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Upgrading Centrifugal Compressors with Polymer Seals in an Ethylene Plant – a Case History



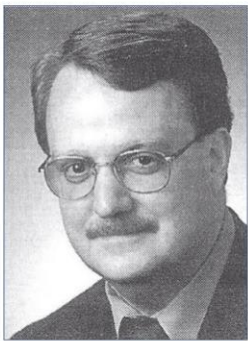
UPGRADING CENTRIFUGAL COMPRESSORS

with Polymer Seals in an Ethylene Plant – a Case History

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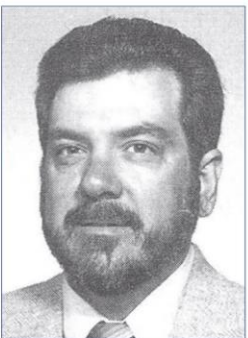
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John K. Whalen was the Engineering Manager and President of TCE (now Miba Industrial Bearings). He spent seven years at Turbodyne Steam Turbines (Dresser-Rand) as a Product Engineer in the Large Turbine Engineering Department and as an Analytical Engineer in the Rotordynamics Group of the Advanced Engineering and

Development Department. In 1988, Mr. Whalen accepted a position with Centritech, as the Assistant Chief Engineer. In 1989, he was promoted to Manager of Engineering. In 1991, he left Centritech to help start TCE (now Miba Industrial Bearings). At TCE (now Miba Industrial Bearings), he was responsible for the engineering department and engineering for the product lines, which include babbitted journal and thrust bearings, Labyrinth seals, and related engineering services.

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ABSTRACT

Thermoplastic use as labyrinth seals in rotating equipment is continuing to gain acceptance in the process industries. Presented in this paper is a discussion on thermoplastic use as a labyrinth seal material in centrifugal process compressors. Labyrinths made from engineering thermoplastics are used to improve efficiency, reliability, and installation time. An introduction to the polymer materials commonly used for these applications is followed by a discussion on polymer labyrinth seal engineering. Finally, the case history is discussed. This particular case history involves the upgrading of seven compressors at an ethylene plant in Orange, Texas. The process involved upgrading and evaluating one compressor then converting the remaining six. A discussion on this process is presented followed by coverage of the installation and subsequent efficiency gains. Included is the presentation of results from an advanced computational fluid dynamic (CFD) analysis of two labyrinth seal designs.

INTRODUCTION

Hundreds of centrifugal compressors are running today with the benefit of thermoplastic labyrinth seals. These seals replaced aluminum parts in order to realize increased efficiency and reliability. Often an additional benefit includes reduced installation times due to easier fitting of the seals to the compressor. The thermoplastics covered in this paper include PEEK and Torlon® (generically referred to as PAI) based products. There is also a short discussion on Fluorosint® (mica filled PTFE). Forthwith the term polymer will be used to address these materials.

Dowson, et al. (1991), presented data on the use of abrasible seal materials in centrifugal compressors and steam turbines. This paper covered the use of various materials for abrasible seals where rotating teeth seal against a smooth bore seal. They presented efficiency improvements of 0.5 percent per stage for high flow machines and 2.5 percent per stage for low flow machines, by reducing clearances.

Whalen (1994) presented an introduction to the use of engineering thermoplastics for centrifugal compressor

labyrinths. Among other things he covered an introduction to the different seal designs offered by CUT. He also presented case histories, demonstrating the efficiency gains possible with upgrades of this type.

Whalen and Miller (1998) present a case history involving two of NOVA chemicals ethylene plants in Alberta, Canada. In 1996, the company upgraded three compressors in its Ethylene 1 unit, two cracked gas compressors and the propylene refrigeration compressor. Efficiency gains of 2 to 3 percent per compressor are reported. Based upon the success of the upgrade in Ethylene 1, they proceeded to upgrade four compressors in Ethylene 2 during their 1998 outage. Also covered in this paper are justification discussions, seal design, and installation. Significantly reduced seal installation times are reported.

The efficiency gains are realized by designing the polymer seals with closer running clearances. These clearances can be reduced because the flexibility of the polymer tooth affords a certain "forgiveness" during the inevitable contact between the seal and the shaft. Contact is assumed to occur when the compressor transverses critical speeds and when the compressor is not at its design speed. These transients are transient in nature. Since seal and rotor damage are avoided during these transients, the reliability of the machine is improved. Another factor regarding reliability has to do with the damage that does occur during prolonged contact. It has been found that, although the seal may be damaged beyond use, the rotor comes through essentially unscathed. With aluminum seals, hard rubs can damage the shaft by galling.

POLYMER SEAL MATERIALS FOR ROTATING EQUIPMENT

Most plastics belong to one of two groups, thermoplastics or thermosetting plastics. Thermoplastics soften when heated, and harden when cooled; they are melted and frozen into their desired shape during processing. Most thermosets harden when heated and they chemically change during processing so they will never melt again. The materials covered here are all thermoplastics.

When evaluating thermoplastics, it is helpful to compare their thermal properties:

- » T_g - Glass transition temperature is the temperature at which the polymer changes from a rigid, crystalline structure to a more active and the polymer begins to soften and become "rubbery."
- » T_m - Melt temperature is the temperature at which the polymer begins to "melt."
- » HDT - Heat distortion temperature is the temperature

the material's flexural modulus drops to 100,000 psi. CUT (G) provides a "CUT" (Critical Use Temperature) "aging" of polymers. The CUT is the temperature a polymer can be exposed to for 100,000 hours (11.4 years) and maintain 50 percent of its mechanical properties.

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Subcategories under thermoplastics are amorphous (PAI) and crystalline (PEEK and mica filled PTFE). Crystalline thermoplastics have a crystalline order structure below their T_g and become amorphous above their T_g . They can be used above their T_g with reinforcement, usually in the form of mica in mica filled PTFE and carbon fibers in PEEK. Their T_g is usually well below their T_m .

Amorphous thermoplastics have no crystalline structure; their T_g is close to their T_m and they are not usually used above their T_g . They normally do not require reinforcement.

THE MATERIALS

Mica Filled PTFE

Mica filled PTFE is considered an advanced engineering plastic. It is a crystalline high-performance polymer with superior chemical resistance. This material is PTFE with mica fillers. The mica fillers provide strength, but the material is very weak (750 to 1200 psi tensile strength), which, of course, needs to be carefully evaluated for each application. The best application of mica filled PTFE in rotating equipment is in the form of smooth bore segments secured in a metal holder, which is rolled as an assembly into the compressor. Here, rotating laby teeth can cut into this very abrasible material. It is an excellent choice when the seal teeth are machined onto the rotating element. Because of its low strength, and the availability of superior materials, it is not recommended for use when the teeth are machined into the stationary part.

PEEK

PEEK (polyetheretherketone) as commonly used in rotating equipment, is either filled with 30 percent carbon fibers or 15 percent carbon fibers, 10 percent graphite powder, and 2 percent PTFE. The carbon fibers are added for strength while the graphite and PTFE are added for lubricity. The 30 percent carbon fiber material is usually used for pump wear rings while the other is usually used for compressor labyrinths. Due to the heat caused by the shearing of carbon fibers while machining, the 30 percent carbon fiber material is more commonly used. PEEK is highly resistant to chemical attack but will be attacked by concentrated, strong acids at high temperature. PEEK is sensitive to chromic, hydrofluoric, nitric, and sulfuric acids. It is unaffected by acetic acid,

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