The secret is in the lining: the use of fluoropolymer materials for corrosive pumping

Corrosive materials are some of the trickiest substances to handle, demanding not just great care, but also a careful selection of the type of pump. Yoshiyuki Sano of Texel Pumps examines the construction and advantages of fluoropolymer lined magnetic drive pumps for corrosive pumping applications.

Chemical process pumps lined with fluoroplastic materials such as PFA, ETFE and PVDF have excellent corrosion resistance capabilities, especially PFA, which can be used in many applications up to 500 F.

PFA (Perfluoroalkoxytetrafluoroethylene) is a copolymer of tetrafluoroethylene and perfluorovinyl ether. PFA is a fully fluorinated thermoplastic with a melting point of 580 F and a maximum service temperature of 500 F. PFA is also virtually inert with slightly lower permeability and better tensile properties than PTFE.

PTFE (Polytetrafluoroethylene) is the oldest and best known of the fluoropolymers. Its melting point is 627 F with a maximum service temperature of 500 F. PTFE is virtually inert to chemical attack with the exception of a few very highly reactive chemicals, which include molten alkali metals, fluorides of chlorine or oxygen and free fluorine.

ETFE (Ethylenetetrafluoroethylene) is a copolymer of ethylene and tetrafluoroethylene. ETFE is a partially fluorinated thermoplastic with a melting point of 520 F and a maximum service temperature of 300 F. ETFE is inert to almost all strong minerals acids, inorganic bases, halogens and metal salt solutions. Alcohols, ketones, ethers and chlorinated hydrocarbons have little effect on ETFE, however strong oxidizers (e.g. nitric acid), organic bases (e.g. amines) and sulfonic acids will attack ETFE.

PVDF (Polyvinylidene Fluoride) is a homopolymer of vinylidene fluoride. PVDF is a partially fluorinated thermoplastic with a melting point of 340 F and a maximum service temperature of 300 F. PVDF will withstand most inorganic acids and bases, hydrocarbons, organic acids, alcohols and halogens and is exceptional in bromine service. PVDF is attacked by hot sulfuric acid, hot alkalis, alkali metals, ketones and strong polar solvents.

Molding methods for fluoroplastics

The molding method used to line the wetted ends of pumps such as rotolining, injection molding, transfer molding or transfer compression molding can affect and change the chemical resistance of fluoroplastic materials. Additionally, the molding method used determines the density and therefore the permeability of the finished part. Transfer compression molded PFA parts have superior chemical resistance and less permeability than ETFE rotolined parts used by many process pump manufacturers today. This article will discuss the various fluoropolymer molding methods and their application in lined magnetic drive process pumps. Table 1 shows the typical molding methods used for manufacturing PFA, ETFE and PVDF lined magnetic drive pump parts. This table shows the specific gravity (S.G.), melting point (M.P.) and continuous enduring temperature

TABLE 1: TYPICAL MOLDING METHODS FOR FLUOROPLASTICS.

Material	Molding method
PFA	$CF_2=CFOCF_3$ *tetrafluoroethylene-perfluoroalkylvinylether copolymer*
S.G: 2.15 M.P.: 310 °C C.E.T.: 260 °C	Injection Transfer Transfer-compression (TTC) Rotolining (rare case)
ETFE	$CF_2=CF_2-CH_2=CH_2$ *ethylene-tetrafluoroethylene copolymer*
S.G: 1.75 M.P.: 270 °C C.E.T.: 170 °C	Injection Rotolining
PVDF	$CH_2=CF_2$ *polyvinylidenefluoride*
S.G: 1.77 M.P.: 170 °C C.E.T.: 150 °C	Injection Transfer Transfer-compression (TTC)

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TABLE 2: MOLDING METHODS, APPLICATIONS AND FEATURES.

Molding method	Material	Application for:	Advantages	Disadvantages
Injection	PFA ETFE PVDF	Casing Impeller Inner magnet Containment shell	• High productivity	• Not suitable for large/medium size casings
Transfer	PFA PVDF	Casing Inner magnet	• No stress cracks • Lower permeability • One-shot seamless moulding	• Low productivity
Roto-lining	ETFE	Casing	• No patterns required	• Low productivity • Thin non-uniform lining • Higher permeability
TTC Transfer-compression	PFA PVDF	Casing Inner magnet	• High productivity • No stress cracks • Lower permeability • One-shot seamless moulding	

(C.E.T.) for each of the fluoropolymer materials.

Injection molding

Most manufacturers use injection molding to manufacture the PFA, ETFE, or PVDF impeller, containment shell (rear casing), inner (driven) magnet coating and small size casings. However, for larger pump casings the injection molding method is not suitable due to deformation of the part after molding. In addition, injection molding can result in stress cracks on the inner magnet assembly caused by residual stress during the molding process.

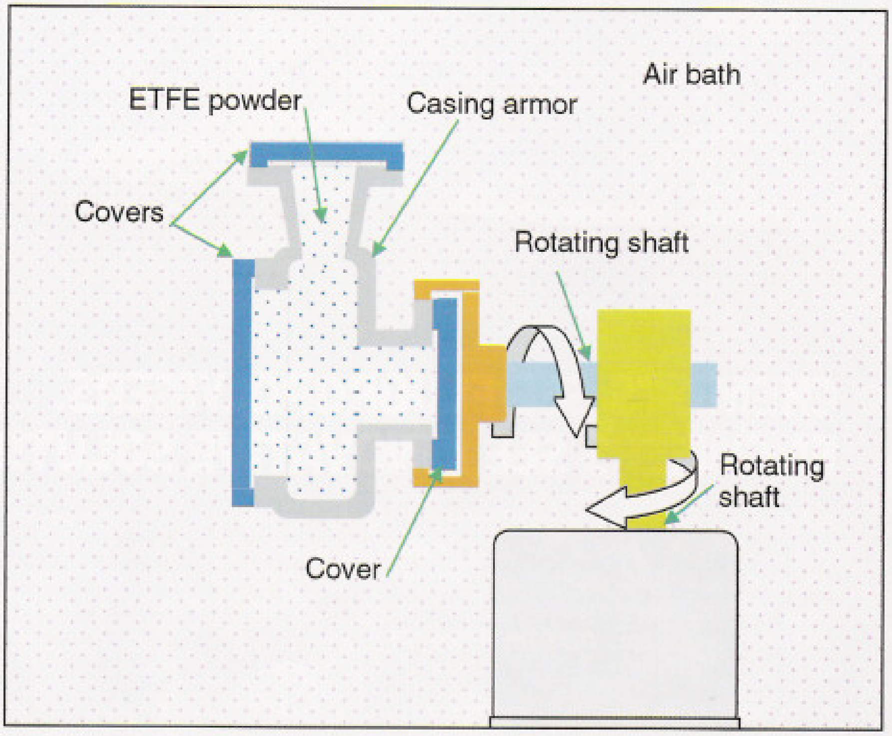
Transfer molding

The transfer molding process is used to mold PFA and PVDF to the casing and the inner magnet. The process employs high pressure (1800-2250 psi) on the fluoropolymer resin and then the mold is cooled down slowly with air and a water quench. This process produces a uniform thickness of fluoropolymer without the stress cracking problem associated with the injection molding process mentioned above. The high pressure employed in this process produces a dense lining which is resistant to permeation, especially when applied to PFA. The transfer molding process cannot be used for ETFE because of it's unsteady thermal properties during the molding process.

Roto-lining

This molding method can only be applied to the ETFE lining of pump casings. Figure 1 shows the roto-lining process. Unlike injection molding and transfer molding this process requires no molding patterns. In this process the ductile iron casing armor and the ETFE powder are preheated separately. The preheated ETFE is then introduced into the ductile iron casing and the casing is closed with aluminum covers. The casing is then rotated in dual directions as illustrated in Figure 1 at the same time as the ETFE is heated to it's melting point so that it flows and lines the casing. Due to the fact that this process does not take place under pressure and is done without molds it is difficult to control the thickness, density, flatness and smoothness of the molding, which

Fig. 1 Outline of Roto-lining Molding Process



will effect the corrosion resistance, permeability and the abrasion resistance of the finished product.

Texel transfer compression Molding (TTC)

This molding process has been developed to address the problems associated with the processes previously described particularly in the areas of stress cracking and permeability.

Figures 2 a c. show the TTC process. The molding machine is constructed of an upper/lower deck, sprue block, sprue block holder and an upper/lower press cylinder. Molding patterns are mounted on both the upper and lower deck and the casing is mounted on the lower deck. An extruder is connected to the sprue block inlet. During the molding process the sprue block and the patterns are heated and controlled to a specific molding temperature by an electric heater. Next, the casing armor, which has been preheated in a hot air bath, is mounted onto the lower molding pattern and the two patterns are fitted together by means of a hydraulic cylinder. After the patterns are set in place, melted PFA resin is injected by the extruder via the sprue block into the mold as shown in figure 2b.

When the pattern is full of resin and compressed by the hydraulic cylinders the patterns are slowly cooled using a combination of air and water at a specified controlled rate. After the cooling period the extruder is removed from the sprue block and the PFA lined casing is removed from the lower pattern as shown in figure 2c. This process produces a superior PFA lining that is uniform in density, thickness, smoothness, is less permeable and is not subject to stress cracking the way as are PFA linings using the injection molding process and ETFE linings using roto-molding.

Liquid permeation of fluoropolymer linings

Liquid permeation occurs when molecules of chemical are small enough to pass through the lining. The density of the lining, liquid temperature and pressure all influence the rate of permeation. Figure 3 shows a typical set-up to test the permeability of various polymers. The chemical to be tested is put into one flask and an equal volume of water is put into the other flask. A sample of the polymer to be tested (50 micrometers in thickness) is placed between the flasks and both flasks are immersed in a controlled temperature water bath. A pH meter is installed on the water side to measure changes in pH as the chemical permeates the polymer sample. Permeation time for various chemicals and polymers is measured as shown in figure 4.

Figure 5 shows the results of laboratory tests for permeation of PFA, PTFE, ETFE and PVDF when immersed in 50% nitric acid and 50% sulfuric at 86 F. The test results show that in the case of nitric acid PFA is the least permeable polymer and in the case of sulfuric acid PVDF is the least permeable.

Abrasion resistance of fluoropolymer materials

Fluoropolymer lined magnetic drive pumps in medium to heavy duty applications are required to handle low percentages of solids in many applications. In general, fluoropolymers have good abrasion handling capabilities when compared to metals such as carbon steel, nickel alloys and titanium etc. because of the surface smoothness of the material. Fluoropolymers with a high degree of polymerization (DP) have better abrasion resistance capabilities than fluoropolymers with lower DP ratings. PTFE has the highest rating followed by PFA, ETFE and finally PVDF. Generally, fluoropolymers with lower friction factors have greater abrasion resistance capability than those with higher friction factors. The static friction factor of PFA is 0.05, ETFE is 0.06 and PVDF is 0.08.

The kinematic friction factor of PFA is 0.2, ETFE is 0.3 and PVDF is 0.39. The molding process employed in manufacturing fluoropolymer-lined parts influences the surface roughness of the finished part which can

Fig. 2a Transfer-compression molding set-up

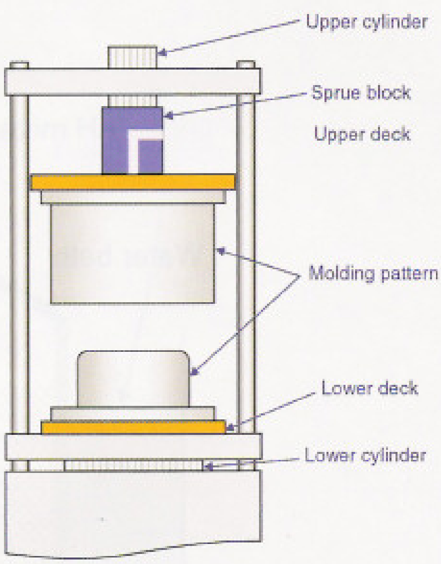


Fig. 2b Transfer-compression molding process

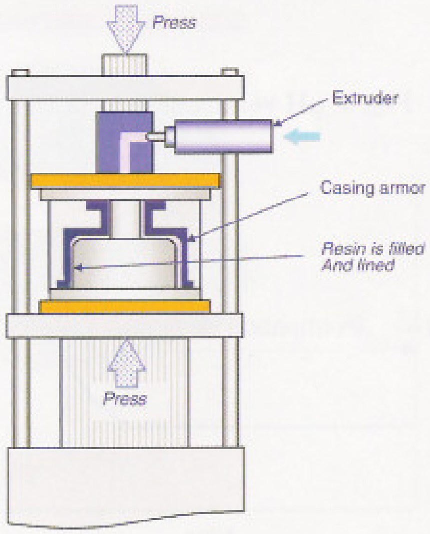


Fig. 2c Remove the casing from the molding pattern

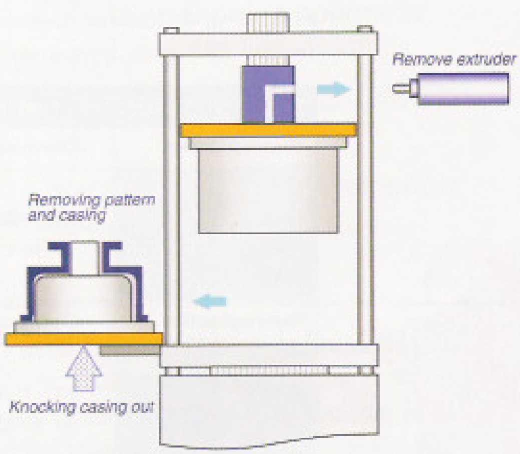


Fig. 3 Liquid permeation test set-up

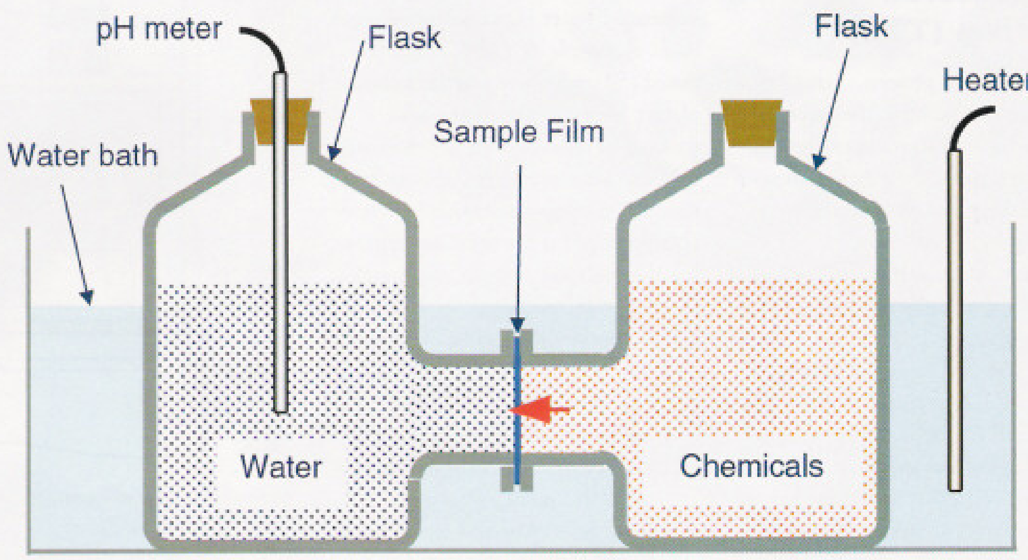
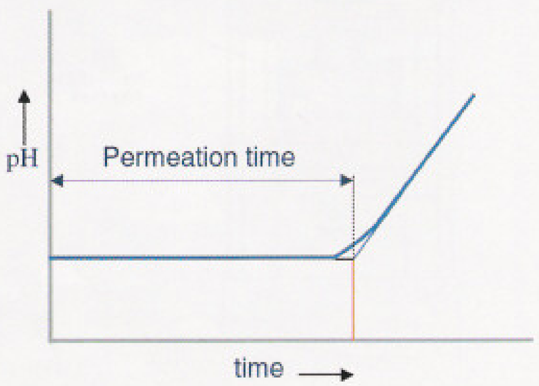


Fig. 4 pH versus permeation time



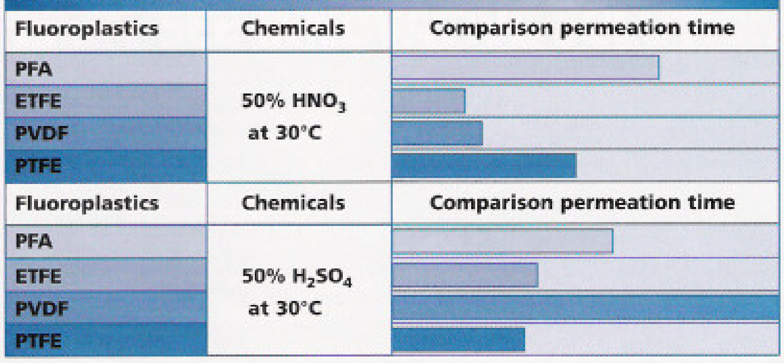
increase or decrease the friction factor. Injection molded, transfer molded and transfer compression molded PFA parts have a smoother finish and therefore a lower friction factor than roto-lined ETFE parts. To test for abrasion resistance in the laboratory, sample pieces are rotated in an abrasive solution and the weight of the sample is measured every 24 hours. Test results show that 304SS and nickel alloys wear 1.5 times faster than fluoropolymers; and carbon steel and cast iron wear four times faster.

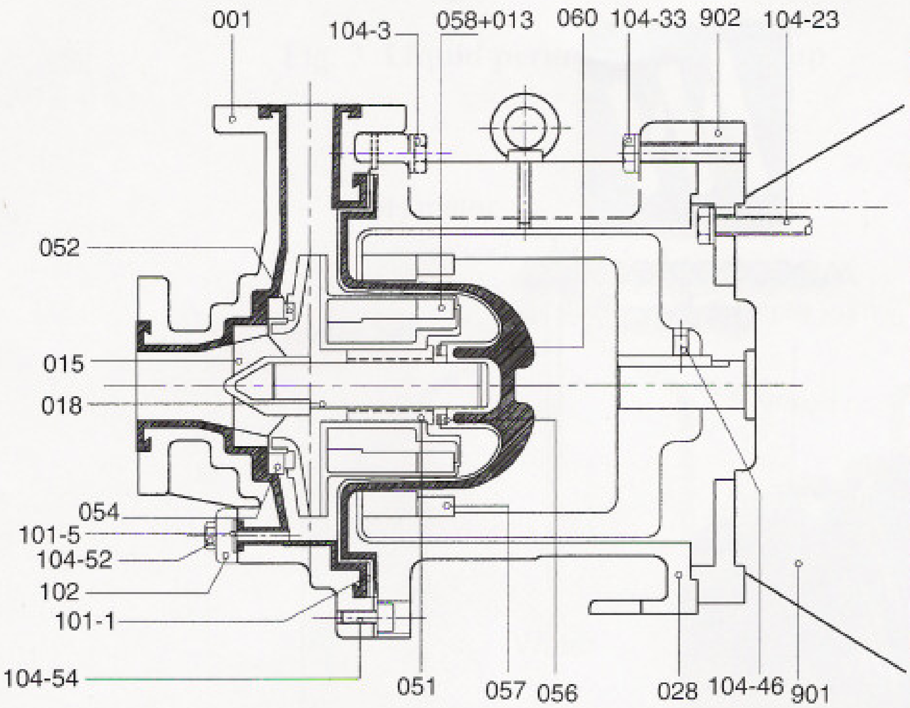
PFA lined magnetic drive pumps

Figure 6 shows a PFA lined pump. The pump casing is lined with transfer compression molded PFA, the inner or driven magnet is encapsulated with a seamless transfer compression molding of PFA, the rear containment shell is constructed from a high strength glass fibre reinforced polyamide lined with injection molded PFA and the impeller is injection molded PFA. The shaft and all bearings and thrust rings are made of silicon carbide ceramics. PFA lined magnetic drive pumps offer superior corrosion resistance making them compatible with mineral and organic acids, bases, alcohols, hydrocarbons and halogens. Due to the high density and low permeation properties of transfer compression molded PFA and to their solids handling capabilities PFA lined pumps make an excellent alternative to ETFE roto-lined or metal magnetic drive pumps. Overall, ANSI dimension PFA lined magnetic drive pumps offer the following advantages to users:

- Seal-less magnetic drive pumps provide long life leak free performance with extended MTBF.
- Non-metallic rear casings provide high efficiency pumping without the hysteresis losses associated with alloy containment shells.
- Lower initial cost than high alloy sealed pumps.
- Lower initial cost than 316 S.S. double mechanical seal pumps with API flush systems.
- Easy to repair in the field with no special tools required.

FIGURE 5 : PERMEATION TIME FOR FLUOROPLASTICS.





No.	Part Name	Material	Qty.
902	Motor Adapter	Steel	1
901	Motor		1
104-54	Rear Casing Bolt	304 SS	4
104-52	Drain Bolt	304 SS	2
104-46	Outer Magnet Set Screw	304 SS	2
104-33	Motor Adapter Bolt	304 SS	2
104-23	Motor Bolt	304 SS	4
104-3	Casing Bolt	304 SS	6
102	Drain Flange	Cast Iron	1
101-5	Drain Gasket	PTFE	1
101-1	Casing Gasket	PTFE	1
060	Rear Casing	PFA + Eng Plastic	1
058 +013	Inner Magnet/Impeller	Rare Earth/ PFA	1
057	Outer Magnet	Rare Earth	1
056	Rear Thrust Ring	SiC	1
054	Front Thrust Ring	SiC	1
052	Mouth Ring	C-PTFE/SiC	1
051	Bushing	C-PTFE/SiC	1
028	Bracket	Cast Iron	1
018	Shaft	SiC	1
015	Shaft Support	PFA	1
001	Casing	PFA + Duct Iron	1

Figure 6. Cross-section of a PFA-lined magnet-drive pump.

Greater range of corrosion resistance than metal pumps.

Compatible with aggressive fluids over the full pH range.

No product contamination in high purity applications.

No piping or baseplate alterations required when replacing existing sealed ANSI pump installations. ■

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