OPERATIONS & MAINTENANCE

LOOKING BEYOND CHEMICAL COMPATIBILITY CHARTS: MATCHING PLASTIC AND ELASTOMER SEALS WITH FLUIDS

By Lucy Heyduk and Tim McCulfor, Trelleborg Sealing Solutions | December 2, 2019

Chemical compatibility charts are often used as a quick and concise way to match the proper fluid with a seal. However, there is much more to consider with the chemical compatibility of a seal in relation to the fluids in a system. This information is critical to gaining a reliable and long-lasting seal — and the selection process can be daunting.

Chemical engineers need to consider the reactions between the polymers used in seals and the chemicals in process fluids, as they can vary greatly. For example, certain chemicals "attack" polymers, breaking chemical bonds and degrading the polymers' properties. In some cases, chemicals extract ingredients from the polymer, leaving it weak or lacking in important functional properties. Other chemicals can permeate a polymer and cause swelling. This can be both an advantage and a disadvantage, further complicating seal specification.

Under all circumstances, it is important to understand the effects that chemicals have on seals and to choose a material that is compatible with the chemical to be sealed. This article reviews the considerations for choosing the right material for a given chemical sealing application for both plastics and elastomers.

The wide variety of fluid-sealing applications and available materials make compatibility a primary concern when making a selection

PLASTICS

The broadest classification of polymers is between plastics and elastomers. This article first looks at plastics, which can be either thermoplastic or thermoset polymers. Thermoplastics are able to be re-melted after polymerization, so they are molded with a melt-processing operation, such as injection molding or extrusion. Thermosets react or crosslink during molding, so they are usually processed by one of the three molding techniques (compression, transfer or injection molding) or extruded.

Generally speaking, plastics are more rigid than elastomers, but their behavior can range from very ductile to brittle, and their chemical resistance varies greatly.

The following sections describe some plastics used in seals with descriptions of their chemical compatibility behavior. They all have good compatibility with water and oils.

Polytetrafluoroethylene (PTFE). PTFE has resistance to virtually all media. There are only a few chemicals in extreme conditions that can attack PTFE, including molten alkali metals, gaseous fluorine at high temperatures and pressures, and a few organic halogenated compounds. In addition, PTFE has a wide usable temperature range and low friction, making it a premiere seal material. As PTFE has no elastic capabilities, these types of seals are usually used in conjunction with an elastomer energizer or spring. Ensuring that the combination of seal and energizer is fully compatible with system chemicals can be difficult and requires suppliers to have a full understanding of material properties.

Polyetheretherketone (PEEK). PEEK has excellent high-temperature properties and good chemical resistance. PEEK excels in systems with high-temperature steam, making it an excellent choice for oil-and-gas applications.

Ultra-high molecular-weight polyethylene (UHMWPE). UHMWPE is extremely tough and has good friction and wear properties. It performs well in water-based fluids and most oils, but can be affected by some aggressive chemicals.

ELASTOMERS

Like plastics, elastomers can also be thermoplastic or thermoset.

Elastomers are characterized by their elastic properties. With some exceptions, they are generally very resilient and excellent for seals that will come into contact with fluids.

However, some elastomers are particularly prone to swelling (fluid can be absorbed by the material through diffusion), and others are prone to shrinkage (plasticizers and additives dissolve in the media and are extracted from the material). All of these variables make the selection process quite complex, so you should work with an expert polymer or seal supplier to identify the optimum material for a given application.

In general, the interaction between elastomer and chemicals follows the rule that like dissolves like. For example, most polar polymers dissolve in polar solvents and rarely dissolve in non-polar solvents (and vice versa). Thus, seals based on ethylene propylene diene monomer (EPDM) rubber are not recommended for sealing in a system designed to hold a petroleum-based products (both are non-polar) where high swell is expected. Conversely, an EPDM seal is well suited for sealing a system involving water, which is polar.

Commonly applied in oil-and-gas applications, automotive manufacturing, medical devices and fluid power systems, EPDM seals are suitable for challenging applications. In fact, EPDM compounds are very useful for the oil-and-gas and related markets, as they provide outstanding resistance to high-temperature steam.

The degree of swelling can be predicted using solubility parameters. If the sealed fluid has a solubility parameter close to that of the elastomer, the attraction will be high, resulting in swelling. The degree of swell decreases when the differential between the solubility of the elastomer and the surrounding media increases.

The seal swells due to a diffusion gradient that is produced between the inside of the elastomer and the fluid outside. For water-swelling elastomers, the swell is determined by the temperature and salinity of the water. These define the elastomer's rate and absolute swell. The absolute swell is defined as the amount of swell that occurs against time for a particular situation. No matter how thick the elastomer, it should never swell more than this particular amount within a specified timeframe.

The many families of elastomeric materials provide advantageous performance benefits in many fluid-sealing applications

During specific tests, swell can be calculated, and in certain applications, a degree of swelling can be an advantage to the sealing function. This is a specialized area of seal specification, and such applications should be reviewed with an elastomer or seal supplier that possesses a full understanding of the process and the compounds involved.

The chemical interaction between elastomer compounds and media is called chemical attack. There are large numbers of chemical species that can degrade elastomers. The severity depends on the agent and the chemistry of the elastomer being attacked.

The degradation may occur by the fluid attacking the polymer backbone itself (for instance, braking or forming additional cross-links or unsaturation) or by interaction with compounding ingredients (such as oxidation of fillers). The chemical attack will manifest itself through the loss of mechanical properties, hardening and surface degradation.

The following sections describe some elastomer types commonly used in seals, as well as their chemical compatibility behavior:

EPM/EPDM. A non-polar synthetic polymer, ethylene-propylene rubber (EPM) is a copolymer of ethylene and propylene. EPDM denotes a terpolymer of ethylene, propylene, and non-conjugated diene.

EPM and EPDM are recommended for the following applications:

- Hot water and steam
- Brake fluids
- Alkalis and acids
- Ketones and alcohols
- Sunlight and ozone

EPM and EPDM are not recommended for use with petroleum oils, mineral oils or fuels.

Nitrile rubber (NBR). NBR is considered the workhorse of the rubber industry. The acrylonitrile content (ranging from 18% to 50%) determines the elastomer's fluid resistance.

NBR is recommended for use with the following fluids:

- Aliphatic and aromatic hydrocarbons
- Oils
- Gasoline
- Greases
- Hydraulic fluids

NBR is not recommended for use with chlorinated hydrocarbons, ketones or esters.

Hydrogenated nitrile rubber (HNBR). HNBR is obtained by either partial or complete hydrogenation of acrylonitrile-butadiene rubber. The main difference between HNBR and NBR is the highly saturated backbone that results in an improvement in resistance to heat and chemical attack.

HNBR is recommended for use with the following fluids:

- Hot water
- Steam
- Oils
- Fuels

HNBR is not recommended for use with polar solvents, strong acids or chlorinated hydrocarbons.

Fluoroelastomers (FKM). The chemical resistance of fluoroelastomer (FKM) is determined by the fluorine content (ranging from 65% to 70% percent) and the type of monomers used. There are five distinct classes of FKM materials based on the types of monomers used in the polymerization process.

FKM is recommended for use with the following fluids:

- Aliphatic and aromatic hydrocarbons
- Gasoline and gasoline/alcohol blends
- Chlorinated solvents

FKM is not recommended for use with Ketones, strong bases or amines.

Fluorosilicone rubber (FVMQ). FVMQ is a modified silicone rubber that has many attributes of silicone rubber but with improved chemical resistance.

FVMQ is recommended for use with:

- Dilute acids
- Alkalis
- Petroleum oils
- Hydrocarbon fuels

FVMQ is not recommended for use with alcohols, ketones or amines.

Perfluoroelastomers (FFKM). Perfluoroelastomers, sometimes referred to as an elastomeric version of PTFE, are the highest-performance group of elastomers. They have a fully fluorinated backbone and possess the broadest possible chemical resistance. Seals made from FFKM are used in extreme chemical environments, such as chemical processing and transportation, oil and gas and semiconductor markets. Some grades are not resistant to steam, and some have reduced amine and base resistance.

While FFKM is suitable for use with an extremely broad range of chemicals, it is not recommended for use with molten alkali metals.

FACTORS THAT CAN AFFECT COMPATIBILITY

The temperature of the sealing application is an important consideration when choosing a sealing material. Both high- and low-temperature fluctuations change properties, so the polymer must remain flexible enough to seal at low temperatures while maintaining structural integrity at the highest exposure temperature.

Keep in mind that the temperature can also affect chemical resistance. Chemical activity increases with temperature, so a seal material that is compatible with a chemical at room temperature may be attacked at higher temperature. In a dynamic seal, frictional heat generation can cause the actual temperature at the seal interface to be higher than the bulk fluid temperature, so this can be an important consideration.

Some seal applications have continuous contact with chemicals and others have only intermittent contact. Chemical attack is a time-dependent process — some materials can resist chemicals when exposed for a short time but are not recommended for longterm exposure.

CHEMICAL COMPATIBILITY CHARTS

Chemical compatibility charts are most useful to determine the generic susceptibility of general classes of polymers with certain chemicals. They are usually compiled from property-change data of test specimens immersed in the specific chemical.

The testing may be done at different temperatures, but most charts just list results from room-temperature exposure. Thus, this information can help manufacturers rule out materials that are clearly incompatible, but determining the compatibility of a specific material-chemical pair for an application requires more research.

In addition, compounds within a type can be engineered to resist chemicals specific to an industry application. Although a type of material may, in general, not work well with a particular chemical, an engineered grade may.

Working closely with an experienced seal supplier is perhaps the best way to ensure specification of a fully compatible polymer. The supplier will be able to recommend materials for specific applications, since they will be familiar with their particular materials and have tested them for resistance. Look for a seal supplier that fully understands the complexities of combining polymers with fluids. Ideally, the supplier will have experience using a specific polymer in the application you are working on so they can discern exactly how it will behave in that system. ♦

Edited by Mary Page Bailey

AUTHORS

Lucy Heyduk is a materials development chemist for Trelleborg Sealing Solutions (tss.trelleborg.com; Lucy.Heyduk@trelleborg.com). She has more than 30 years of experience in the rubber industry specializing in compound development for specific market segments, such as automotive and aerospace. She has been with Trelleborg Sealing Solutions in her current position for 14 years. Heyduk graduated from University of Wrocław in Poland with an M.S. degree in chemistry.

Tim McCulfor is the material development manager for Trelleborg Sealing Solutions (Tim.McCulfor@trelleborg.com). He graduated from Michigan State University with a B.S.Ch.E. McCulfor has more than 30 years of experience in the plastics industry working on compound development of thermoplastic- and thermoset-based materials.