ElringKlinger Kunststofftechnik **June 12, 2015**

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Fluid management, as old as mankind and older …..

Increasing requirements and their innovative solutions using high-performance plastics in technical systems in the field of fluid management.

As far back as 5,000 years ago, the rulers of ancient Egypt began to build irrigation canals in order to provide their people with an infrastructure that would make survival possible in a rather inhospitable environment: the distribution, provision and dispensing of the most important fluid on our planet – water. Even though the term 'fluid management' with near-absolute certainty will not be found in the hieroglyphs it was a crucial element of an advanced civilization spanning millenniums.

Fluids in 'biological systems,' in animals, in plants and in the most complex form of life on our planet – humans – have been managed for an even much longer period and involve clearly greater complexity. A wide range of fluids perform highly complex functions without which we would not be able to live. Even minor disruptions of these systems can cause physical problems that may lead to illness and, in the worst case, death. Our body requires fluids for temperature management, transportation of nutrients, protective functions for organs, lubrication of joints, and a large number of other vital functions without which we could not exist in this form. This is where nature has been setting a successful example of a complex form of fluid management for millions of years.

Today's technical systems require a form of fluid management that is equally complex. Fluids have to be transported, cleaned, distributed, filled or bottled, exchanged or provided. A few decades ago, special materials such as high-performance plastics began to make the things possible that have been taking place in our body in similar form for thousands of years.

What may be an easy feat for our cells, namely to have a semipermeable 'outer skin,' still poses a major technical challenge. However, with specially processed PTFE it is possible to achieve technical components that have a similar membrane or diaphragm function. Porous PTFE① can assume the function of 'breathing,' in other words to ensure an exchange of gas, and at the same time protect against the intrusion of fluids. Today, automotive engineering takes advantage of this so-called porous property, for instance in the areas of oxygen sensors or venting of electronic control units of vehicle transmissions and engines. In addition, these special diaphragms②, if designed for this purpose, can perform the function of a safety valve by bursting in the case of defined excess pressure and allowing the interior pressure to escape. Such applications can be found today in the area of batteries used in the E-mobility sector. In the field of functional clothing, PTFE membranes – even though their manufacturing processes differ – have practically become indispensable.

Our pump – the heart – with a maximum pressure of approx. 15mbar and a maximum volumetric flow rate of 5l/min delivers performance that appears to be disappointing from the perspective of compressors and pumps in technical systems. Only the fact that the heart, by now, can achieve continuous maintenance-free operation of up to 100 years is head and shoulders above the achievable lifecycles of modern pumps. But this is another segment in which high-performance plastics help to reliably support continually increasing requirements regarding lifecycles, friction, pressure or the use of aggressive media. Rotary shaft seals③ with stainless steel housings and PTFE sealing lips for instance operate in dry or low-lube conditions and temperatures of up to 150 °C where the same seals made from elastomeric materials would have long failed. Pressure peaks of up to 10bar, reduction of the so-called stick-slip effect, minimization of friction or small assembly spaces are other relevant requirements which are met by the utilization of high-performance plastics.

An application example to illustrate the point in this context is an initially inconspicuous component for a filling valve of a beverage filling machine. Without the utilization of special materials and processing techniques, it would be difficult to specify this component. It not only has to ensure reliable sealing at a fill pressure of up to 6bar but, at the same time, guide a sliding piston. The relevant requirements for the material are suitability for food contact – for which FDA conformance is a key prerequisite – neutral taste in contact with beverages, sterilizability with hot steam, and resistance against aggressive cleaning media like hydrogen peroxide and peracetic acid. Requirements such as smooth component surfaces, absence of pores, and a design without undercuts are imperative for aseptic components, while radial stress levels of up to 20MPa pose additional technical challenges. The solution developed jointly with the customer for this application is an injection-molded Moldflon®④ component.

The entire length of the blood vessels in our body amounts to approx. 100,000 km. If any of these vessels are partially blocked or completely clogged we are threatened by severe illness. To ensure reliable flow conditions in technical systems, manufacturers of painting lines use so-called 'pigs.' Due to the outstanding sliding properties of PTFE these components are pressed through the pipe systems by compressed air, cleaning the pipes in the process. Integrated magnets ensure detection and guidance of these components.

No technical system accommodating such a long network of lines in as small a space as the human body is equally complex, as the total length of our blood vessels is approx. 100,000 km. However, the requirements of technical systems for transporting fluids are a lot harsher. Aggressive media such as acids and lyes, pressures, color coding, very small diameters down to a few tenths of a millimeter, and sterilizability are today's requirements for tubes⑤or tubing. PTFE tubes or tube assemblies help to meet these demands as well. They are typically produced by extrusion from pasty PTFE compounds, followed by sintering.

An example of an application that would be inconceivable without the afore-mentioned materials to be mentioned here is a catheter tube⑥ utilized in the field of minimally invasive surgery for so-called argon plasma coagulation. In this procedure, a plasma gas is transported and directed within a probe to the lesion to be treated and ignited there. In addition to very high temperature resistance, the tip of the probe must have very low friction. Biocompatibility and PTFE's inertness against argon gas and non-flammability are requirements in this case just like the sterilizability of the assembly. The dimensions of the probe, i.e. 2.3mm outer diameter by 1.6mm inner diameter, are very small.

Unfortunately, the outstanding properties of PTFE in terms of media resistance, friction coefficient or temperature stability come at the great expense of this material not being suitable for processing by conventional injection molding technology. If maximum degrees of freedom regarding the geometry of the parts are desired anyhow, a wide range of manufacturing processes of the kind installed at ElringKlinger Kunststofftechnik are necessary. These may be conventional techniques more commonly expected in metalworking, such as turning, milling, drilling, grinding or lapping, as well as the production of sheets by peeling, further processing for instance by gluing, or marking/coding required particularly by PTFE tubes used in medical technology.

Whenever these processes reach their limits and geometries can only be achieved by using injection molding, viable solutions are now available as well. ElringKlinger Kunststofftechnik, together with a material manufacturer, has developed Moldflon®, a PTFE compound that can be processed by injection molding and thus combines the classic properties of PTFE with the geometric degrees of freedom offered by well-known plastics. Studies have shown that approx. 75% of the PTFE being processed around the world by machining is lost in the form of chips that practically cannot be reused. The utilization of injection molded parts makes a major contribution to the conservation of resources ⑦, as nearly the entire material being processed is used for producing the component.

Moldflon® is currently increasingly being used in the field of thermal management in the automotive sector or in medical technology.

The utilization of high-performance plastics such as PTFE, PEEK, PVDF or proprietary brands like Moldflon® has become indispensable whenever high demands are made on components regarding friction, temperature resistance and media resistance, or sterilizability. As one of Europe's major processors of this group of materials, ElringKlinger Kunststofftechnik GmbH in Bietigheim-Bissingen (Germany) is an expert development partner in this field.

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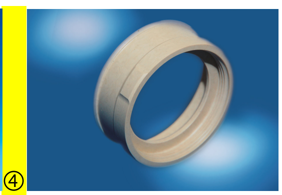

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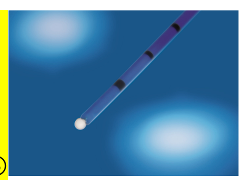

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⑦Shown at left: Component and material requirement in injection molding; shown at right: Component, material requirement and chip waste in machining

Image caption:

CNC machining of a pump housing

Injection molding of a Moldflon® component