Ceramic Materials in Pump Engineering

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Introduction

When it comes to pumps for industrial applications, the first pumps to come to mind are those made of steel or metallic materials.

Tanks, pipelines and pumps made of plastics are also known. But only very few people are aware that ceramic materials can also be very interesting for industrial-scale applications.

For this reason, an overview of selected centrifugal pumps made of ceramic and their applications is given here.

The Rheinhütte Pumps Division in FRIATEC AG has been manufacturing pumps for 90 years now. The first pumps made of Frikorund® and Frikotherm B® ceramic were made more than 40 years ago by FRIATEC.

Fig. 1
FNC 65-320 pump: clearly visible is the grey Frikorund® ceramic of the impeller and casing; the casing is armoured with cast iron

Ceramic materials in pump engineering

Typical, widely found ceramic components in pump engineering include silicon carbide slide rings for mechanical seals. This report does not address these as they have already been described as the proven state of the art. Typical ceramic materials used in pump engineering are zirconia (e.g. Frialit FZM), alumina and silicate ceramics. Pumps are also made of silicon-infiltrated silicon carbide (SiSiC), however, these are not found widely on the market owing to their high manufacturing cost.

At FRIATEC AG – Rheinhütte Pumps Division, engineering ceramics under the product names Frikotherm B® and Frikorund® are used. The two materials are classed as high-grade stoneware and are gas-tight without glaze.

Frikorund® is a silicate ceramic that also contains corundum and other minerals. The pump components made of Frikorund® ceramic are manufactured by means of slip casting. Frikotherm B® is also a silicate ceramic, which is optimized with regard to thermal shock. The pump components are made by means of cold isostatic pressing and subsequent machining of the pre-fired pieces. The two materials Frikorund® and Frikotherm B® are ground to the final dimensions. Like porcelain, silicate ceramic materials are resistant to almost all media, apart from fluoride-containing media and strong or hot lyes. Unfavourable properties of this material group are the brittle behaviour and the high sensitivity against abrupt temperature changes (danger of thermal

Keywords
pump engineering, SiSiC, alumina, zirconia

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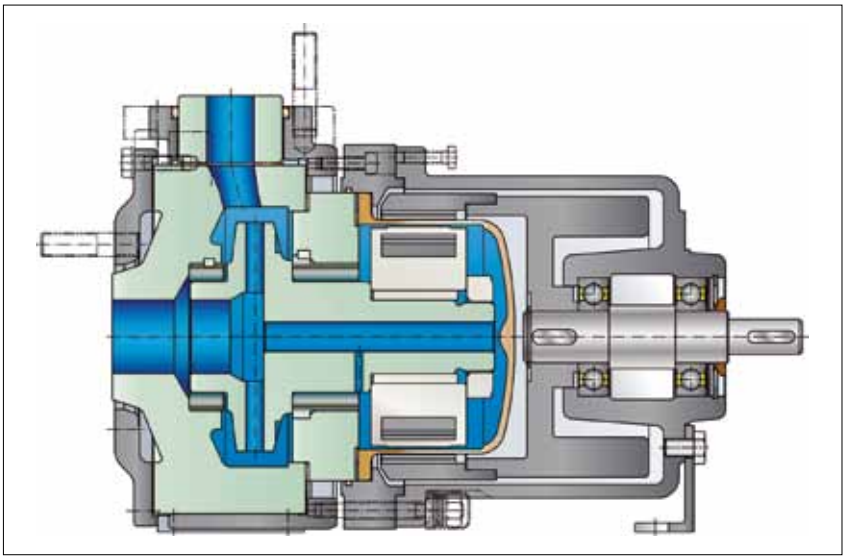

Fig. 2
Sectional drawing of the magnet-coupled FMA ceramic pump. Shown in yellow is the spacer made of FRIALIT FZM zirconia that seals the pump hermetically; the ceramic components made of Frikotherm B® are shown in the light-green colour

shock). Ceramic materials therefore need a design to match their requirements. The metallic designs cannot be adopted as, for example, very thin-walled filigree components are difficult to realize in ceramics. In addition, low dimensional tolerances are difficult to produce with ceramic materials as shrinkage and run-in of components cause far more problems.

Most metals and even many plastics can be welded. Ceramics cannot be welded, and cannot be adhesive-bonded depending on the medium to be pumped. As ceramics are very brittle, engineers have reservations against this material in pump engineering. As always, it is necessary to check in each individual case whether the considerable advantages, which are presented in the following, do not outweigh these reservations.

All following pumps are centrifugal pumps made of ceramic materials in which a rotating impeller conveys a liquid or gaseous medium.

FNC standardized chemical pump made of Frikorund® technical ceramic

The FNC series pumps are designed for applications in the chemical industry. All components in contact in with the medium are made of the technical ceramic Frikorund®. As ceramic components can withstand compressive stress better than tensile stress and threads are also difficult to produce, the pump volute casing is embedded in cast iron. In addition, this has the big advantage for safety that any leakages can be shielded by the armouring. There is no danger that the pump can burst.

The FNC pump type (Fig. 1) is manufactured in 11 different sizes, which, depending on the application, can be operated between 950 and 3500 rpm. The largest size 150/400 has a delivery rate of over 500 m^3/h at a pump head up to 50 m.

The Frikorund® ceramic used in the FNC becomes interesting especially in applications with hydrochloric acid, mixed acids, sulphuric acid or nitric acid because these acids cannot attack the ceramics. Even aqua regia poses no problem for Frikorund® ceramic. In these media almost all materials fail and plastics soon reach the limits of their resistance, especially at elevated temperatures.

As the FRIATEC stoneware, Frikorund® and Frikotherm B®, contains a considerable percentage of glassy phase, it has a dense-sintered body. As a result, diffusion phenomena, as in the case of many plastics, are not observed. For instance, when pumps handle chlorine water, chlorine can diffuse into plastics. With Frikorund®, this does not happen.

On account of the high hardness of Frikorund® (6–8 Mohs hardness), this ceramic is very resistant against wear, abrasion and erosion. This is a key advantage compared to metallic materials and plastics.

Most plastics only exhibit low resistance to abrasion. In the case of metallic materials, hard materials like Duplex steels can be selected but these materials exhibit 4 Mohs hardness at the most (around 270 –300 HB Brinell hardness). Even pumps made of Duplex steel, which are used, for example, to handle the medium of seawater containing sand (Mohs hardness 7), have only short lifetimes on account of the differences in hardness and the resulting wear.

Especially titanium, zirconium, tantalum and pure nickel are very resistant to corrosion in speciality applications, but at the same time they exhibit only low abrasion resistance. The short lifetimes resulting from this and the high acquisition costs often make the pumps economically inefficient. Especially in these special applications with severe abrasion, ceramic pumps can play out the advantage of reasonable acquisition costs and a longer lifetime and are therefore attractive when metallic materials become too expensive.

Another argument in favour of the ceramic material: often centrifugal pumps are designed to be bigger because customers want reserves in terms of pumping capacity and pumping height. This leads, however, to the pumps not being operated under full hydraulic load in real applications. This partial load phenomenon leads to additional undesirable flow within the pump. If solids are pumped, this additional flow can in turn cause a substantial increase in wear. Here too, ceramic pumps exhibit superior wear properties as the ceramic materials are harder than all plastics and almost all metallic materials.

Such unfavourable operating conditions can even bring the pumps even within the range of cavitation. Here too a pump made of the harder ceramic material will be able to achieve longer lifetimes than comparable pumps made from other material groups.

The FNC pump is sealed either with a seal of packing rings or with single- or double-acting mechanical seals.

As an alternative to the mechanical seal, an FMA ceramic pump with a magnetic drive is available, in which the drive power is transmitted via two shafts connected with a magnetic coupling. The pump is hermetically sealed by means of the ceramic spacer can made of ZrO_2 (Frialit FZM)

(Fig. 2). This prevents any highly volatile and/or toxic substances from escaping into the environment. The FMA with magnetic coupling is made of Frikorund B® ceramic and is leak-proof. This pump can be used, for example, to pump up to 80 m^3/h to 50 m delivery head. The Frikotherm B® ceramic has the advantage that temperature shock up to 180 °C is permissible. The pump at room temperature can be suddenly filled with 200 °C-hot solution without suffering any damage.

Pumps of this type are used in the production of pesticides. At one customer's operation, many different media used in the production of pesticides are conveyed by the same pump – a huge challenge for the material and its resistance. Both the FNC and FMA series of pumps correspond to the standard dimensions (DIN EN 22858), and accordingly can easily be used to replace standard pumps made of other materials.

FGP – Liquid Ring Gas Pump made of Frikorund® technical ceramic

This pump is used either as a vacuum pump or as a compressor. Typical delivery rates are volumes to 600 m^3/h at pressures up to 30 mbar (absolute). The FGP is made of Frikorund® and is armoured like the FNC (Fig. 3). A typical application for the FGP is pumping moist chlorine gas in chlorine-alkali electrolysis to pump the chlorine gas produced from the cells. The pump is sealed with a liquid ring of water. In certain cases, instead of water, other media can be used as the liquid ring. Other proven applications for these Rheinhütte pumps are gases and vapours such as hydrochloric acid, hydrobromic acid, chlorinated hydrocarbons, pesticide vapours, pharmaceutical products and highly volatile organic vapours. Even aerosols (in the sense of fumes) can be easily conveyed with an FGP, the solid wear then not being of any significance.

This full ceramic gas pump competes with high-quality metal pumps made of nickel-based alloys (C4 2.4686), titanium or titanium-palladium or zirconium. The metallic materials are expensive and only offer excellent performance in certain areas. Rheinhütte full ceramic also offers a much wider range of chemical resistance compared to any coating. While ceramic pumps only demonstrate advantages in specific applications, it is especially in these applications that these pumps prove themselves as rugged and at the same time low-cost all-rounders – for industrial-scale applications too.

Fig. 3
Opened FGP liquid ring gas pump: the impeller is in an eccentric position, which is typical for liquid ring pumps