



HOFIM Sealed – a compact yet powerful turbocompressor

Hermetically sealed, oil-free turbo-compressor with electric high-speed motor and magnetic bearings for the oil and gas industries

By Roger Suter & Uwe Lauber

Turbocompressors with magnetic bearings and dry gas seals have been successfully used for gas compression and pipeline operation for more than a decade. These installations have demonstrated that the elimination of the lube oil system results in increased availability and is economically viable. Furthermore, electric high-speed drives offer significant technical and economic advantages, allowing a wide operating range with no emissions. Nevertheless, with a conventional compressor-coupling-motor train

a seal system (i.e. dry gas seals) is necessary to seal the process gas against the environment. Unfortunately every seal installation produces leakages either to the process gas (contamination) or to the environment (flare). Further, the complexity of the sealing system leads to reduced availability and increased maintenance costs. These disadvantages were completely eliminated with this novel, unique design.

In 1990, Sulzer Turbo started with the development of the so called MOPICO (Motor Pipeline Compressor) units. This two stage machine is a hermetically sealed compressor without seals, driven by a high frequency motor. Due to the fact that magnetic bearings have been used, no oil system is required at all. The main application for this type of machine is gas transportation/pipeline application. Due to the market demand of having higher pressure ratios for other applications, a further development has been started towards the so called HOFIM (high-speed oil-free) compressor. The main features incorporated in this machine are the use of magnetic bearings (no oil) for the compressor and for the stand alone high frequency motor. As the motor is separated from the compressor side, a dry gas seal system has again been used for sealing the unit to the atmosphere. As a consequent way forward, the advantages of the MOPICO units have been combined with the stand alone HOFIM unit. This lead to the development of the HOFIM sealed type.

Due to its unique hermetically sealed design, the HOFIM SEALED offers an essentially leakage-, wear- and maintenance-free remote operation with maximum flow variations at highest availability with all benefits of cost efficient and environmentally compatible design.

Gas compression is needed at many places in the chemical, oil and gas industry, mainly for collecting (i.e. moving gas from the wells on- or off-shore upstream to the processing plants), gas transmission from the terminals to the downstream and chemical industries and for gas re-storage in storage facilities for use in peak hours. In specific applications, processing the gas downstream (hydrocarbon processing industries and chemical industries) and gas distribution to the end-user needs compression as well. The demand for natural gas can be expected to increase over the next years due to increasing demand from households as well as from gas fired power plants. The natural gas industry recognizes the importance of efficient, flexible compression equipment for the transmission of gas. In the beginning, the gas industry met its compression objectives with many small reciprocating compressor units. As competition increased, gas

Stages in compressor development from the MOPICO via the HOFIM to the HOFIM Sealed





companies began employing more cost efficient larger units and eventually gas turbines became the prime mover of choice. While gas fired engine driven compressors are convenient for gas companies the conditions for their installation are subject to changes: Environmental restrictions have tightened making permitting difficult. The larger gas turbine units seemed a solution because they were the low capital cost prime mover and allowed relatively clean burning. However, gas turbines have not yet achieved the high degree of flexibility and fuel efficiency that gas transporters had hoped for. Flexibility has become an increasingly important issue because of the new “peaking power plants” that are coming on-line. Gas companies are trying to solve the problem of low cost, low maintenance compression that can be quickly ramped up to meet peak demands. The idea of using electric motors to drive compressors to minimize the environmental, regulatory and maintenance issues is not new. But progress in the area of power electronics and magnetic bearings have made them attractive.

Advantages of electric high-speed drives

The development of cost efficient power converters for high power did not only lead to an increase of the adjustable speed market (new installations as well as

retrofits) but opens the market for high-speed drives. The on-going progress in the area of power electronics helps to realize power converters for higher frequencies at lower cost than in the past.

Efficiency

The efficiency of an electric high-speed drive is above 94 percent with efficiencies above 96.5 percent for the motor, 98.5 percent for the power converter and 99 percent for the transformer. Thus, the total efficiency of an electric high-speed drive is in the range of 30 to 50 percent, depending on the efficiency of the power plant, when centralized power generation is considered and transmission and distribution losses are taken into account. This may be higher than the efficiency of a modern industrial gas turbine with an efficiency of about 30 to 40 percent. When utilizing the waste heat at the gas turbine outlet (cogeneration), there may on the other hand be merits in favor of gas turbines.

Compared with low-speed drives, high-speed drives with magnetic bearings offer an additional efficiency gain due to reduced bearing losses and the elimination of the gearbox losses. The efficiency of a gearbox is typically in the range of 98 to 98.5 percent. Together with reduced losses on magnetic bearings compared with oil bearings, the efficiency of an electric high-speed drive is about 1.5 to 2 percent higher than for an electric low-speed drive with gearbox.



1+2 Comparison of the HOFIM with oil and auxiliary systems and the new HOFIM Sealed

Capital cost

Capital cost for electric drives is significantly lower than for gas turbines, provided electricity is available or can be made available without extraordinary effort and, for example, cost for electrification. Obviously, gas turbines will, on the other hand, offer advantages in remote areas.

Weight and foot-print

When gas turbines with all auxiliary systems are compared with electric drives, i.e. motor, power converter and transformer, then weight and size, i.e. foot-print, of electric drives are smaller.

Reliability and availability

The reliability and availability of electric adjustable speed drives is dominated by the power electronics. Today's power converters achieve a mean time between failure (MTBF) of 6 years and more. Typically, the mean time to repair (MTTR) is less than 4 hours. These values have been proven with several hundred installations of adjustable speed drives over the last years [9]. Thus, electric drives achieve an availability as high as 99 percent and above. This is much higher than typical figures for gas turbines where reliability is about 99 percent and availability is in

the range of 96 to 98 percent. This point of view presupposes that the supply network is available 100%, this being not assured in some areas.

Maintenance costs

It is obvious that an electric drive with its relatively simple design requires less maintenance than gas turbines and gas engines that have many hot gas parts and wearing parts. Electric high-speed drives require even less maintenance than electric low-speed drives with gearbox. The elimination of the gearbox and of the lube oil system makes the drive simpler and more reliable. The two parts of an electric motor that need most service and maintenance are obsolete with high-speed drives. It is estimated that maintenance costs for high-speed drives are only half of the costs for low-speed electric drives with gearbox.





HOFIM Sealed – hermetically closed, oil-free compressor for high-pressure applications

Safety and environmental aspects

Electric drives have no emissions on-site and total emissions are reduced as well. The lower noise levels compared with gas turbines make electric drives very attractive for urban areas. Furthermore, they are much better suited for remote control and unmanned operation. For electric high-speed drives the elimination of the gearbox, the entire lube oil system and the necessary auxiliary systems does not only increase efficiency and availability but also increases safety. No oil leakage and no fires are possible. Furthermore, with the elimination of the gearbox one noise source is eliminated. It is to be expected that before long gas turbines, and of course also the driven machines, can likewise be equipped with magnetic bearings.

Flexibility

Compressor drives need to have a certain speed range capability in order to allow a variation of the transported gas flow. Gas turbines usually have a limited speed range whereas adjustable speed drives offer more flexibility because power and rotational speed can easily be adjusted with the power converter. Furthermore, variable speed operation allows higher part load compressor efficiency and reduced emissions. Moreover, compressors need to be quickly ramped up to cover peak demands. Electric drives are much easier to start and can be ramped up to full speed within seconds. With electric drives the operating speed can be controlled more accurately than with gas turbines. The flexibility allows optimization of the pipeline operation whereas accurate speed control is more important for process control.

Compressor design

The HOFIM Sealed is a hermetically sealed compressor-motor unit that was designed, constructed and tested according to API STANDARD 617, sixth edition.

Casings

Casings are of the vertical split design and permit rapid and economical maintenance by easy withdrawal of the major parts without breaking any process piping connections. Compressor and motor are stud bolted and keyed together metal-to-metal to ensure accurate, repeatable alignment. The compressor outer casing is machined from a single steel forging with integral suction and discharge flanges. The motor outer casing is a simple welded pressure containing structure. All pressure containing welds are examined by Section VIII, Division 1 of the ASME Code.

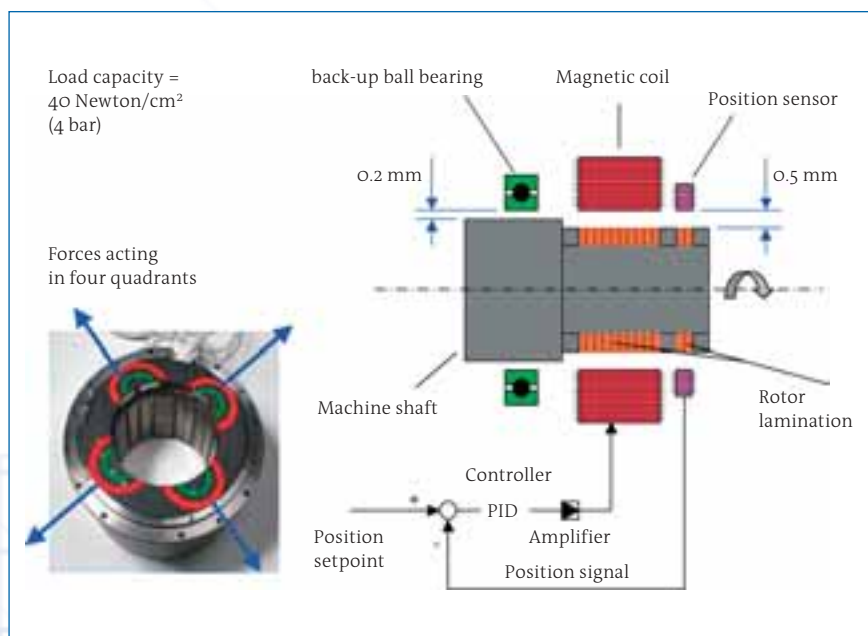
Rotor

The compressor rotor is made out of a single piece of forged steel equipped with hydraulically fitted tapered coupling hub and thrust disk. Welded or milled/brazed, closed type impellers and magnetic lamination packages are shrunk-fitted to the shaft. Coupling hubs, thrust collar and each impeller are spin-tested and individually balanced before assembling onto the shaft. The final assembled compressor rotor is high-speed balanced.

Magnetic bearings

The complete rotating assembly is supported by axial and radial magnetic bearings. They are cooled by process gas, have no wear and low power consumption. The rotor position is monitored continuously by amplified direct current signal sensors. Magnetic bearings with their excellent damping capabilities offer significant technical advantages and are the key technique to an oil-free and sealed solution. All bearings are standardized in a modular way with pre-defined bearing design and a limited number of sizes to cope with the motor-compressor frame sizes. This means moving away from an approach for magnetic bearings that tries to optimize the design for each application towards an approach that does not squeeze the bearing design and may lead to over-dimensioning. Such a design may not be optimal for each motor but it appears to be the best and most cost efficient approach for a range of motor-compressor units. This concept also leads to a robust design, reduces the engineering effort and simplifies and standardizes manufacturing processes.

Diagrammatic presentation of magnetic bearings





Three HOFIM Sealed units for the Stagecoach Gas Storage project in New York State, USA

f the electric high-speed motors is optimized by using pressurized process gas with increased heat transfer rate in a closed loop. Although the losses of the magnetic bearings are relatively low, the bearings need to be cooled as well to avoid overheating. A small amount of the cooling gas is fed through the magnetic bearings integrating them into the closed cooling loop of the whole unit. Optionally to increase total efficiency the heat losses can be removed using an external cooler before the cooling gas re-enters the compression process.

Conclusions and outlook

Also in the future the main field of application of gas turbines will be in the following sectors:

- In remote areas without an independent stable and reliable electricity supply system as well as
- in regions with high ambient temperatures where extensive cooling facilities are required for the power electronics and
- generally in all those cases where energy costs are higher compared to those of natural gas.

These applications, too, represent growth markets, since oil and gas are increasingly found in the most distant regions. With their extensive range of products MAN TURBO are able to offer to their customers solutions which are specifically suited to meet the individual requirements.

It has been shown that a hermetically sealed, oil-free turbocompressor with electric high-speed drive and magnetic bearings offers significant advantages for gas compression and pipeline applications.

Lower capital cost, lower total cost of operation, oil-free operation without on-site emissions, increased safety, higher availability and lower maintenance costs out-perform low-speed drives with a gearbox both technically and commercially and make this design the best solution as regards environmental compatibility.

Due to the deregulation of the electricity market and increased importance of environmental aspects, the HOFIM Sealed will have a bright future.

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