Dynamic sealings

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The primary function of an elastomeric seal is to maintain the separation of material phases. In general, seals prevent the exit (leaking) of material from a particular system. In addition to preventing leakage they also prevent the introduction of foreign material contaminants into the same system.

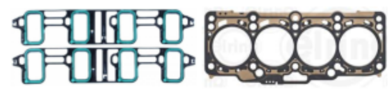
Elastomeric seals can be broadly segmented into two primary categories -static seals and dynamic seals. While the basic purpose of each is the same, the design and function can be quite different. As the name suggests, static seals are not exposed to movement while dynamic seals experience a variety of types of movement.

Static seals are affixed between stationary materials and are most often held under some degree of compression. Given the elastic nature of rubber seals the material “pushes back” against the stationary material thereby forming a seal tight enough to secure the contents of the system.

Some practical examples of elastomeric static seals include: O-rings, gaskets, & washers.

Static seals such as o-rings and washers are most often single piece rubber only constructions that are inserted into a gland/opening designed specifically for the system they are intended to seal.

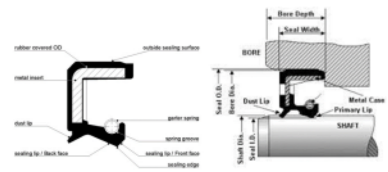
Gaskets can either be a single piece of rubber as shown above, or they can also be overmolded or coated onto rigid carriers made of metal, thermoplastic, or composite materials as in the examples of air intake manifold gaskets and cylinder head gaskets found on internal combustion engines.



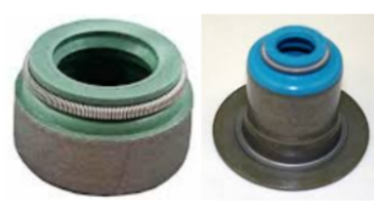
Dynamic seals are almost always overmolded to a rigid substrate and are affixed on one side to a stationary material but experience movement of one or more other materials in contact with on the opposite side of the seal. This movement is generally either rotating or reciprocating.

Some practical examples of dynamic seals exposed to rotational motion would be engine and/or transmission shaft seals which are located at the crank shaft or drive shaft exit points of an internal combustion engine or transmission. In either case the seal serves to keep the lubricants securely inside the system while also preventing water, dirt, and debris from contaminating the same system.

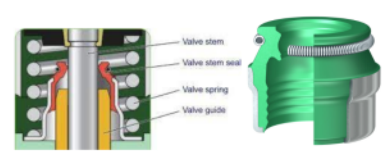
The external walls of the seals are stationary and affixed into a bore. A metal shaft passes through the inner opening of the seal as it exits the engine or transmission. The internal side of the seal is in contact with the shaft which rotates at speeds ranging from 0 to over 5000 rpm in either rotational direction. The sealing element contacting the shaft, often called the lip, is usually (but not always) held in place under modest compression by a metal garter spring. In addition to the heat generated by the system itself, the movement of the shaft against the seal being forced against the metal surface by the spring creates additional frictional heating which can contribute to thermal degradation, cracking, and wearing away of the elastomeric seal material and ultimately leaking of the lubricant.



A practical example of a seal exposed to reciprocal motion would be a valve stem seal which is located on the top of an internal combustion engine along the valve train. The valve and stem assembly moves up and down, opening and closing the intake and exhaust ports with each combustion cycle for every cylinder.



The metal base and or/ external wall of the seal is stationary and affixed to the engine while the valve stem passes through the elastomeric opening of the seal which is held against the stem by a metal garter spring. The stem is continually coated with engine oil in its downstroke movement. In the upstroke movement, as it passes through the seal, the oil is wiped down by the seal to a very thin film on the stem. In addition to the nearby heat of the combustion chamber of engine, and the hot exhaust gasses, the movement of the stem against the spring loaded rubber seal generates frictional heating which can lead to thermal degradation, cracking, and wearing away of the sealing surface that ultimately causes excess oil film formation leading to leakage.

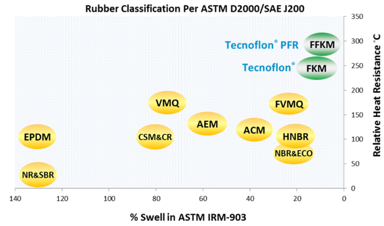


A wide variety of both static and dynamic elastomeric seals are found in modern machinery in practically all market segments. While often easy to overlook, their criticality should not be underestimated. One seemingly minor leak from a small rubber seal has the potential to soon destroy a complex machine.

Materials for Elastomeric Seals

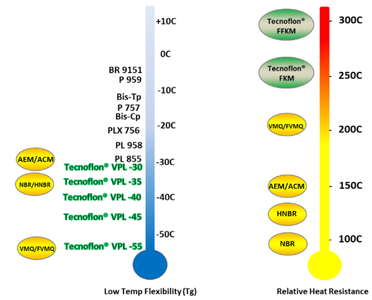
Elastomeric seals can be made from a wide variety of rubber types. The application requirements should dictate the material selection. Specific technical considerations must be addressed in the material selection such as the type/nature media to be sealed, operating temperatures (low/high), static/dynamic function, and product performance requirements. More broadly the product life cycle, warranty cost, and risk of failure must be considered when selecting the right elastomer for the job.

Solvay's Tecnoflon FKM and FFKM elastomers are uniquely positioned to offer best in class performance for sealing applications. Among all of the elastomer choices for sealing applications Tecnoflon offers the greatest chemical resistance, highest temperature capability, and best balance of low temperature flexibility to meet the most demanding challenges.



Wear resistance of elastomeric seals

Relatively simple industry standard methods for quantifying and establishing the chemical resistance, high temperature capability, and low temperature flexibility of elastomers in a meaningful and comparative way have been used for many years with a proven track record. However, the question of elastomer wear resistance, in particular for dynamic shaft seals, is a different matter. Few methods exist and those that do are often considered poor predictors of actual performance. For example, taber abrasion data is sometimes suggested as an indicator of dynamic seal wear resistance. However, there is sufficient anecdotal evidence of the unreliable wear predictability of tabor data to call into question its relevance. As a result, seal makers and designers have developed numerous highly specialized and often proprietary individualized methods to predict functional performance (including wear) of unique seals in application. These methods, second only to actual validation in service, require significant investment, are highly specialized, sometimes considered proprietary, and the results are often relevant only to a particular application and therefore may not easily translate.



This is an example of a typical radial shaft seal test rig. (Est. cost +$100K/unit)

Input variables

- Shaft diameter & surface roughness
- RPM protocol and time
- Temperature protocol -40 to +200C
- Lube/no lube conditions
- Seal design –each is unique
- Seal compound –each is unique
- Installation offset and/or runout

Measurables

- Leak/no leak
- Time to leak
- Wear band width
    - Torque on shaft from seal
    - Temp profile at/near lip contact point
    - Appearance of seal & shaft after test
    - NVH/sound observed during the test

Aside from initial cost, radial shaft seal test rigs require the availability of actual molded seals as well as specifically designed and manufactured shafts and bores. In addition, time is often a limiting factor. Some tests are designed to run over the course of 1-5 days but common endurance tests for the automotive industry can run 3-6 months or longer. For this reason seal makers usually must have at their disposal multiple test machines.

Factors impacting dynamic shaft seal wear performance.

Wear performance of a shaft seal is a complex matter. There are multiple factors at play that impact the wear behavior. They include but are not limited to:

- Intrinsic base polymer properties
    - Viscosity
    - Cure type
    - % Fluorine
    - molecular structure (MWD, branching, linearity, etc)
    - end group chemistry
- Formulation of the final compound
    - Hardness and mechanical property requirements
    - Mineral vs black filled vs blends
    - Special "wear enhancing" additives
    - Process aids
- Compound mixing methodology
    - Dispersion and incorporation of compounding ingredients
    - Compound mixing/work history
- Molding and tool design
    - Knit (weld) lines placement
    - Tool venting and gassing
    - Engineered waste (Flash) and gassing
- Seal design features
    - Lip geometry (shape)
    - Lip flexion (modulus vs elongation)

    - Spring tension
    - Helical pumping features
    - Knife trimmed vs molded contact sealing surface
    - Adhesion to inserts
- Set up of the actual seal test
    - Shaft rugosity/roughness
    - Time and temp protocols
    - RPM pattern protocols
    - Fluid type and amount
    - Fluid change intervals
    - Seal installation alignment against shaft and bore

It's clear that from an elastomeric polymer manufacturer's perspective there is very little beyond the intrinsic properties of the base polymer itself that can significantly influence the wear behavior of the final product. For this reason, most elastomeric polymer manufacturers tend not to focus intently on measuring wear behavior of sealing materials. However, it's relatively common for seal makers and compounders to inquire of the elastomeric polymer manufacturer about the wear behavior and properties of various materials.

In order to develop a greater understanding of the role and influence the elastomer manufacturer can have regarding the wear behavior of a final sealing product a less complex test should be used that gives relevant information in a simple to measure method. Solvay's ADL group has developed a test that might be just what is needed. This test uses a simple 0.214 size molded o-ring that is affixed stationary on one side and a rotating counter surface is moved against the opposite side of the o-ring in a controlled way. The test measures material loss, wear band width/depth, and coefficient of friction. The test is quick and simple to operate and so far shows a good distinction between samples of different formulations. Validation of this test is currently underway and the intent is to compare materials of "known good" wear behavior in real world radial shaft seal applications with experimental materials. Once the method is more fully validated, the intent is to work with customers to compare grades, formulations, etc in order to help them optimize their compounds for wear and friction using our Tecnoflon elastomeric polymers