings also leads to reduced mechanical losses.

### Capacity control

Process gas compressors are often required to operate on a partial load. In order to enable operation with improved efficiency over a wide range, inlet guide vane or variable diffuser vane devices can be equipped for each stage. Figure 5 shows an example of an inlet guide vane device.

### Further energy saving

It is possible to combine the SUPERTURBO with other rotating machinery, such as steam turbines or power recovery turbines, by adding another pinion or utilising an open end pinion with no impeller. In this case, the generator, and other auxiliaries that would be required for conventional steam turbine or power recovery turbine systems can be eliminated so that not only a considerable reduction of space can be realised, but also the total system efficiency can be improved because various losses such as mechanical losses of the combined rotating machinery and generator losses can be eliminated.

### Packaged design

SUPERTURBO is usually configured with packaged design concept where not only the compressor and driver, but also all the auxiliaries such as lube oil components or gas coolers are mounted on the single common base plate. The compressor casings (from one up to eight casings) are mounted on the integral gear case. The integral gear case has a hole in its bottom through which the return oil travels directly down to the lube oil reservoir, which is integrated within the common base plate. The main oil pump is usually driven by the main equipment shaft end so that the lube oil head tank can be eliminated, as the main oil pump will run regardless of availability of power source as long as the main equipment is rotating.

### Foundation space requirement

Due to the packaged design, SUPERTURBO does not require elevated foundation and, because the equipment can be configured in one unit, the space required for equipment is substantially less.

### Site erection

The packaged design concept removes the need to construct elevated foundations, conduct interconnecting oil piping work, mount overhead tanks, etc. Oil flushing work, one of the most time consuming works during site erection, is all done at the compressor manufacturer's shop. Although the actual time period required for site erection work depends on various site conditions, the relative time requirement is typically half that of conventional machines.

## Applications

The SUPERTURBO provides pressure and flow characteristics for most process requirements based on API617 7<sup>th</sup> edition Chapter 3. It has been used in HyCO plants producing CO and hydrogen, polypropylene/polyethylene applications, vinyl chloride monomer (VCM) applications, PP splitter, gas processing and various petrochemical and chemical applications.

## Typical references

Figure 6 shows CO compressors used in a HyCO plant. Typically 2 - 4 loops are required in this kind of process and a multi stage integrally geared compressor is a suitable selection due to process requirements such as high pressure ratio, number of side loads, and necessity of inter cooling. In addition, this process needs special consideration on each stage discharge temperature due to potential problem of carbon soot. 