EXPERT KNOWLEDGE
FAILURE ANALYSIS
OF ELASTOMER COMPONENTS

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O RING PRÜFLABOR RICHTER

TESTING CONSULTING DEVELOPING

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Explosive Decompression and Explosive Overheating – Strong and Sudden Changes in Pressure or Temperature Can Cause Severe Sealing Damage

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1. Classification and Frequency of the Damage Pattern

Of the four main damage mechanisms, installation damage is assigned to the third main group:

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

The third main group can be divided into three subgroups: incorrect installation space, physical overload due to operating conditions and installation errors. This error pattern is due to physical overstrain and is one of the most frequent causes of failure within this group along with gap extrusion and abrasion.

2. Technical Background Knowledge on the Damage Pattern

2.1 Explosive Decompression

Elastomers are more or less permeable, depending on the base elastomer and fillers, meaning gases can infiltrate into the rubber material and diffuse out again. The higher the pressure of a gas, the easier it can permeate into the elastomer. If this pressure is suddenly reduced in the sealing system, the gas that has permeated cannot escape quickly enough. It then creates cracks in the seal core, which propagate to the outside. In other cases, bubbles form on the surface of the seal. These can burst and damage the surface. For a critical permeation to occur, a rubber seal must normally have been under a high gas pressure of more than approx. 30 bar for at least 2 to 4 hours.
In addition to the formulation-related resistance of the material, the extent of the damage depends primarily on the level of pressure drop and the ratio of pressures before and after relaxation. In practical terms, this means this damage pattern is most frequently found on O-rings after emergency shutdowns if uncontrolled expansion to ambient pressure has taken place.
The "explosive decompression" damage pattern has been known for many decades and has often been described in literature. Less well known and hardly to be found in literature, however, is a related crack damage mechanism on seals resulting from vapor bubble formation, namely explosive evaporation or explosive overheating.

2.2 Explosive Overheating or Explosive Evaporation

Explosive overheating occurs when a medium which has permeated into a seal swells and rapidly heats above its boiling point. If this infiltrated fluid suddenly passes from the liquid phase into the vapor phase, small vapor bubbles can form in the O-ring. A sudden transition to the vapor phase can be caused by rapid overheating or a rapid drop in pressure. Here, too, increased temperatures raise the susceptibility to cracking.

3. Damage Pattern

3.1 Description of the Damage Pattern and Problematic Areas

Immediately after the relaxation there are often bubbles on the surface, which usually disappear again. Typical permanent damages are cracks in the core, which partially propagate to the surface, see **Figs. 1 and 2.** The damage pattern of explosive evaporation is not fundamentally different from explosive decompression, see **Figs. 3 and 4**.

Fig. 1: Bubbles on the surface and cracks in the circumferential direction due to explosive decompression

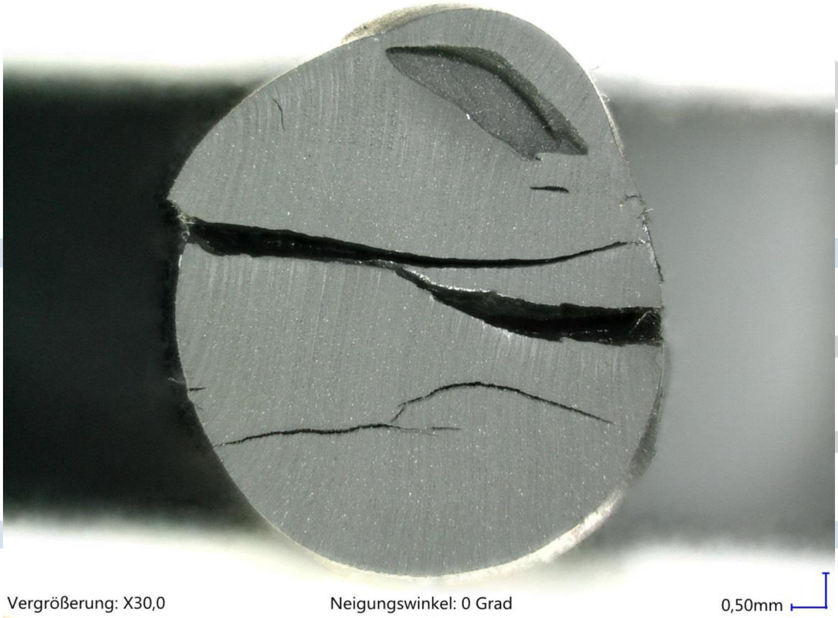

Fig. 2: Cross section cracks due to explosive decompression

In many cases in explosive overheating, cracks are more numerous and smaller. The internal crack formation is typical for the damage mechanism of an explosive superheat.

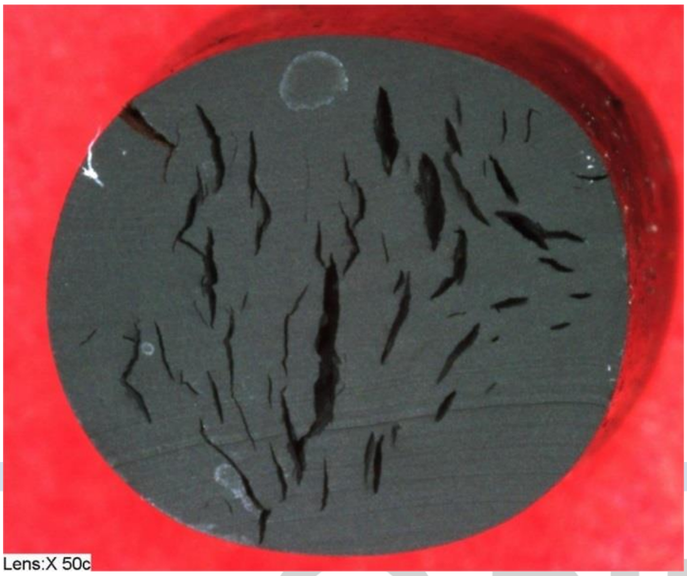

Fig. 3: Explosive overheating: FFKM O-ring in a mechanical seal after 16 bar and 165°C in water: Damage either by multiple overheating during start-up or by temporary dry running

Fig. 4: Internal cracks due to explosive overheating or explosive evaporation

3.2 Effects of the Damage

Typically, this damage leads to the failure of the sealing system and must be avoided in any case.

3.3 Differentiation from Similar Types of Damage

The damage pattern of internal cracks can also be caused by stress cracks due to excessive deformation and the simultaneous action of high temperatures or by manufacturing defects at normal degrees of deformation and typical temperature exposure, see **Fig. 5**.

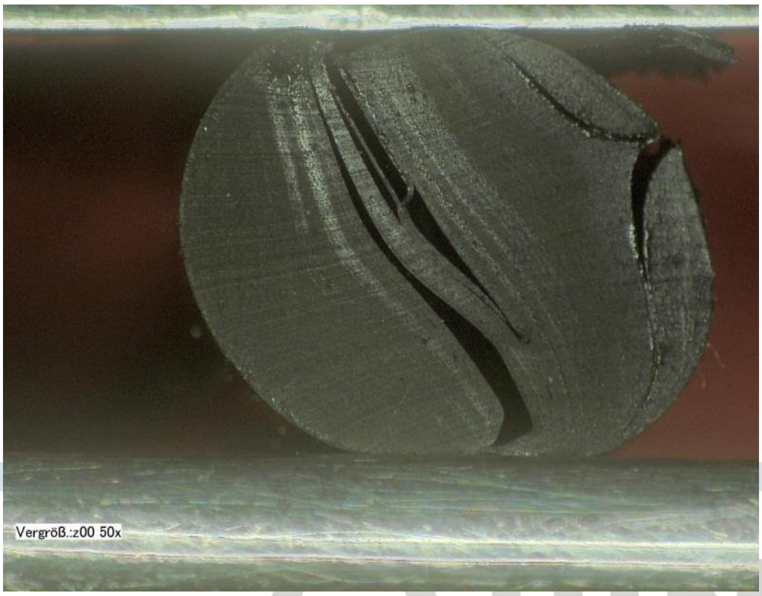

Fig. 5: Cracks due to manufacturing defects and the exposure to normal deformations and temperatures

4. Preventative Measures

If an explosive decompression stress occurs cyclically, the use of elastomers should be avoided altogether as elastomers always have a limited inhomogeneity in the material. This promotes the formation of microcracks, which propagate to cracks. If, however, the number of relief cycles can be limited, the use of special formulations (Norsork M 710 approval) can help. Due to the smaller ratio of free surface to mass, the susceptibility of O-rings increases with increasing cord thickness. Higher temperatures (> 60°C) also increase the risk of cracking, as the load limits of elastomers decrease at higher temperatures

5. Practical Tips (Testing Possibilities / Standard Recommendations)

Special test methods can be used to compare the resistance of different elastomers to explosive decompression.
The Norsork M-710 standard and NACE standards are well known in this field. These tests use the technical abbreviation RGD (= Rapid Gas Decompression) to determine the resistance to explosive decompression. It should be noted, however, that these tests are considered positive even though there are still significant cracks and only a very limited number of pressure cycles are tested.

6. Others

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