EXPERT KNOWLEDGE
FAILURE ANALYSIS
OF ELASTOMER COMPONENTS

An offer of

O RING PRÜFLABOR RICHTER

TESTING CONSULTING DEVELOPING

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Cracks as a Result of Manufacturing Problems –
A Severe Fault that Often Leads to Seal Failure

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1. Classification and Frequency of the Damage Pattern

Of the four main damage mechanisms, cracks in seals can be classified into different main groups. The following article deals with cracks due to manufacturing defects and belongs to the fourth main group:

1. Mediums
2. Temperature / Aging
3. Mechanical / Physical Effects
► **4. Manufacturing Defects**

From an evaluation of over 2000 damage cases processed and analyzed in the O-Ring

Prüflabor Richter, manufacturing-caused cracks were the reason for the failure of a seal in approx. 10-15% of the cases.

2. Technical Background Knowledge on the Damage Pattern

Today, the formation and propagation of cracks in elastomers is a field intensively dealt with by polymer physics, which will not be dealt with in detail in this article. This article will deal with the practical differentiation of a production-related crack from an overload crack.
In engineering it is a generally accepted requirement that gaskets must not show any cracks. For example, ISO 3601-3 (August 2010) states: "In the non-stretched state, the surface of the O-ring must be free from cracks (...) at twice magnification under appropriate lighting."[1]
However, it should be mentioned at this point that on a microscopic level almost every elastomer component contains defects (e.g. organic/inorganic dirt particles, residues of chemical demolding agents, poorly dispersed compounds, residues of previously processed compounds, etc.). Even the most careful manufacturing process can never completely rule these out, but only reduce them. In the tensile test on standard specimens, for example, larger components have lower strength values than smaller ones. "As a general rule, the larger the initial cross-section or the larger the volume of the specimen, the lower the tensile strength. This dependency can be explained by the number of flaws in the specimen. The smaller the volume of the specimen, the less likely it is that defects will be present."[2] The decisive factor, however, is the size of these flaws and sometimes micro cracks in connection with the later area of application of the given seal. Static seals are usually much more tolerant of cracks than dynamically loaded seals.
It should also be mentioned that there are also materials for which crack propagation requires relatively little energy, which means that they have a low tear propagation resistance (e.g. many (but not all) VMQ materials or peroxide crosslinked EPDM materials with good low-temperature flexibility). The tear resistance also depends on the temperature, the higher the temperature, the lower the tear resistance (although it varies depending on the elastomer type and filler).
The problem is that many critical cracks are not visible to the naked eye, either because they are too small or not visible on the mostly low-contrast black seals, or because they only show when the elastomer component is stretched in a certain direction.
Since cracks in elastomer components can have a variety of causes, this article is limited to manufacturing defects only. This can be divided into 6 common crack causes:

- Incorrect vulcanization (e.g. with critical materials such as ACM[3])
- Superimposed compound (already started to vulcanize)
- Cracks due to impurities

[1] DIN ISO 3601-3 (August 2010): Fluidtechnik – O-Ringe – Teil 3: Form- und Oberflächenabweichungen (ISO 3601-3:2005), S.7
[2] NAGDI, Khairi: Gummi-Werkstoffe Ein Ratgeber für Anwender, Ratingen, ²2002, S. 290
[3] „Acrylatkautschuke haben eine relativ niedrige Viskosität und sind klebrig, die Viskosität nimmt unter Scherung deutlich ab. (…) Die Lagerstabilität des Compounds ist gering.“ RÖTHEMEYER, F. und SOMMER, F.: Kautschuktechnologie, Carl Hanser Verlag, München, 2001, S. 187

- Shrink cracks
- Demolding cracks
- Cracks due to post-processing

2.1 Incorrect Vulcanization

There can be several different reasons for vulcanization errors. A high scorch susceptibility of the compound can cause problems. This can lead to notches and flow lines and/or increased susceptibility to cracking, especially in the area of confluence points. Strictly speaking, cross-linking begins already at room temperature and becomes critical when it exceeds a certain "threshold". This happens - at least in conventional injection molding without a cold runner - mainly in two ways:
1. In the cylinder: This is the case when - especially in very "tight" (i.e. highly viscous) compounds - a high cylinder temperature is selected in combination with long dwell times in the cylinder (large cylinder and small shot volume, shift change, pauses, etc.). Due to the poor thermal conductivity of the rubber compound, the compound parts in the edge areas of the cylinder are more likely to be affected.
2. In the tool (during injection): This is caused by a tool temperature that is too high (to save cycle time), possibly also in combination with a high mass temperature at the cylinder outlet.

In injection compression molding, an insufficient embossing gap and the resulting increase in temperature due to friction can also play a role. In cold runner production, temperature management in the cold runner and the ratio of shot volume to cold runner size (dwell time in the cold runner) are critical.

In compression molding, the greatest risks are the blanks, which are not vulcanized, with a dwell time that's too long on the hot tool during loading (especially in large presses with many cavities and a poor loading concept).

There are polymers, such as ACM materials, which are particularly sensitive to temperature control, but if production parameters are not optimal, cracks can also occur in all other elastomers due to vulcanization defects: If vulcanization is to be accelerated too much by high temperatures, any compound can vulcanize too early. In the application, this may only reveal itself under deformation and high temperatures (see **Fig. 1**).

2.2 Scorched Compound

Each elastomer compound has a specific best-before date. After this date, it should no longer be used or only if it can be ensured by reliable tests (e.g. rheometer test, processability studies in the injection molding machine, etc.) that the compound still contains a tolerable degree of pre-crosslinking and can be processed without problems.

Some compounds also require storage in a cooling house. If this is forgotten or carried out under the wrong conditions, the mixture may become unusable within its expiry date. Due to the irreversible chemical cross-linking that occurs, the compound cannot be made usable again through any work steps.

Due to the globalization of manufacturing processes, compounds produced in Italy or Germany are now processed all over the world. Especially in cases of damage with critical mixtures (e.g. ACM), the transport routes and conditions (e.g. use of uncooled trucks in midsummer) should be closely monitored. A further reason for pre-vulcanization may be excessive heat generation

during extrusion (production of blanks) or straining (sieving of the compound to filter out filler agglomerates and to homogenize the compound).
If a compound is heavily scorched, the seal manufacturer will often find this relatively easy to detect, as the high proportion of pre-crosslinked material makes it impossible or only partially possible to inject the compound into the mold. Far more critical and frequent problems occur in practice with compounds at the limits of their usability. This limit range can only be identified by the application of Rheovulkameter tests and requires consistent scrapping of superimposed compounds, which can cause considerable financial losses of up to several thousand euros.
A superimposed compound can be the cause of increased deformation and surface defects, especially flow defects, and it can lead to a significantly greater scattering concerning the elongation at break of the components and also lead to lower mechanical strength. This can be seen when the relative standard deviation in the tensile test on the finished parts is 15% or higher. On a component that has been damaged and then torn through, there is usually a frayed or undulating crack pattern and an inhomogeneous, often fissured fracture surface. In the case of highly superimposed compounds, a layer-like structure can form, so that even small deformations cause internal cracks in the seal.

2.3 Cracks Due to Impurities[4]

Flow defects and resulting cracks can also be caused by impurities. If tool cleaning is inadequate, certain compounds may become heavily soiled, and both dissolved particles and filmic impurities may trigger cracks. Likewise, an unsuitable or too highly dosed mold release agent can lead to problems. Poorly mixed compounds, which have not been sufficiently dispersed, can also be susceptible to cracking.

2.4 Shrinkage Cracks

During cooling, the high shrinkage factor of rubber can cause thick-walled parts in particular to show slight "erosion" at the mold parting, which can lead to cracking. For O-rings, limit values are specified in DIN ISO 3601-3 under the characteristic "notches".

2.5 Demolding Cracks

After the pressing or injection process, the elastomer component is removed from the tool either manually or automatically (e.g. by brushes or grippers). Cracks occur regularly during this process. This can either be caused by a dirty tool, which hinders the removal, or by a compound-induced adhesion which is " too high in the tool"[5]. Reasons for this could be that, for example, the use of a release agent has been forgotten or that the mixture is particularly sticky (e.g. peroxide cross-linked FKM).
An insufficient component design (e.g. sharp edges, undercuts) can also promote demolding cracks.

[4] Vgl. CHARLES, Joachim (Hg.): Technologische Verfahren der Elastverarbeitung, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig, 1983, S. 225
[5] CHARLES, Joachim (Hg.): Technologische Verfahren der Elastverarbeitung, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig, 1983, S. 225

Defects in the production tool can lead to "tearing at the tool parting line due to tilted [or damaged] press plates".[6]
In the case of materials with a low hot tear resistance (e.g. peroxidic cross-linked FKM or EPDM materials / **see table 1**), even small forces or tilts are sufficient to produce a crack.
In addition, the premature removal of an elastomer component from the mold can lead to cracks, as it was not yet sufficiently cross-linked.[7]

	Test Temperature	FKM 55 ShA	FKM 60 ShA	FKM 75 ShA
Tensile Strength [N/mm²]	23°C	8.5	11.1	10.4
	70°C	3.0	4.6	5.4
	120°C	2.1	2.6	3.7
	150°C	1.8	2.2	3.3
Elongation at Break [%]	23°C	282	236	231
	70°C	170	143	140
	120°C	116	99	84
	150°C	90	81	72

Tab. 1: Influence of temperature and different hardness values on tensile strength and elongation at break of bisphenolic cross-linked FKM compounds. (The results come from experiments carried out by Freudenberg Research Services (FFD), Weinheim on behalf of O-Ring Prüflabor Richter GmbH.)

2.6 Cracks Due to Post-Processing steps

With some gaskets, the sealing surface is not achieved during shaping, but only during the finishing process. For example, rectangular sealing rings are cut off extruded hoses or, in most radial shaft seals, the sealing surface is created by cutting-off. In this process step, the seal may break out or be damaged, resulting in cracks.
In order to ensure that the cavities are completely filled, the cavities are overfilled both during injection molding and compression molding, resulting in a thin sprout (= burr) in the parting plane. In order to remove this unwanted flash from the actual molded parts, almost all elastomer seals must be deburred after vulcanization. For this purpose, cold deburring has established itself as the most practicable process for almost all seal manufacturers. The parts to be deburred are frozen with liquid nitrogen and then blasted in the frozen state with a plastic granulate accelerated by a spinning wheel. With perfectly adjusted parameters (temperature, granulate size, impeller speed) the kinetic energy of this granulate is sufficient to remove the thin skin from the thicker-walled parts without damaging them. In practice, the parts to be deburred are often damaged due to incorrect parameters or fluctuations in the granulate size (seals with low cord thickness are most susceptible). Cracked parts are particularly critical, as

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[6] Ebd., S.225
[7] Vgl. hierzu: PUJOL, J.-M.: Cracking while Curing in Silicone Sealants: 156th ACS Rubber Division Meeting – Fal 1999, Conference preprint, Orlando, 21-23.09.1999, paper 70 in: BROWN, R.P.: Rubber Product Failure, Rapra Review Reports, Vol. 13, No. 3, 2002, S.35 *(This describes the tearing of VMQ-RTV expansion joints in the construction sector. Due to the slow cross-linking caused by the ambient humidity, building movements often occur during the relatively long vulcanization process. Even elongations of less than 10% can lead to cracks.)*

this pre-damage can only be detected with appropriate stretching and can lead to failure during application.
Likewise, incorrect post-cure or an incorrectly adjusted or defective furnace can cause cracks during post-cure.

1. Damage Pattern

3.1 Description of the Damage Pattern and Problematic Areas

The distinction between a surface recess and a crack is not always clear. The classification of a surface defect as a crack is justified if the depth clearly exceeds 0.1 mm and if there is a linear characteristic in delimitation to a planar characteristic and the defect can be recognized under two-fold magnification.

3.1.1 Damage Pattern "Cracks Due to Faulty Vulcanization"

During the damage analysis, the fracture point is not only to be examined, but also the entire seal.
If vulcanization is faulty, flow lines may appear on the gasket in addition to the inhomogeneous fracture surface. This ensures that manufacturing defects are the cause of the crack. This can be a single defect, because economical rubber processing is not possible without scrap and this defect had not been detected during the final inspection, or there is a serious process problem that leads to an accumulation of flow defects. Therefore, a comparison with a larger number of new unused seals from current series production is often helpful. Sometimes the same defect can be detected on these seals to a lesser extent.
Cracks caused by flow lines are often parabolic and symmetrical to the mold parting line (see **Figs. 2 to 4**). In the case of faulty vulcanization, an inhomogeneous fracture point usually appears in the area of the fracture point (see **Figs. 5 and 6**), sometimes there are also conspicuously smooth areas in the fracture surface. Typical for cracks caused by vulcanization defects is also a rounded transition from the surface to the crack (see **Fig. 7**) compared to a case of damage caused by a cut

Fig. 1: Cracks in an FKM O-ring due to over-vulcanization after a compression set test of 168h / 200°C

Fig. 2: Crack due to a vulcanization defect, recognizable by the parabolic crack shape symmetrical to the mold parting line

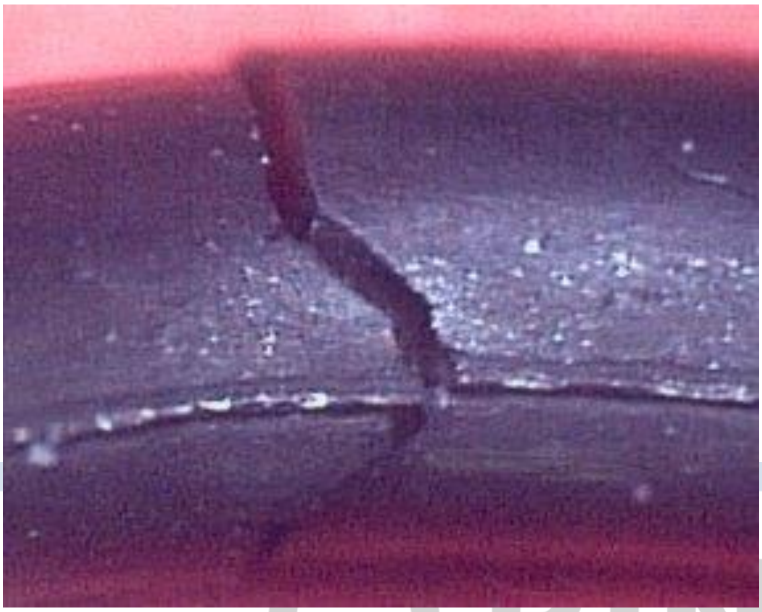


Fig. 3: Manufacturing crack, parabolic and symmetrical to the mold parting line

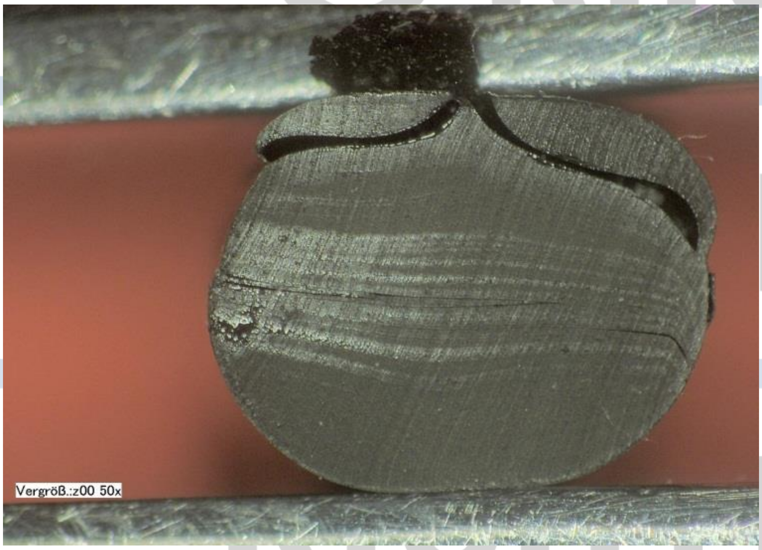


Fig. 4: Cracks due to a super-imposed elastomer compound

Fig. 5: Torn O-ring caused by a vulcanization error

Fig. 6: Torn O-ring due to vulcanization defect: Inhomogeneous, fissured fracture surface

Fig. 7: Vulcanization defects due to production: Rounded crack transition (same O-ring as in **Fig. 4**)

Fig. 8: Production-related cracks due to a superimposed compound

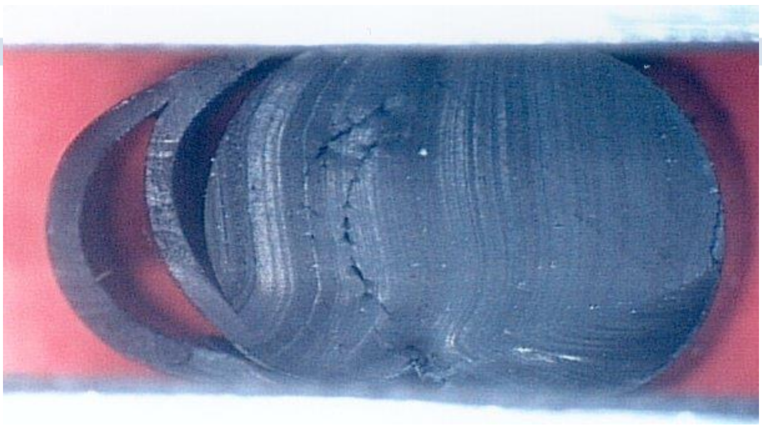


Fig. 9: Cracks or peeling on an O-ring due to faulty vulcanization (cause: superimposed compound)

<u>3.1.2 Damage Pattern "Cracks Due to Impurities"</u>

If foreign particles are detected on a cracked seal in the area of the fracture surface with a microscope, they can be the trigger for the crack (see **Figs. 10 and 11**). Today, the FT-IR microscope and/or the REM-EDX analysis are available for a more in-depth analysis of the foreign material.

The fracture surface clearly shows the area of contamination where insufficient vulcanization has taken place and the area of crack propagation (regular, slightly roughened structure, stress-driven, i.e. usually radial crack propagation).

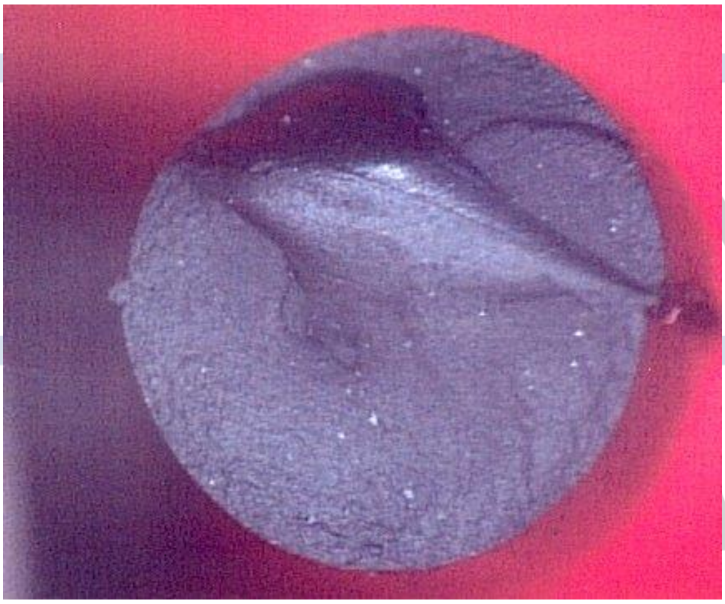


Fig. 10: Manufacturing crack due to foreign material (mold release agent)

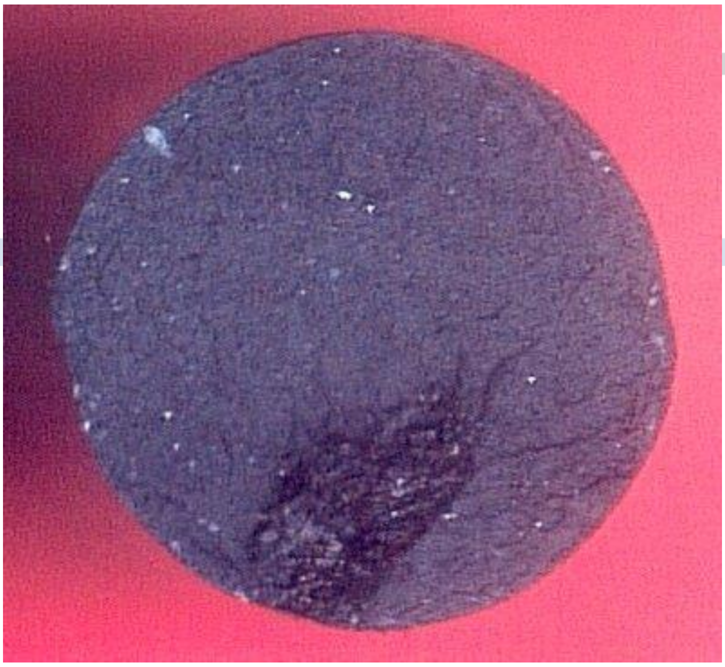
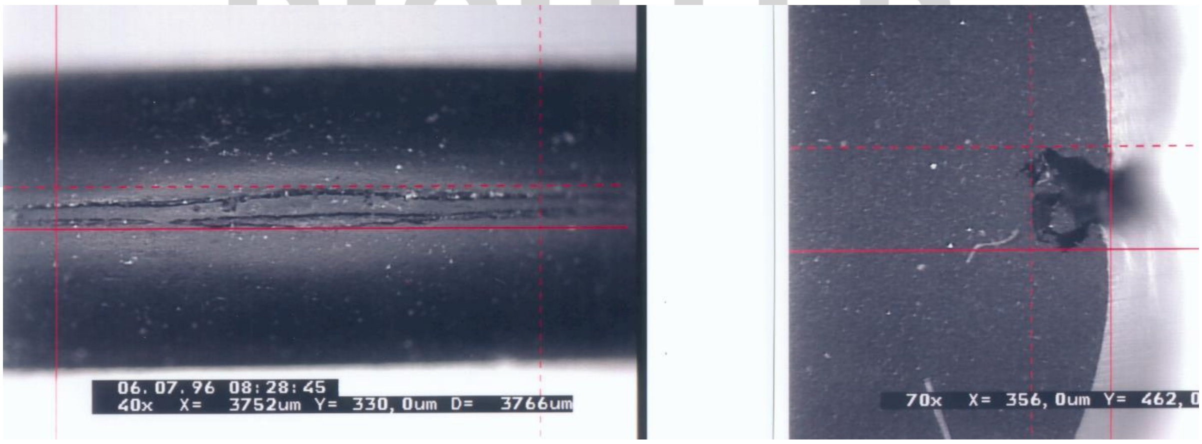


Fig. 11: Crack triggered by foreign material entry

3.1.3 Damage Pattern "Shrinkage Cracks"

This type of crack starts at the parting plane (see **Figs. 12** and **13**). Often in the cross section of an O-ring a circumferential entry point with a wide "U" or "W"-shaped cross section (see **Fig. 14**) can be seen. The draw-in point is a flat, plate-shaped depression, sometimes triangular in section at the parting line at the inner and/or outer diameter. This is caused by damage of the tool edge and/or the high shrinkage factor of rubber.
This type of crack is permitted up to a certain extent in O-rings, see grade characteristics N and S according to ISO 3601-3. The characteristics shown here are inadmissible and can lead to leakages. However, these shrinkage cracks do not lead to a sudden system failure and their effect can be estimated by leakage tests.

Fig. 12: Shrinkage crack on an O-ring



Figs. 13 and 14: Shrinkage cracks at the tool parting plane of an O-ring and on the right in a cross-cut O-ring

3.1.4 Damage Pattern "Demolding Cracks"

These often occur at sharp transitions, edges (see **Fig. 15**) or undercuts (see **Fig. 16**). In addition, an excessively high demolding temperature can favor this.
Since these are violent fractures and cracking and propagation occur at high temperatures, the fracture surface is usually relatively smooth.
Demolding cracks originate from the parting plane or another tool edge and then propagate perpendicular to the demolding load. The dangerous thing about these cracks is that they usually cannot be detected under a stress-free visual inspection. Also, small cracks do not immediately lead to leakage. The leakage only occurs when a crack has propagated to a rupture under the influence of operating temperature and pressure. This can be the case after 100 operating hours or more.

Fig. 15: Demolding crack on a molded gasket

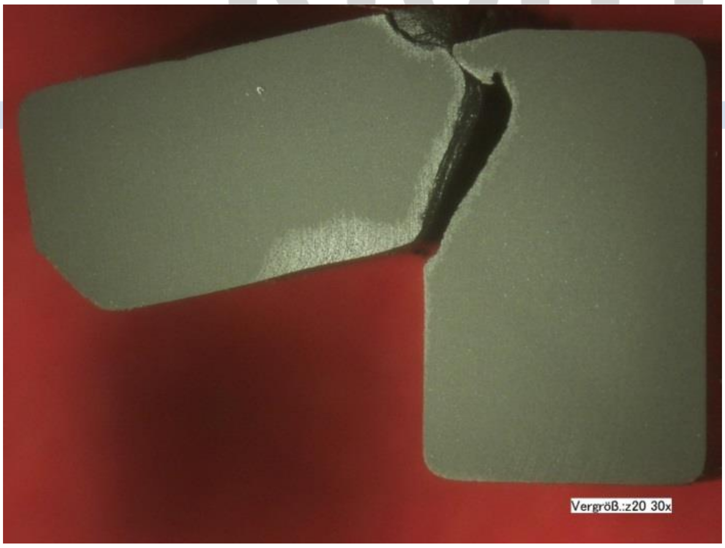


Fig. 16: Demolding crack at a sealing element

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3.1.5 Damage Pattern "Cracks Due to Post-Processing"

This damage pattern shows damage or cracks in the area of the post-processed surface (see **Figs. 17** and **18**). If the machining method and tool are known, the cause of the damage can be determined even more reliably.

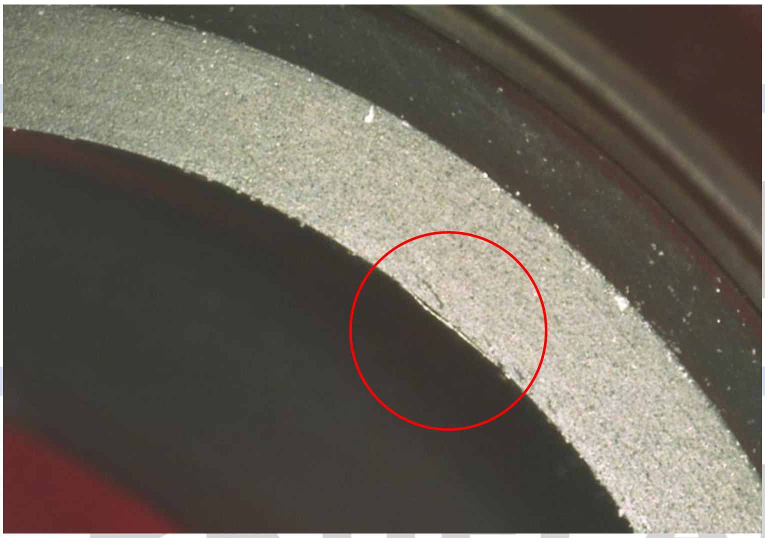

Fig. 17: Cracking caused by the finishing step "cutting off the sealing edge"

Fig. 18: Cracks caused by the post-processing step "post-curing" (local overheating due to defective or incorrectly set tempering furnace)

3.2 Effects of the Damage

The rupture of a seal usually leads to a total failure of the system and must be absolutely avoided.
In the event of small marks or small cracks, the sealing system can still function, but there is a risk that the flexing work typical of O-rings or many other elastomer seals will be enough to propagate the crack due to pressure and temperature stress. As temperatures rise, the elastomer's resistance to crack propagation decreases.

3.3 Differentiation from Similar Types of Damage

Because cracks can be caused by a variety of other causes and because they often lead to a total failure of the gasket, it is very important to make a precise distinction from similar damage patterns.

3.3.1 Distinction from Ozone Cracks

Ozone cracks can only occur in elastomers that have a double bond in the main chain (diene rubbers). This type of rubber can be recognized by the "R" in the abbreviation (e.g. NBR, SBR, etc.). An exception is a fully hydrogenated HNBR, which is relatively well ozone resistant.
In order for ozone cracks to form, the seal must be stretched (see **Fig. 19**). Even small elongations of 5% are sufficient. With increasing elongation, the number of cracks also increases.
Ozone cracks are usually very deep and are always oriented perpendicular to the direction of the stress.
No increased ozone concentration is necessary for the formation of ozone cracks, the ozone present in the ambient air is sufficient to cause this damage.

Fig. 19: Pre-assembled O-ring, which showed ozone cracks after several weeks due to the pre-stressing and ozone from the ambient air.

3.3.2 Differentiation from Fatigue Cracks

Fatigue cracks (see **Fig. 20**) are very similar to ozone cracks. A clear differentiation is usually only possible if the stress that led to the damage is known. If a failed seal is not made of a diene rubber (e.g. FKM), but shows damage similar to ozone cracks, an immediate exclusion of ozone cracks as cause of damage is possible.

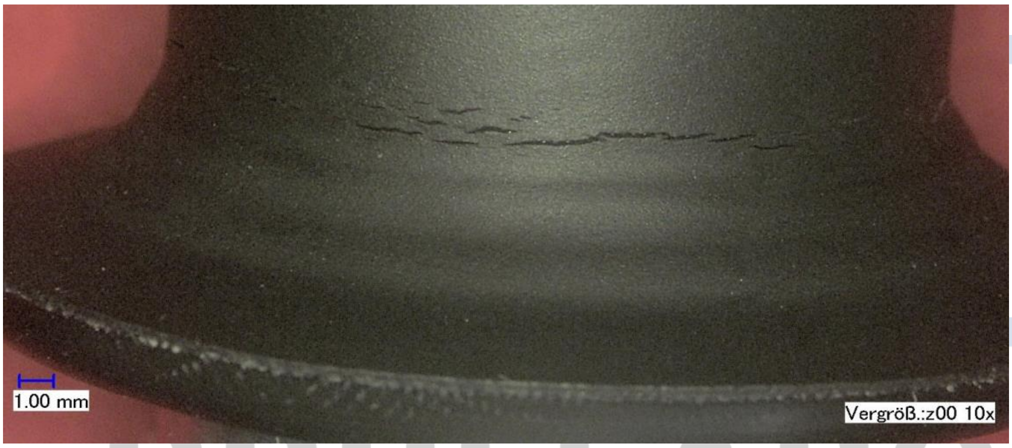

Fig. 20: Fatigue cracks on an FKM membrane

3.3.3 Distinction from Cracks Due to Aging by Heat and Oxygen

"In the event of thermal overloading over long periods of time, the O-ring or seal becomes brittle over the entire cross-section (see **Fig. 21**). When bending, the cracks appear preferably on the air side or on the sealing surfaces where the heat was supplied (see **Fig. 22**).
Short periods of strong overheating lead to deep fine cracks (scaling or embrittlement only at the edges), which only appear when the seals are pulled or bent, without the seal becoming brittle overall. Due to the short period of loading and the insulating effect of the rubber material, the excessively high temperature cannot yet visibly damage the inner areas".[8]
In the literature, these cracks on the running surfaces of radial shaft seals are also described as "hardness cracks".[9]

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[8] translated from RICHTER, B. und BLOBNER, U.: Fachwissen Schadensanalyse von Elastomerbauteilen: Thermische Überbeanspruchung „Überhitzung", 05/2017, Internetpublikation, S. 3 (http://www.o-ring-prueflabor.de/files/fachwissen_schaden_ueberhitzung_05_2017.pdf)
[9] FACHVERBAND FLUIDTECHNIK im VDMA: Dichtsysteme für fluidtechnische Anwendungen – Schadensatlas CD-ROM, März 2005, S.137

Fig. 21: Thermally damaged O-ring, fully hardened, cracks visible on the contact surfaces when bending

Fig. 22: Cracks due to aging due to heat and oxygen under slight elongation can be seen on the contact surface of an O-ring

3.3.4 Distinction from Assembly Cracks or Incorrect Seal Application

Assembly cracks are usually violent fractures with a regular, slightly rough fracture surface. The degree of roughness also depends on the tear resistance of the material (see **Fig. 23**). Fractures caused by manufacturing show inhomogeneous, often relief-like raised areas in the fracture surface. The crack origin in assembly cracks shows a noticeably linear beginning (see **Figs. 24 and 25**), also no rounded transition from the surface to the crack can be seen in the case of damage caused by sharp-edged installation spaces. In the case of slightly rounded edges there is an impression and/or slight plastic deformation.
Assembly-related cracks show typical load-related crack patterns, which can be explained by the installation space and the assembly sequence.

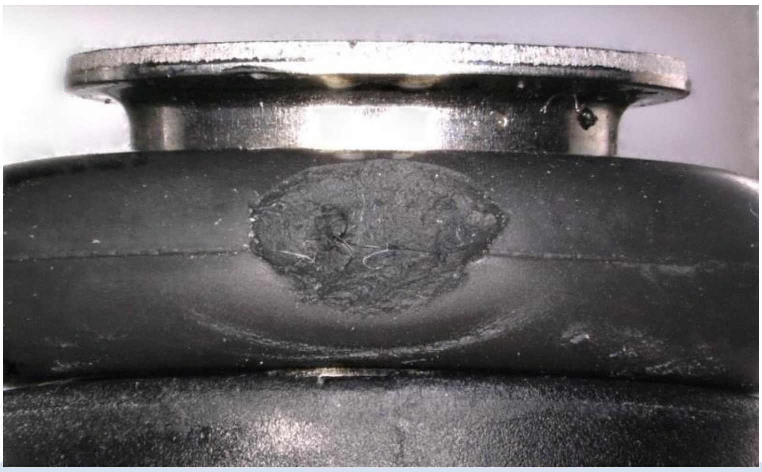

Fig. 23: Chipping out during assembly: The damage occurred at room temperature and resulted in a non-smooth fracture surface; the characteristics of the fracture surface are also strongly dependent on the tear resistance of a material.

Fig. 24: Installation crack due to the impact of a sharp edge in the installation space

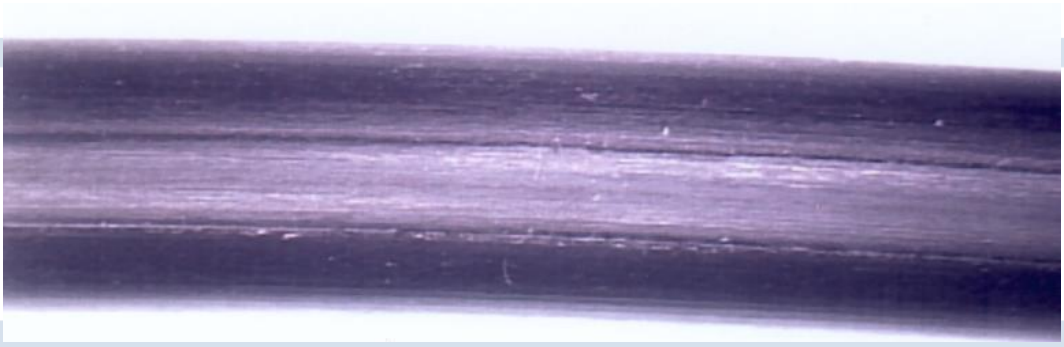

Fig. 25: Crack caused by a sharp edge during installation

3.3.5 Differentiation from Cracks Due to Chemical Degradation

A chemical degradation can cause cracks to appear, but not necessarily. The cracks are visible on the side of the impacting medium and can sometimes only be seen after stretching and under the microscope. If side-effects such as strong setting behavior, sticky surface or hardening occur, the probability of a chemical degradation increases considerably. Chemically induced cracks, however, usually only occur after rather long operating times (>1000 operating hours), with the cracks usually covering larger areas (see **Fig. 26**), whereas in the case of production induced cracks the failure occurs after a short time (usually less than 100 operating hours) and the cracks are only partially found on the surface.

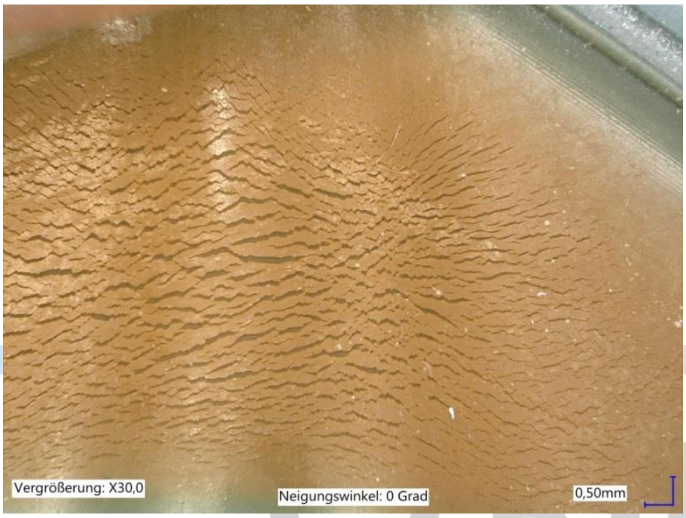

Fig. 26: Chemical degradation of an FVMQ membrane: The cracks cover a larger area.

4. Preventative Measures

The manufacturing process of a rubber part is very complex and therefore requires sufficient competence and care on the part of the manufacturer. This can be seen in the list below. Purchasing a highly stressed gasket is therefore always an act of trust towards the supplier. For this reason, it makes sense for the user to get an idea of the supplier's capabilities first-hand. If the assessment is then positive, appropriate incoming goods inspections should still be defined with regard to shape and surface defects of the seals used.

4.1 Requirements for Crack-Free Production of Seals

4.1.1 Elastomeric Compound

A constant storage temperature throughout the entire supply chain must be ensured for the elastomer compound. This applies in particular to elastomer compounds that are susceptible to scorching.
It is also important that the elastomer compounds used are also suitable for the planned production process. It should be noted that not every compound can be injection molded. Particularly in the case of special manufacturing variants (cold runner injection molding, injection compression molding), the suitability of the respective compound type with regard to viscosity/process ability and demolding properties must be questioned.
Furthermore, it is recommended to use compounds which keep material contamination low in order to reduce the cleaning effort and the risk of crack-inducing contamination.
If the compounds are not produced directly by the seal manufacturer but purchased from an external compounder, it is advisable to run a rheometer curve at the incoming goods inspection or before processing the compound and compare this with the delivery certificate of the compound supplier.

4.1.2 Injection Molding Process

Tooling Design

Wherever possible, sharp-edged areas and undercuts in the component should be removed. In addition, care must be taken to ensure that the venting of the cavities is sufficiently large and correctly positioned. Finally, a process-compatible design of the flow channels and gate areas is important. Particularly in the case of expensive special compounds, seal manufacturers have an interest in designing these areas to be as material-saving as possible. This can result in inadmissible temperature peaks in the material generated by shear forces and increased pressure consumption by the injection molding machine at the expense of process reliability.

Shaping Process

The most important condition for a faultless production of rubber parts is the complete and reliable filling of the individual cavities within the incubation period of the rubber compound to be processed. The shorter the incubation time of the compound used (compounds with a short incubation time are also referred to as "fast" compounds), the more demanding is the determination of the perfect processing parameters. The main parameters to be considered when setting up an injection molding machine in the elastomer sector will be briefly discussed below:

Cylinder Temperature / Screw Speed

These parameters can be used to influence the mass temperature of the rubber compound when it enters the tool. High cylinder temperatures and a high screw speed (corresponds to high shear forces) lead to an increased mass temperature. It should be noted here that a high mass temperature reduces the viscosity of the compound and therefore enhances the injection process, but at the same time increases the risk of unwanted premature vulcanization (both in the cylinder and during the injection process in the tool). A higher mass temperature also reduces cycle times while maintaining the tool temperature.

Tool Temperature

A higher tool temperature shortens the cycle time and thereby reduces manufacturing costs. At the same time, however, a higher tool temperature reduces the time available for filling the cavities. In addition, a high tool temperature can promote the formation of buildup in the tool (mold contamination). Since almost all rubber compounds have a low hot tear resistance, the risk of damage during demolding increases proportionally to the mold temperature. The higher this temperature is selected, the narrower the available process window becomes and the more demanding is the determination of perfect machine parameters. However, a reduction in the tool temperature is only possible within certain limits and is limited by economic (cycle time) and physical (degree of cross-linking) aspects.

Injection Time

The injection time describes the time between the entry of the rubber compound into the mold and the switchover to the following phase (switchover from path-controlled injection to pressure-controlled injection, usually at a filling degree of approx. 99%). It is defined by the selection of a certain injection speed (feed rate of the screw in the injection cylinder) as well as the mold design (flow paths, number of cavities, etc.) and must be shorter than the incubation time of the material to be processed in order to ensure flawless production of the rubber parts. A constant injection time for each shot is an indicator for constant conditions during the injection process and thus also an indicator for consistent component quality. In order to guarantee a constant injection time, the injection molding machine must always have a pressure reserve during the injection process in order to be able to readjust in the event of slight fluctuations in the rubber compound. The viscosity of the rubber compound is always subject to certain fluctuations when it exits the cylinder, caused by fluctuations in the feed of the compound band into the injection cylinder or local fluctuations in the compound due to uneven distribution of the compound components.

4.1.3 Component Design

Production problems can already be reduced or avoided in advance through rubber-compatible component design. For example, edges on the molded gasket, where demolding cracks can occur regularly, should be structurally defused (e.g. by radius, avoidance of undercuts).

4.1.4 Visual Inspection

If no crack-free production can be guaranteed despite all the measures described above, a visual 100% inspection is necessary. In most cases, one standard test machine is sufficient. However, if the cracks can only be detected under stretching, special testing machines are required which slightly stretch[10] or squeeze[11] the seals before visual inspection.

2. Practical Tips (Testing Possibilities / Standard Recommendations)

In general, cracks are not permitted as even slight cracks can lead to a seal failure.
If a crack is discovered in a delivery lot, the entire delivery lot should be inspected. For better detection of cracks in incoming inspection, seals should be slightly stretched manually (10-30%) and inspected under a well-lit magnifying glass with 2-4x magnification. For critical series parts, automated visual inspection under deformation is also possible.

3. Other

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[10] MIHO Inspektionssysteme (http://miho-securo.de/pages/verfahren.html) Webseite abgerufen am 28.09.2017
[11] Patentiertes Verfahren der Firma DOSS (IT): http://www.dossvisualsolution.com/products/visual-inspection-machines/o-ring/squeezer_10.html Webseite abgerufen am 28.09.2017