

Magnetic Bearing Equipped Motor Drives

Twenty-five years after the first commercial application of this technology, the cost advantages of Magnetic Bearing equipped compressors have been realized. Gas turbine driven, Magnetic Bearing equipped compressors have proven to be an economic success in application in NOVA's gas pipeline system within Alberta after initial design and quality assurance flaws were cured. More recently, NAM in Holland has shown how economics may be significantly enhanced by combining this technology with state-of-the-art electric motor drive technology to enable cost effective electric compression. An increasing number of pipeline compressor applications for Magnetic Bearings have taken place in the last few years. Justification for the use of Magnetic Bearings, of course, must come from continued good availability experience of existing units, and comprehensive economic analyses in the planning stages of these new pipeline projects. The case for the shift to this technology has been especially strong where consideration is given to life cycle costs or "total cost of ownership" as applied by NAM. In addition, many operators will be able to justify the use of this technology based on less tangible benefits such as safety (especially the elimination of the associated fire hazard with high pressure lubricating oil) or environment without the need for fully developed life cycle cost economic models.

Environmental economics are playing an increasingly important role as initiatives from the Kyoto Conference and other environmental legislation are already being enacted. Electric compression allows the complete elimination of harmful exhaust emissions into the atmosphere at the local compressor station. Magnetic Bearings eliminate the hazard of oil spills and the associated clean-up costs as well as oil disposal costs, which can reach \$800 per barrel. In addition, as shown by NAM, Magnetic Bearing equipped, electric driven compressors can contribute to overall station noise reductions and a reduced visual profile on the landscape.

Where fully developed life cycle cost models is utilized to compare the economics of electric drive and Magnetic Bearings to conventional installations, certain aspects can become problematic. As with any economic analysis where turbomachinery is involved, the calculated costs often belie the importance of correct sizing for the service. Modern electric variable speed drive allows the correct matching of compressor head and flow capability to system requirements without a speed increasing gear set or fluid coupling.

These drives also eliminate the severe efficiency losses caused by discharge throttling or bypass flow operation. Where variable speed drive is specified, Magnetic Bearings offer an unequalled capability for optimized rotor dynamic control and diagnostics. Unlike a hydrodynamic bearing, residual vibration has no impact on the life of a Magnetic Bearing system. Magnetic Bearings have an extremely wide operating speed capability and can be implemented to control traversing of critical speeds, or indeed, allow operation at speeds coincident with critical speeds as demonstrated with the NAM compressors. Thus, the efficiency advantages of variable speed operation are more easily realizable with Magnetic Bearings since vibration problems are minimized and actively controlled.

Developing a low speed and wide speed range capability with a hydrodynamic bearing is often impossible.

The most obvious cost savings with Magnetic Bearings usually comes from the elimination of the oil lubrication system expense. In addition, an operating cost savings is derived from the elimination of oil shear, oil churning losses and pumping losses associated with hydrodynamic bearings and their separate lubrication systems. This factor can easily yield a 99% reduction in power consumption



compared to an oil lubricated system. For example, the bearing power consumption of the 23 MW, 11-ton rotor for the NAM motor compressor train is only about 6.5 kW.

Maintainability and associated costs are also improved with Magnetic Bearings. NAM's total cost of ownership approach allows for maintenance staff reductions with Magnetic Bearing supported electric compression. The high reliability of Magnetic Bearing actuators and sensors reduces the likelihood of machine teardowns for repair. When maintenance is required, the ease of maintenance is assisted by the absence of oil from the machine internals; many millwrights cite this as their favorite feature of Magnetic Bearings.

The service condition of dry lubricated, bushing-type auxiliary bearings as offered by Waukesha Magnetic Bearings is observable from the control cabinet; unlike rolling element type bearings, there is no need to disassemble the machine to assess the condition of these bearings. Indeed, all monitoring for the entire system is conducted from the remote location of the control cabinet or via modem and ISDN Lines for the data communication network. NAM utilizes totally unmanned stations after field installations and Commissioning are complete.

Any required maintenance is usually restricted to the control cabinet where a control card may require infrequent replacement. This control cabinet can be sited in a motor control center or other indoor enclosure making access convenient and easy. This feature further enhances the ability to site the compressor itself in an outdoor environment. Overall, estimates of reductions in maintenance costs show that savings of up to 85% are achievable.

There are other reasons to employ Magnetic Bearings with electric drive or conventional, gas turbine drive. In addition to the high cost of ancillary equipment for oil lubrication, a "dry-dry" approach with Magnetic Bearings and Dry Gas Seals often allows civil engineering costs for buildings and foundations to be significantly reduced. Dry bearing and seal systems are quite amenable to outdoor installations. The performance of Magnetic Bearings does not have the same sensitivity to clearances as oil film bearings; clearances in a Magnetic Bearing system are much larger. Moreover, there is no need for space heaters to keep the oil warm during shutdown periods. It is well documented that Magnetic Bearing equipped machines may be readily started in sub-zero, cold conditions without prolonged long warm-up periods. In addition, the frequency and time between successive starts is limited by the driver characteristics, not the bearings. Specifications that require 250 or more starts per year are readily achievable. Accordingly, a compressor building may not be required at all (e.g. NAM) or a smaller one may be built without the required real estate for the oil lubrication system. Of course, this savings is accompanied by others for lighting, fire protection, etc. The cost for foundations and pipe supports may also be significantly reduce, since the installed height above grade of the compressor may be optimized for cost without consideration for lubricant oil gravity drains and header tanks. The lowest cost arrangement for piping may be pursued and realized.

The utilization of Magnetic Bearings in gas pipeline electric compression has another, more subtle benefit. Since the bearing system is also electric driven, and the compressor installation is classified as hazardous environment, it is possible (e.g. NAM) to place the bearings inside the pressurized motor cooling circuit thereby reducing the sealing length of the motor enclosure. This yields benefits in power consumption of the motor cooling fan, reduced noise emissions and bearing cooling. This design aspect once again provides an illustration of how the implementation of Magnetic Bearings serves to simplify the overall machine design arrangement by reducing or eliminating the need for

ancillary support equipment. In summary, the following direct and indirect cost benefits of Magnetic Bearings, particularly when used with electric motor drive, have been identified:

Capital Cost Savings

1. Elimination of oil lubrication system.
2. Elimination of speed increasing gear set or fluid coupling.
3. Elimination of, or reduction in size of, compressor enclosure.
4. Reduction in foundation and piping support costs.
5. Reduction in costs for building lighting, fire protection, etc.
6. Possible reductions in the cost for noise control equipment and treatments.

Operating Cost Savings

1. Significantly less power consumption.
2. Improved safety including diminished fire hazards. Reductions in insurance premiums.
3. Reduced or eliminated gas emissions to the environment.
4. Elimination of oil spills and the cost of oil disposal.
5. Machine efficiency gains through the implementation of good rotor dynamic control over a very low speed or a very wide speed range.
6. Reduced operations and maintenance staff costs.
7. Reduced start-up times and the capability for rapid re-starts.

Possible reduction in motor cooling fan power consumption.