Offshore gas compression challenges to reduce the carbon footprint in a needed transition.

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Abstract

The Oil and Gas industry must reduce its carbon footprint and transition to a more sustainable operating model while meeting an increase in demand for gas. To address this challenge, offshore operators are seeking new solutions that can reduce carbon emissions, increase reliability, and enable unmanned operations.

This paper proposes oil-free high-speed moto-compressor solutions as a technical alternative to overcome the drawbacks of traditional oil-lubricated compression solutions. High-speed motors offer the possibility to reduce rotor weight and overall dimensions, better match the speed to the compressor's optimal one, and eliminate the need for an intermediate gearbox. Oil-free compression solutions can also result in a reduction in the overall package footprint and weight of up to 50% while providing unmanned capability.

Magnetic bearings have been used in natural gas centrifugal compressors since the late 1980s, providing higher speed capabilities, improved reliability, and reduced friction and wear. Baker Hughes has been a leader in implementing magnetic bearing technology and continues to develop this technology in various applications, including hybrid platform solutions.

The use of stand-alone magnetic bearing compressors is seen as a promising solution to tap offshore wells more effectively and address the challenges of decarbonization, new geopolitical situations, and technology improvements. This paper will compare two type of electric motor possibilities, one based on a Low-speed motor with a gearbox and a stand-alone compressor all on oil bearing solutions and the other with a direct drive high speed electric motor with a stand alone compressor on magnetic bearings (oil free solution*)*.

Keywords: *compressors, active magnetic bearings, carbon footprint, platform*

1. Introduction

The raising need of gas as an energy transition and the Ukraine Crises has pushed the oil and gas industry to expand their production to respond to the needs. Gas recuperation has been a main target and on offshore applications with the new technical developments has allow not only to increase but also to optimize the well utilization and prolong its life. For this centrifugal compressor technology was one of the key factors.

In parallel, the CO_2 emission limitation criteria's have been increased. Meaning that the Gas Turbine driven compressors trains are replaced by more effective and reliable electric motor driven solutions. To supply the needed power, there are different ways of approach:

-On site effective power generators creating the needed energy on the platform

-Implement renewable energy source like offshore wind farmers (possibly combined with gensets) [1]

-Supply the energy from a remote onshore facility [2] [3] [4]

The use of Electric Driven compressors has also allowed the reduction of the needed footprint, a higher availability and to reach towards an unmanned installation.

This paper is focused to compare the different electric driven solutions which are:

-Conventional Electric Motor with gearbox driven compressor

-Oil free High Speed Electric Motor (HSEM) driven compressor

in terms of footprint and different feature that are advantages for the offshore (platform or vessel) applications.

2. Setting system boundary

The base case is the comparison of a compression train from a conventional solution compared to an oil free HSEM solution equipped with Active Magnetic Bearings (AMB). The conventional solution is based on a low-speed motor on oil bearings coupled to a multiplier that accelerates the rotation of the compressor on oil bearings, added to that there is the Dry Gas Seals (DGS) and the lube-oil system. As the conventional solution is better known, we will concentrate on the oil free solution. We have considered a power supplied from shore as both are electrical driven solutions.

3. Oil-Free High speed motor drive compressor description

The Oil-Free High speed motor driven compressor is decomposed of the following components/system:

- Centrifugal compressor equipped with AMB and DGS cartridges
- Electric motor on AMB
- Direct power transmission coupling
- Seal gas panel
- Seal gas conditioning skid with booster and/or heater as required by process gas
- Units control panel

A general description of certain parts will be done to explain the technology.

Fig. 1: Oil-free high-speed motor-compressor

- **The Magnetic bearing technology.**

Active Magnetic bearings are electromagnetic mechatronic systems maintaining the position of a rotor inside the stator part. The bearings are used to levitate the rotating parts and with the help of a closed system of positions, temperature and speed sensor continuously corrects its position as shown in Fig. 2 below.

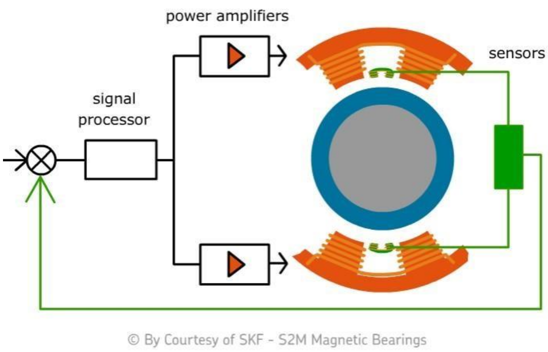


Fig. 2: Bearing and control schematic

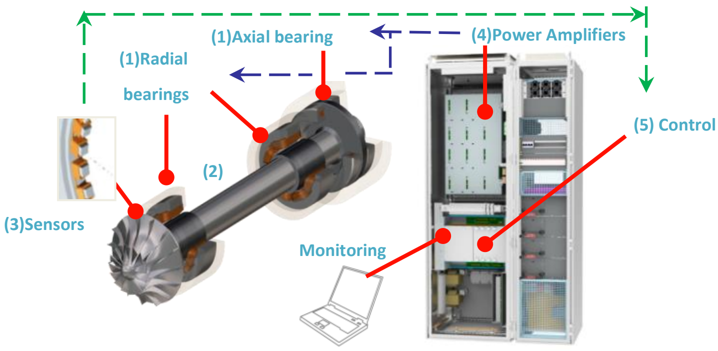


Fig. 3: AMB Components

According to Fig. 3, the magnetic bearing is made of electromagnets (1) that attract the rotor (2) towards the central rotation axis. It is contactless with a radial clearance of 0.3 to 1 mm. The rotor position is measured and controlled in real time by position sensors (3), through a digital control (5) and power current amplifiers (4). To avoid any physical contact between the magnetic bears and the rotor, auxiliary bearings are built in. They allow a safe shut down and protect the system in case of failure or process overload.
Radial Bearing are the bearings that lift the rotor when the machine is horizontal in a static mode and control the shaft in a safe position in the dynamic mode. Axial Bearing is the bearing that controls the forces applied on the thrust disk. Auxiliary bearings, also known as landing bearings, are the bearings on which the compressor rotor is still when the system is in rest condition.
The use of AMB technology versus the traditional oil bearings allow to remove the contact friction and components wear, reduce the mechanical losses, and embed monitoring which allow remote control features .

- **High Speed Electric Motor.**

On HSEM solution inductive motors are typically used with a relevant driver that feeds the motor with higher electric frequency with respect to the grid which in turn causes the rotor to rotate at high speed (typically greater than 3600 rpm) and produce mechanical power.

The high speed introduces additional challenges for the design of the machine that finally bring to technical solution that may differs from traditional machine mainly for what concern the rotor since the higher centrifugal forces limit the usage of shrinking parts on forged shaft, like laminations and require specific smoothed surfaces design to limit losses for friction and turbulence.

High-speed motors have generally smaller footprint and weight compared to a traditional low-speed design (for the same rated power) with the rotor much lighter and smaller in diameter due to the reduced torque. As consequence, the reduction of rotor weight and diameter fit perfectly with the magnetic bearing technology.

- **Centrifugal compressor equipped with AMB and dry gas seal cartridge.**

An AMB centrifugal compressor is like the conventional one: the bearings area is segregated from the process gas by the dry gas seals cartridge allowing the compressor to handle all type of gases (sour, wet, acid etc.). Here below in Fig. 4 the schematic drawing for a typical compressor cross-section.

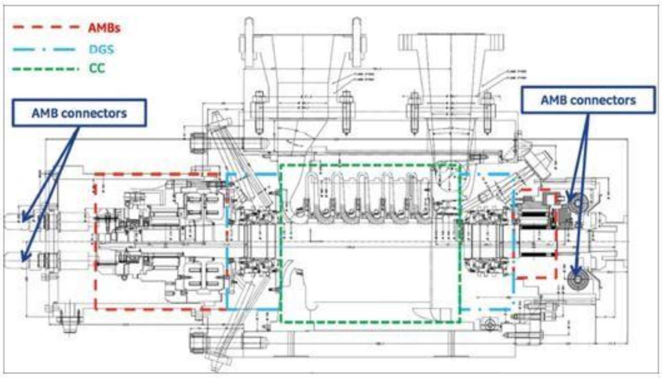


Fig 4: Compressor cross-section

The rotordynamic assessment of a motor-compressor train is typically performed considering each unit alone, being the spacer-type flexible coupling, used to connect the motor to the compressor, capable to segregate the units dynamically.

Differently from oil bearings, the stiffness and damping of the AMB are varying with the frequency and they are dependent by the controller parameters that typically can be defined and adjusted to make the rigid modes and first bending mode well damped allowing the unit to extend the operating speed range.

- **Cooling System.**

Despite the absence of contact, the AMBs are generating power losses (iron, windage and copper losses) so that all active magnetic bearings mounted on centrifugal compressor and electric motor need to be cooled by a dedicated cooling system.

For the centrifugal compressor the AMB cooling circuit is based on a quasi-closed loop using the plant instrument air where air circulation can be forced by a dedicated impeller installed on the compressor shaft as shown in the Fig 5 or through an external blower.

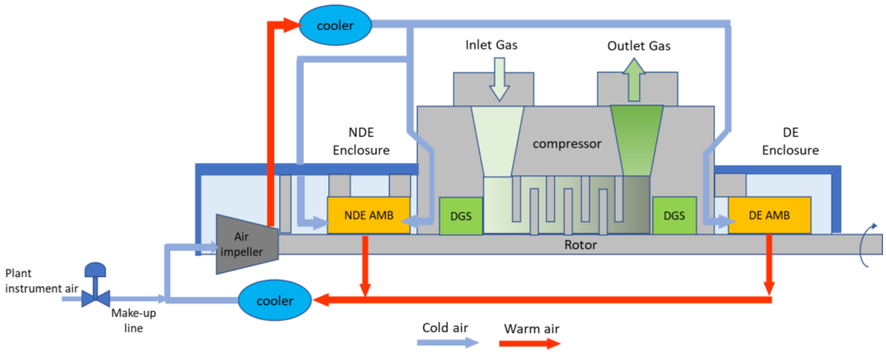


Fig. 5: AMB cooling layout.

The air temperature is regulated by water coolers, and the air leakages on the coupling side are compensated by a make-up line fed by plant instrument air.
For the electric motor, instead, the cooling of the active magnetic bearings is ensured by the internal motor cooling system using the cooled air from ventilation system.

Primary function of air system is to cool the AMB to dissipate the heat generated from air friction and electrical losses.

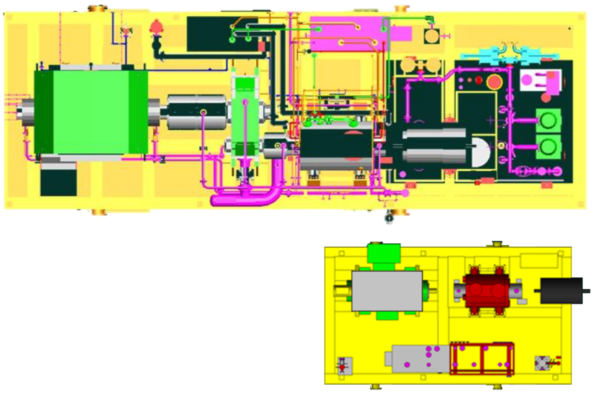
Secondary function of air system is to prevent any migration of explosive mixture in the AMB enclosure from either external environment or from dry gas seal. A principle of minimum overpressure with respect to those zones is applied.

Same air system is used during purging sequence, at start-up, to avoid any potential explosive mixture in the AMB enclosures before the magnetic bearings energization.

In operation, AMB coil temperature and enclosures pressure are monitored. Below a minimum enclosure pressure threshold and/or above a certain AMB temperature threshold, a general trip of units will occur. Alarms are also displayed to the main control unit screen. We can roughly estimate a power need of 1kW cooling system for 1MW compression power on a AMB equipped compressor.

4. Main benefits for oil-free configurations

When comparing high-speed oil-free compression package with conventional oil-lubricated motor-compressor, the simplification of the architecture is clear as shown in Fig. 6 and the following benefit can be highlighted:



	Dimensions [m]	Footprint [m^2]	Weight [tons]
Conventional train	16.7 x 4.8	80	188
Oil-free train	10.4 x 3.8	39.5	85
Var %	N/A	-50%	-55%

Fig. 6: Oil-free vs conventional

Advantages oil-free high speed motor driven compressor

➔ CAPEX:

- Gain of space and weight: The reduction of the weight and the footprint by 50% reduces considerably the needed platform support, cutting cost on the construction.
- Installation and Commissioning: By simplifying the connectivity between machine skid and auxiliaries, avoiding all the oil tube piping work and the flushing system on platform. The installation and commissioning time is reduced by 20%
- Integrated instrumentation and digital technology allow high frequency monitoring, limiting physical additional physical sensor and cabling. This monitoring technology is suited for remote and offshore application and enables easier condition monitoring possibilities.

➔ OPEX:

- The all-electric solution allows to avoid all the periodic visual inspections, limit the regular maintenances activities due to the oil-based auxiliaries (oil lude system, oil cooling system, gearbox…).
- The power consumption of the cooling of the AMB is about 2 times lower than the consumption of the full lube-oil system, allowing to lower the energy consumption and the CO_2 emissions of the oil-free compression train.

- By limiting the number of measurement points due less auxiliaries, the cost of maintaining theses points, collecting the data, and analyzing the information are practically divided by 2.

➔ PRODUCTION:

- Higher availability and reliability, through the limitation of auxiliaries and the cleaner technology (no oil pollution) there is less maintenance stoppage needed (every 5 years) and the Dry Gas Seals (DGS) usually the weak point, is less contaminated and increase their reliability. This has been proven by the reliability, availability and maintainability (RAM) analysis.
- Unmanned enabler due to the full electric design and less maintenance needs, little or no crew is needed to survey the installation. This can also affect the living quarters and the spare part storage space required, lowering the general size of the infrastructure.

5. Enhanced configuration

An alternative solution is represented by the semi-sealed compressor on which, similarly to the hermetically sealed compressor concept, the AMBs are cooled by the process gas with only one dry gas seal located on the coupling side. This configuration reduces the gas leakages but an in-depth study on the gas composition needs to be done as it is in contact with the AMB. Today protection technology has improved and new "upstream" projects using more resistant technology have been launched.

The spearhead technology development based on a compressor train directly at the well head, on the seafloor is the proof that everything is possible. Subsea projects are equipped also with SKF S2M bearing have proven their capability since the commissioning in 2015.

6. Conclusion

This study shows the following benefits:

➔ The remote monitoring and control allow to lower the needed crew on the platform and enabling the installation in critical environment locations.
➔ Environment and operational: All electric solution, less construction material to support train...
➔ Total Cost of Ownership: Installation costs, operational costs, maintenance costs, energy costs lowered.
➔ Production: less maintenance stops, higher availability, and reliability.

All these advantages have not been calculated but each of them could be evaluated case by case according to the application and/or specific plant location.

Off-shore project should leverage on these benefits adopting the oil-free high speed motor driven compressors (where applicable) without hesitation.

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