**INTRODUCTION**

In the petrochemical and power industries, a wide range of bearings and wear rings are used in the pump systems. These are very critical components, since the represent the link between high-velocity rotating parts (up to 3600 rpm) and stationary parts. Different materials are still in use in practice, such as metals, ceramics, and thermoplastic composites. The latter have shown great potential when sliding against metals, because they have excellent mechanical properties, they are able to run dry for extended periods of time, they can withstand high operating temperatures (up to 260°C) and they exhibit excellent chemical resistance. However, their tribological behavior is not well-known. Therefore, the purpose of this project was to assess the influence of the matrix nature, the fiber orientation and the fiber volume fraction on the tribological behavior of bearings made out of CF/PEEK and CF/PFA composites.

To do so, Greene, Tweed designed and built a journal bearing test rig which allows to test dry and lubricated bearings against steel counterparts (journal). In a first phase, dry sliding tests were run, because periods of non-lubricated contact quite often occur in these pump systems. In order to improve the bearing durability in absence of any lubricant, high wear resistance and thermal expansion are required. In a second running phase, some water-lubricated tests were carried out. First, the goal was to observe the effect of the wettability (PEEK versus PFA-based composites) on the transition between the mixed and hydrodynamic regimes. Then, the wear resistance of some bearings was evaluated in the mixed lubrication regime.

**Bearing manufacturing**

Two different molding processes were selected to produce finished parts. Annealing and machining was always required after molding.

The **Techna™ process** (property of Greene, Tweed), which allows to produce tubes (without through-thickness fibers). The material at the interior of the tube (the part which is tested) was often different from the external material, whose role was to increase the resistance and decrease the thermal expansion.

**Compression molding** Both hollow and solid cylinders were molded depending on the raw material selected. Compression molded parts have all the fibers preferentially oriented in the plane perpendicular to the cylinder axis (most of the fibers have a through-thickness component).

**Testing**

110 dry tests were carried out for a duration of 3 hours and sometimes 6 hours. At least 3 values of pv (the pressure times the velocity) were applied on each type of bearing. Each test configuration was repeated at least 3 times.

The shaft (journal) was made out of 304 stainless steel and a new part was used for each test. Real conductivity and thermal expansion are required. In a second running phase, some water-lubricated tests were carried out. The shaft diameter measured 68.5 mm and the bearing inner diameter was set to 70 mm. For the lubricated tests, the shaft diameters was of 70 mm and the bearing inner diameter measured 70.2 mm.

**RESULTS**

**Friction (dry sliding)**

- For UD composites, a large amount of debris was produced, which influenced the friction. However, there is still a clear effect of the fiber orientation.
- For the UD composites, UD 0° shows the lowest coefficient of friction, followed by UD 45° and UD 90°.

The polymer melts above pv= 0.5 MPa·m/s.

**Bearings wear (dry sliding)**

**PEEK-based bearings:**

- The PEEK-based bearings (and their corresponding counterparts) suffered from severe wear. Abrasive wear was the dominant mechanism because no transfer film was formed on the counterface.
- For the UD composites, UD 0° is the most wear resistant, followed by UD 45° and UD 90°.
- Wear is lower when using aramid fibers (AF) instead of CF because these fibers do not abrade steel. However, the friction induced by the AF is so high that this material is not interesting for bearing applications where periods of dry-run can be encountered.
- Incorporation of fillers (PTFE and graphite) allows to promote the formation of a transfer film and therefore to drastically decrease wear.

**Thermal conductivity**

A linear relationship exists between pv and the steady state temperature at a certain distance from the bearing surface. The higher the slope, the higher the thermal conductivity is expected. Therefore, higher thermal conductivities are measured when the fibers have a through-thickness component. At high speeds, the motor cools the housing.

**Water-lubricated tests**

There is no effect of the wettability (water slip) on the transition between the mixed and hydrodynamic regimes. However, the adhesion fiber/matrix increases the wear resistance.

At high velocities (3000 rpm), the bearings having all the fibers in the sliding plane (shearing between the layers) than for those having all the fibers out of the sliding plane.

Wear slightly decreases with increasing fiber volume fraction (for the braids).

Improving the adhesion fiber/matrix increases the wear resistance.

At high velocities (3000 rpm), the bearings having all the fibers in the sliding plane show a higher wear resistance. Wear increases with increasing velocity and decreasing pressure (same pv value).

**PFA-based bearings:**

- Wear is up to 2 orders of magnitude lower when a transfer film is formed on the counterface.
- The PFA-based bearings were always able to form a transfer film.
- Wear is higher for the bearings having all the fibers in the sliding plane (shearing between the layers) than for those having all the fibers out of the sliding plane.
- Wear slightly decreases with increasing fiber volume fraction (for the braids).

**Conclusions**

The formation of a transfer film on the counterface is the key point when carbon fibers are used as reinforcement. Without fillers, the PEEK-based bearings studied exhibit severe wear in dry conditions. The PFA-based bearings are very promising thanks to their extremely low friction against steel and their ability to form a thin and strongly bonded transfer film, which prevents abrasive wear to occur. Even though both compression molding of CF/PFA composites and co-molding of CF/PEEK composites allow to obtain bearings with excellent tribological properties, compression molded bearings showed the best compromise between friction, wear, thermal conductivity and thermal expansion.