CASE STUDY

Greene Tweed's Arlon® 4020 Labyrinth Seal Solution Enables MAN Energy Solutions to Achieve Substantial Efficiency Gain

Challenge

MAN Energy Solutions, a Greene Tweed customer, wanted to minimize leakage with their traditional metallic labyrinth seals in an integrally geared compressor. They needed to develop a solution that provided substantial leakage reduction and increased their overall compressor efficiency.

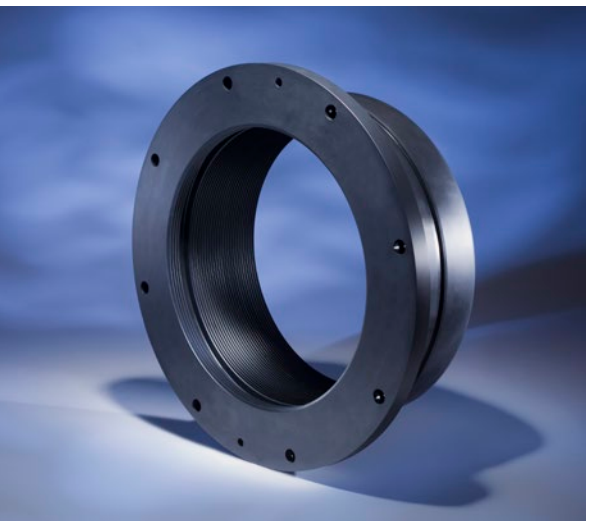
Integrally geared compressors are very high-speed machines that are used in a wide variety of applications where efficiency is paramount, such as air separation, CO_2 compression, or Terephthalic Acid (PTA) compression.

MAN, based in Berlin, Germany, is the center of competence for integrally geared centrifugal compressors, which use several shafts to separately drive up to 10 impellers. Running the various shafts at different speeds, and using cooling devices between each stage, enable higher efficiency vs. traditional single-shaft compressors.

Solution

Greene Tweed partnered with MAN to develop a non-metallic labyrinth seal for their compressors to reduce leakage and increase efficiency.

We recommended our +20-year, industry-proven Arlon® 4020 material combined with our unique tooth profile to further increase laby seal performance.



The Arlon® 4020 labyrinth seal features an engineered tooth design that flexes at a controlled amount to reduce clearance when subjected to an increased temperature and a pressure differential during operation.

Greene Tweed's Arlon® 4020 labyrinth seals offered significantly enhanced performance over the traditional metal seals that MAN used. The Arlon® 4020 labyrinth seal features a custom-engineered tooth profile with a controlled flow pattern that enhances efficiency by encouraging vortex generation and reducing "carry-over" media that can bypass chambers, particularly in high-velocity applications.

This unique design also provides corrosion resistance and superior dimensional stability, which enables a cyclic flex- and-return motion to withstand contact during critical speed, and increases reliability by providing tighter clearances.

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Solution

MAN and Greene Tweed performed numerous tests to confirm the properties of the Arlon® 4020 labyrinth seal solution under pressure and temperature influence. The first compressor tests were conducted in Zurich and Berlin, and at a maintenance machine in Hamburg for an end-user (Linde Gas AG).

We validated our new tooth profile in three steps:

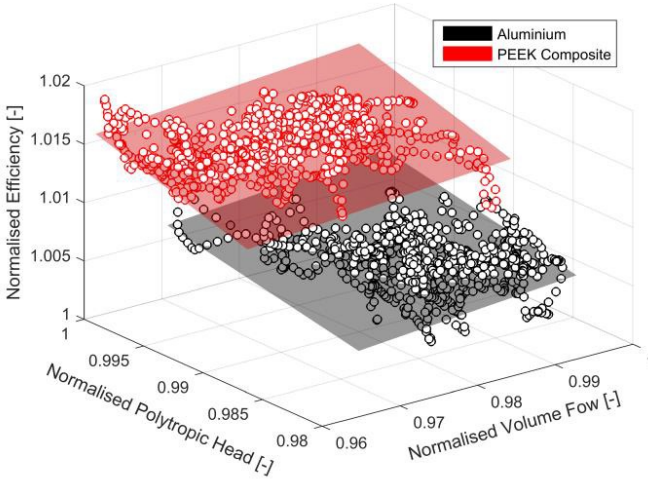
1. Theoretical calculation phase to predict rotor-stator clearance in various operating conditions and define optimum seal design
2. Test campaign performed on a test rig in Berlin
3. Field testing at an end-user

The Greene Tweed labyrinth tooth design achieved maximum efficiency gain, approximately 1 to 1.5 percent overall. The expected efficiency gain of +1% calculated on the base of leakage reduction shows good correlation with the measured values.

Performance data show good operational compatibility between aluminum and PEEK composite seals.

The figure below shows the efficiency measured with aluminum and with PEEK composite seals, depending on volume flow and polytropic head. The single points represent the measured data, where the planes illustrate spline-fitted approximations. The nearly constant offset of the two planes confirms the efficiency gain valid for all operational points within the measured range of volume flow and head.

The results demonstrated a very good correlation between the test results and predicted values from the FEA. A thermodynamic field test of a compressor stage confirmed the predicted efficiency gain compared to traditional metallic seals.



Due to the teeth design and the greater coefficient of thermal expansion compared to metals, thermoplastic labyrinth seals offer a unique opportunity of realizing different gaps at assembly conditions, during startup and normal operation.

The minimum gap at normal operational conditions is determined only by the level of rotor-dynamic vibrations. The higher amplitudes at critical startup speed are compensated by bigger gaps due to smaller thermal expansion and smaller deflection under pressure. The flexible teeth of the Arlon® 4020 labyrinth seals can withstand temporary contact during rundown or off-design operation.

The achievable efficiency gain compared to traditional metallic seals is dependent on the stage pressure and impeller size and corresponds roughly to ca. 1%-point of the gas power of the respective compressor stage.

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Features and Benefits

- Increased efficiency gain and tight running clearances deliver energy savings, reduce the mass flow rate to enhance sealing performance and increase efficiency, and decrease the spatial footprint for dramatic cost savings and environmental benefits
- Optimized thermal expansion allows for retrofit and like-for-like replacement of conventional metallic designs
- Provides minimal leakage flow across an impeller labyrinth seal in a radial-geared compressor
- Creates an aggressive seal geometry to reduce the rotor-to-stator clearance gap without compromising reliability
- Greene Tweed can now machine seals up to 32 inches OD

Arlon® 4020 (PEEK) exhibits excellent tribological properties, which provide the following advantages:

- Reduces friction and wear during contact, eliminating permanent deformation and gall to extend seal life and reduce maintenance costs and the likelihood of catastrophic damage occurrences
- Enhanced corrosion and erosion resistance deliver exceptional performance in severe sealing applications

Results

With its engineered tooth design and thermoplastic material properties, Greene Tweed's Arlon® 4020 labyrinth seals delivered superior performance compared to traditional metallic seals. Knowing the effects of thermal expansion, centrifugal force, and dynamic vibrations on the rotor enabled the optimization of labyrinth gaps at all operational conditions.

Interchangeable Design

The interchangeable design offers efficiency improvements for older machines with minimal investment costs, since the impeller seal can be kept as a spare part. Its corrosion- and erosion-resistant materials make it ideally suited to severe sealing applications, including high acid or mercury contents and high-velocity media.

Consistent Quality Results in Predictable Performance

The Arlon® 4020 labyrinth seal design offers highly predictable performance and stability during manufacture and operation demonstrated as follows:

- The billet-to-billet consistency of the PEEK material properties
- The non-load bearing manufacturing method
- Multiple cutting operations which allow material stress relief

Efficiency Gain

The Arlon® 4020 seal solution enabled MAN to achieve a substantial efficiency gain of approximately 1% of the gas power of the compressor stage, which was confirmed by validation in the field. The estimated total life-cycle cost savings for a typical new booster air compressor with four closed impellers and 3-MW average power per stage would be $300,000, based on an average power cost evaluation of 0.025 $/kWh.

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