GE
Oil & Gas

New Composite Materials for Pumps

Benefits

- Increased production
- **Higher efficiency**
- Compliance with environmental regulations
- **Availability and Reliability**
- **Life extension**

Customer benefits include:

- More reliable operation and significant reduction of failures
- Lower vibration levels
- Energy saving
- Lower maintenance costs

What it is

The demand for pump reliability and performance is ever increasing. Today the primary characteristics sought by pump users are higher reliability, lower vibration levels and better efficiency across a wide range of operating conditions.
In order to satisfy these requests GE Oil & Gas introduced new composite materials with better performance. The use of this kind of materials for wear components in centrifugal pumps is not entirely new. However, the practice in recent years is more prevalent than ever before. This is due to the introduction of new composite materials that have the ability to cover applications that traditional composites were not suitable for and the inclusion of PEEK (Poly-Ether-Ether-Ketone) based composites in the American Petroleum Institute (API) 610 9th edition standards.
Additionally, GE Oil & Gas, developed expertise on the successful application of composites, has developed a matrix of situations in which composite wear parts may be applied to give our customers innovative and cost effective solutions for their demanding applications.

In general, polymer-based composite materials have excellent strength and wear properties, and do not cause galling or seizing. This permits a dramatic reduction in clearances between rotating and stationary wear parts which leads to a multitude of performance advantages.

Sleeve bushing and wear ring in peek

What it is

A composite consists of two or more distinct materials that, when combined, create a material that, is stronger, tougher and/or more durable than the individual materials would be standing alone.
The recently released (January 2003) API 610 9th edition, recognizes and lists polymer-based composites as an acceptable option for replacing metal wear parts to improve pump performance in appropriate applications. It is important to point out that there are almost as many different types of composite materials as there are applications for their use. This is because the make up of a composite can and should be tailored to have physical properties and characteristics that match the demands of the application.
Polymer-based composite materials are typically made up of a thermoplastic (often referred to as the matrix) and a reinforcing fiber material (often referred to as the filler). GE Oil & Gas offers two types of composites for centrifugal pumps, both of which meet API standards. These classes of polymer-based composites contain the same two base materials, Poly-Ether-Ether-Ketone (PEEK) thermoplastic and carbon fiber. The moulding of the blended resin allows the thermoplastic (PEEK) to flow around and encapsulate the filler (carbon fiber) creating a quite homogeneous material. The ratio between the polymer matrix and the filler is manipulated to yield materials with a desired range of properties and characteristics that match the requirements of the intended application. The type of filler, percentage of filler, and shape, size and orientation of the filler, all play an important part in determining the physical properties and different thermal characteristics of the composite (*Figure 1*). The following paragraph gives a brief description of these materials and defines their use parameters.

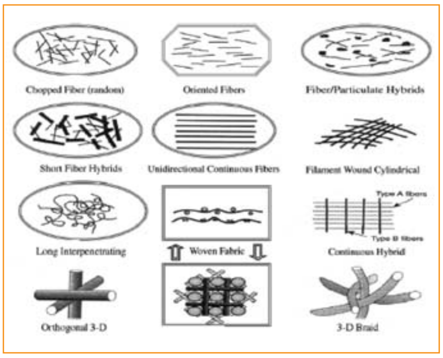

Figure 1: Illustration of characteristics of filler types

How it works

API pumps and most heavy industrial pumps are designed and fitted with sets of replaceable wear components (i.e., bushings and wear rings). These wear components are designed to support and stabilize the pump rotor and offer protection to the shaft, impeller(s) and pump casing because they absorb wear and abuse from regular use and upset conditions. In addition to these roles, wear rings act as internal seals. They help to restrict the flow of media moving from the discharge side of the impeller through the wear ring clearances back into the suction eye of the impeller which is a cause of loss of efficiency (*Figure 2*).
The smaller the clearance between wear ring interfaces, the better the pump efficiency. Traditionally, bushings and wear rings have been made from metallic materials, but today, composite materials are being used as a replacement for these metal wear parts. Using reinforced polymer-based composite materials can lead to some dramatic advantages including minimized running clearances, lower vibration levels, extended wear life and lower repair cost.
Minimized running clearances are possible due to the non-galling and non-seizing nature of reinforced polymer composites. Since galling and seizing are not an issue, clearances can be designed to approximately half of that recommended for metal-to-metal configurations (see below API Table 4). These slimmer running clearances restrict internal leakage which results in greater pump efficiency.
In addition to gains in efficiency as a result of reductions in running

API 610 9th ed. - Table H.4 Non-metallic wear part materials

Material	Temperature limits Min	Temperature limits Max	Limiting pressure differential	Application
PEEK Chopped carbon fibre filled	-30 °C (-20°F)	135°C (275°F)	2 000 kPa (20 bar) (300 psi)	Stationary parts
PEEK Continuous carbon fibre wound	-30 °C (-20°F)	230°C (450°F)	3 500 kPa (35 bar) (500 psi), or 14 000 kPa (140 bar) (2000 psi) if suitably supported	Stationary or rotating
Polyamide	Need information relative to experience			
Carbon graphite Resin impregnated Babbit impregnated Nickel impregnated Copper impregnated	 -50 °C (-55°F) -100 °C (-150°F) -195 °C (-320°F) -100 °C (-450°F)	 285°C (550°F) 150°C (300°F) 400°C (750°F)	 2 000 kPa (20 bar) (300 psi) 2 750 kPa (27,5 bar) (400 psi) 3 500 kPa (35 bar) (500 psi)	Stationary parts
Non metallic wear part materials, which are proven to be compatible with the specified process fluid, may be proposed within the above limits. See 5.7.4.c. Such materials may be selected as wear components to be mated against a suitably selected metallic component such as hardened 12% Cr steel or hardfaced austenitic stainless steel. Materials may be used beyond these limits if proven application experience can be provided, and if approved by the purchaser.				

clearances, vibration levels are often favorably impacted. Close clearance bushings and wear rings are better able to generate a thin liquid film on which the rotor can glide. Basically, wear rings and bushings are transformed into hydrostatic radial bearings. This is more difficult to achieve when there is a larger space between the rotating and stationary interfaces. As stated earlier, polymer composites contain thermoplastics as PEEK. This is a ductile material which absorbs shocks and vibrations, dampening the effects of resonating metal components.
PEEK wear components are always mated against metal wear surfaces. They posses high strength properties, excellent impact resistance and an extremely low coefficient of friction but they are much softer than metals and are intended to be the sacrificial component should severe upset conditions develop. Composites can withstand hard contact with little or no damage and can handle intermittent dry run episodes. In cases where dry run is quite extensive, the composite will suffer surface melt but will not damage expensive metal parts such as impellers, shafts or pump casings.
The first type of composite listed in API 610 is a chopped carbon fiber filled PEEK. This is a matrix (PEEK thermoplastic) dominated composite consisting of a compression-moulded material of approximately 70% PEEK and reinforcing fibers with a random orientation. Since this is a PEEK dominant compound, it's Coefficient of Linear Thermal Expansion (CLTE) (1) is twice that of carbon steel (2). Due to the difference in expansion rates, it is best suited for and typically used for stationary, pressed-in parts such as bushings or case wear rings in applications above ambient temperatures. API pumps suitable for this application include Horizontal and Vertical in-line Overhung (OH2-OH3) pumps, Between-Bearings single or multistage radially split (BB2-BB5) pumps, and Vertical suspended single and double casing (VS5-VS6-VS7) pumps. Conversely, this material will contract at a higher rate than most metals and will be more suited for press-on applications in sub-ambient temperature environments.
The API limits for continuous use of chopped carbon fiber are within the temperature range of -30°C to 135°C, but applications outside of this range can be evaluated.
The second type is a continuous carbon fiber wound PEEK. This is a fiber dominated composite in which a carbon fiber ribbon is impregnated with PEEK, which acts as a binder. The ratio is about 70% carbon fiber and 30% PEEK. With this high percentage of carbon fiber, the thermal expansion coefficient (3) is much less than that of carbon steel (2). This material is commonly used but not limited to the manufacture of rotating pump parts such as impeller wear rings and shaft sleeves. All API pump types are candidates for these composites in press-on assemblies, and any limitations that may exist are generally related to the fluid handled and specific application conditions.
GE Oil & Gas, in collaboration with primary composite manufacturers, has defined a guideline to maximize the pump output which also considers any potential process limitations.
The API limits continuous use of fiber wound composites to a temperature range of -30°C to 230°C, but out of range applications can be evaluated.

(1) WR-300 is a chopped carbon fiber filled PEEK composite manufactured by Green, Tweed. This composite has a CLTE equal to 15.3x10-6 in/in/°F over a range of 23°C to 143°C.
(2) The CLTE for carbon steel is 7.5x10-6 in/in/°F.
(3) WR-525 is a continuous carbon parallel fiber wound PEEK composite manufactured by Green, Tweed. This composite has a CLTE equal to 1.5x10-6 in/in/°F.

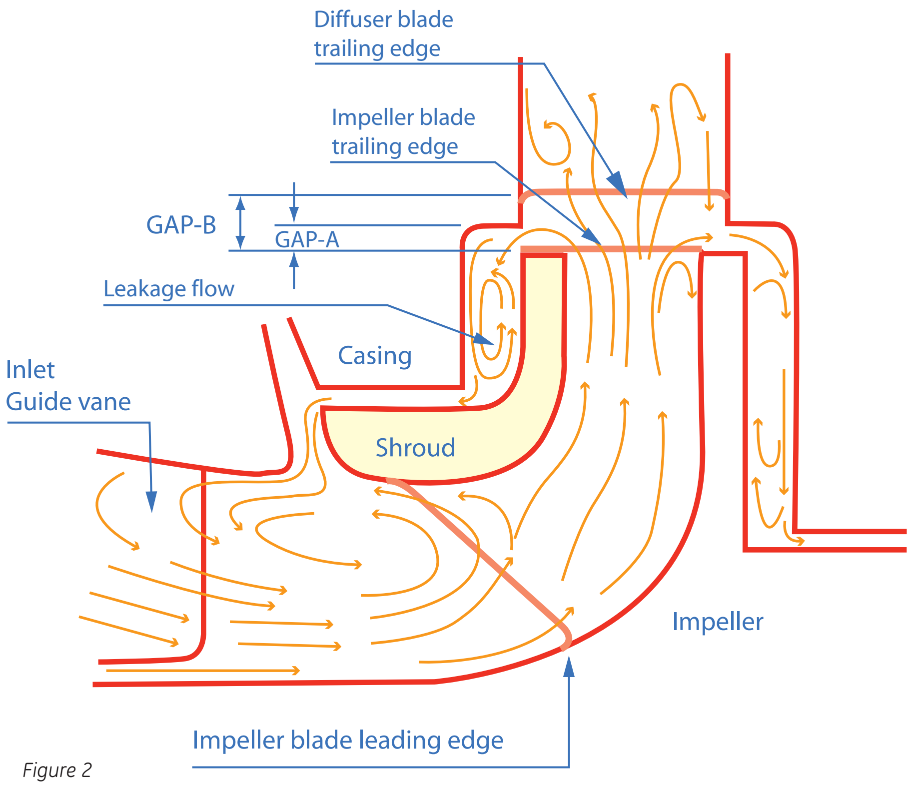

Figure 2

How it works

Of course, composites, as all other materials, have limitations. It is important that pump users consider the use of this new material for pump components only under the advise of the pump Original Equipment Manufactures (OEM). Our Engineering Department will determine if the proposed composite has the necessary properties and characteristics to perform successfully in the customer's application and whether the Mean Time Between Maintenance (MTBF) of the pump will be improved rather than compromised.
Some points to consider are listed below:

- **Chemical compatibility** with the fluid handled and corrosion resistance. This is usually not a concern for seawater or river water applications but API pumps used in refineries often encounter trace amounts of many different chemicals. In these applications, chemical compatibility should be analyzed and evaluated against best practices.
- **Temperature** – when evaluating thermoplastics, their thermal properties, especially Tg, must be considered. Tg, the glass transition temperature, is the temperature at which the polymer chains of a thermoplastic become active and the polymer begins to soften and become "rubbery".
- **Abrasives** – traditional fiber reinforced composites have poor abrasion resistance.
- **Design parameters** – It is important to consider the Coefficient of Linear Thermal Expansion (CLTE) of the composite compared to that of the mating metal components. Incorrect selection of the difference in thermal expansion properties may yield more mechanical efficiency losses than the increased efficiency derived from the reduced hydraulic leakage.
- **Fillers** –The fiber orientation is very important in determining the CLTE of the composite. Carbon fibers are the most common fillers. Glass and aramid fibers are also used but these fiber types can be very abrasive and may require the opposing surface to be hard coated.
- **Water absorption** – Some matrix materials are known to absorb water and swell when exposed to a wet environment. This consideration may require the design of larger than normal running clearances to insure that wear parts do not contact opposing surfaces during operation due to swelling.

GE Oil & Gas thanks Green, Tweed & Co. for information included in this booklet.

GE imagination at work

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