EXPERT KNOWLEDGE OF ELASTOMER COMPONENTS

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Better and Cheaper –
Why This Can Still Work with O-Rings

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Introduction

It is certainly no coincidence that billions of O-rings, which are used every year, function without any problems with continuously decreasing purchase prices. However, it should not be overlooked that the damage caused by failed O-rings probably exceeds the total purchasing costs by far. This means that many users have not yet found the most cost-effective way of handling O-rings. At the same time, the boundary conditions for users have improved considerably. A global procurement world and advances in polymer and manufacturing technology have resulted in significantly lower manufacturing costs for O-rings. Advances in technology have also had a positive impact on the performance potential of the materials available, such as media resistance, low-temperature flexibility and long-term performance. In addition, the market is increasingly offering manufacturer-independent expertise in advising on the establishment of effective ordering specifications, employee training and the testing of O-rings and O-ring materials. The author is convinced that the conditions are now in place to further reduce the total costs currently incurred by O-rings and at the same time extend the performance limits of O-rings. Ultimately, the user wants to make full use of the market's range of services in order to find the best approach to the use of O-rings for specific applications and companies. Then the motto "better and cheaper" can also apply to the use of O-rings in the future. Using concrete examples, this lecture will demonstrate where and how this can be achieved through standardization, new material developments and new services.

Better Materials

When talking about better materials for O-rings, this can refer to different properties which help to meet the market requirements for higher temperature resistance or longer service life, better low-temperature flexibility or better chemical resistance. Since the sealing market is a very conservative sales market for new products, it often takes years for new material developments to reach the application. For this reason, a few retrospective examples of material developments have considerably expanded the performance potential of O-rings in recent years and are presented below:

- Many NBR applications have been replaced by HNBR O-rings, which have better high temperature properties and better physical properties, although they often show shortcomings in the low-temperature performance (manufacturers often specify the low-temperature performance too optimistically). Therefore, it is recommended to consistently include the TR10 value of the O-rings in the data sheet, in combination with a compression set at low temperatures, if possible). Generally, HNBR materials with good low-temperature flexibility are also available /1/. There are also publications on HNBR materials with significantly improved high-temperature resistance compared with the previous HNBR types /2/.
- Many bisphenolic cross-linked standard FKM materials have been replaced by special materials with peroxide cross-linking and improved low-temperature flexibility and/or improved chemical resistance. The development of a special low-temperature FKM polymer with a TR10 value of approx. -40°C /3/ is particularly remarkable.
- The supply of the market for FFKM materials with very good chemical resistance has increased significantly, resulting in at least limited price pressure on the market. FFKM materials have therefore partially replaced FEP/PFA-coated O-rings, which are more sensitive to surface defects of the sealing surfaces and O-rings and are more susceptible to assembly errors.
- Also, the availability of special FKM elastomers with sufficient swelling resistance to strongly polar fluids (e.g. acetone, MEK) has increased, which has reduced the susceptibility of FKM O-rings previously used to excessive swelling or chemical corrosion /4/16/.
- In the automotive industry, standard ACM O-rings have been replaced by high temperature ACM or AEM materials with improved high and low temperature limits /5/17/ and partly with improved physical properties, resulting in lower susceptibility to assembly errors.
- In hydraulics, NBR, HNBR or FKM O-rings with 90 ShoreA have been replaced by thermoplastic polyurethane O-rings with 90-95 ShoreA in some high-pressure applications

(P>300 bar) for better extrusion resistance, which has significantly improved reliability against pressure surges.

- It should also be mentioned that when using EPDM O-rings, much greater differentiation is made on the basis of formulations with good long-term behavior /6/ while special emphasis is placed on a good degree of cross-linking the O-rings. As a result, in some cases sulfur-crosslinked EPDM O-rings have been replaced by peroxidically crosslinked EPDM O-rings in hot water applications; in other cases, EPDM formulations containing high levels of plasticizers have been replaced by formulations with little or no plasticizers.

The above examples show in review that the use of new and better materials has certainly increased the material quality of the O-rings on average. However, it should also be noted that only failures, customer complaints and service life problems have led to the replacement of existing O-ring solutions by better ones. In other words, far too often it is a learning process of trial and error. The significance of the O-ring regarding the market success of a product or customer satisfaction is still underestimated due to its low procurement price. Consequently, responsible employees are not sufficiently qualified to recognize the complexity of the influences of formulation properties, process influences during production, groove design and application limits. To be able to act appropriately on future challenges to the O-rings and not only react, the training courses offered should also be taken advantage. Therefore, an essential requirement for the implementation of the state of the art in O-ring technology is better qualification of employees.

Better Qualified

First of all, Charles Goodyear (1800-1860), the inventor of Sulphur vulcanization in natural rubber, should be quoted as saying: "There is no other substance whose properties arouse as much curiosity, surprise and wonder in the human mind as those of elastic rubber" /7/. And at that time there was not any synthetic rubber, no injection molding machines, the number of possible contact mediums was limited, and the topic of environmental protection and occupational safety was not yet an issue. This should point out that attending a seminar on the subject of "elastomer materials" doesn’t turn an O-ring user into a rubber specialist. Rather, attendees of such a training event should be equipped to find their way around the world of rubber without having understood or wanting to understand everything in detail. Instead of admiring the knowledge of the Seminar-Instructor at the end of a seminar one should rather be able to grasp what is technically feasible or technically necessary from the sealing industry, be it with regard to the required formulation properties or in particular to the finished part properties, which in the case of elastomers are particularly strongly dependent on the manufacturing process. Consequently, the seminars offered by the sealing industry or conducted by its instructors are in danger of training admirers, while instructors outside the sealing industry are in danger of not having adequate competence. Therefore, in the long run both kinds of seminars are justified, but the benefit of these seminars should be realistically estimated. Reviewing the past, it can be concluded that there has been a considerable increase in the number of seminars on the subject of elastomer materials, O-rings and other seals as well as damage analysis, which has already led to a far better understanding on this subject for many users. This range of seminars will continue to gain importance in the future, as only competent decision-makers will set the right course for O-rings in the long term, i.e. drawing up supplier-independent order specifications that adequately define the formulation and finished part properties of the O-rings for the application and also sensibly determine the effort required for the respective qualification and conformity certificates. A decision-making person should also be able to realistically assess the performance potential of an O-ring supplier and recognize whether the supplier has the potential to ensure consistent quality. If the supplier performs well, the purchasing department can use the forces of the free market without compromising the quality of the O-rings, which ensures realistic market prices. Attending appropriate specialist seminars should help to build up the necessary expertise in the field of O-rings. The O-Ring Prüflabor Richter has been offering manufacturer-independent specialist seminars as open events or company-specific in-house seminars for more than 15 years with an increasing response /8/, which in 2012 is expected to be more than 50 events, each with 10 to 20 participants. This shows that many companies already increasingly value a good qualification of their employees in terms of O-rings and seals. The increasing availability of seminar courses from various suppliers /9/10/18/19/ in this field suggests that this also applies to other training providers. A good qualification of the employees is therefore seen as an important prerequisite for mastering future challenges of the market.

Better Specialized

The essential prerequisite for a good O-ring specification is not only defined in important formulation properties, but also in the degree of vulcanization of the O-rings. This means that the supplier must also guarantee certain properties on O-rings itself and not only on standard specimens. Many companies have already reacted to this request and defined their own specifications. Particularly worth mentioning here is a draft on a material standard for O-rings, ready to be passed (ISO/TC 131/SC 7/WG 3 -ISO 3601-5, Obfrau Frau Frick, Trelleborg Sealing Solution), which defines important formulation properties as well as O-ring properties (hardness and compression set) for all essential material families. If this draft is approved, it will be possible for the first time in the history of the O-ring to actually speak of a standard component, which, if implemented consistently, will lead to considerably greater safety for users. Cheap suppliers of O-rings that produce very poor qualities can thereby be obstructed in their access to users.

Better Test Methods

Due to the more widespread use of analytical test methods (e.g. FTIR spectroscopy, thermogravimetry, differential scanning calorimetry), different formulation and finished part properties can be determined more reliably. The frequent and increased use of other physical test methods can help identify application limits in low-temperature (TR10 test ISO 2921/ASTM D 1329) or long-term behavior (compressive stress relaxation ISO 3384-1). The increased use of these tests, requiring rather extensive equipment technology, provides users with reliable characteristic values for making important decisions when qualifying new formulations or replacing established ones. This reduces the risk of wrong decisions and the costs of unnecessary tests.

Better Tested

Continuously increasing demands on QA systems have also established themselves in materials testing and are reflected in DIN EN ISO 17025. Consistent implementation of these requirements minimizes the risk of incorrect test procedures which leads to more reliable results. An accredited laboratory for this purpose is inspected regularly (at least every 18 months) by various auditors in order to ensure both, the conformity of the established QA system and the professional competence of the testing laboratory. Results from accredited laboratories are also validated in front of the courts, which shows that these results are rated higher than results from non-accredited laboratories. Accredited testing laboratories therefore offer not only a high standard of quality but also more legal security. At the same time, the testing equipment required for the tests can be better utilized, which of course results in lower costs. It is therefore not surprising that accredited testing laboratories are increasingly being involved in the qualification of new materials or O-rings. This trend will most likely even intensify in the future, as a professional testing laboratory can support its customers not only with more reliable test results at lower prices, but also as a know-how carrier. The O-Ring Prüflabor Richter is also increasingly used as an independent testing laboratory for incoming goods testing of O-rings and other seals, such as compression set tests.

Better Monitored

The difficult processing of elastomeric materials makes error-free O-ring production (almost) unaffordable. Therefore, a sorting or controlling department is an important part of an O-ring production facility unless this service is outsourced. What ultimately counts as an impermissible surface deviation is regulated in ISO 3601 Part 3. For about 15 years, control machines have been increasingly used to sort out defective O-rings /11/12/13/14/. These are available from different manufacturers, from the simple one-sided, to the all-round visual inspection, in either a relaxed or stretched state, whereby even tears can be detected. The enormous advantage of an automatic visual inspection is the low slip rate of faulty O-rings compared to a manual inspection. The use of these machines usually results in additional costs, but also in greater safety and therefore lower failure costs.

Better Assembled

In particular, the use of plasma cleaning processes has made it possible to bond rubber surfaces with bonded coatings or even apply a coating directly in the plasma. The purpose of this lubricating intensification of the surface of O-rings is primarily to reduce the assembly force in order to prevent assembly damage without having to use grease or oil. This prevents surfaces from being contaminated with these lubricating aids and, in addition, greases in particular can prevent a gas transfer at a cut-in or damaged O-ring during the final leak test, and therefore significantly reduce the efficiency of leak tests. The additional costs of the coating could therefore be recouped within a short time by a reduction in reclamations.

Better Indeed - But Also Cheaper?

Some trends have been highlighted, indicating that O-rings can become even better in the future, which means that the market has the potential to meet also the users' future requirements. However, the question remains as to whether this is possible at a lower price. Over all it can be emphasized as generally known, that quality costs money, and this is of course also the case with O-rings. It is however obvious that the total costs that O-rings generate only result to a small extent from procurement. Considering the total costs of O-rings, all costs generated by O-rings have to be considered (qualification tests, procurement costs, test costs, assembly costs, storage costs, complaint costs). Non-quantifiable costs are cancelled orders due to dissatisfied customers. O-rings become therefore in the total account "cheaper" if the total bundle of costs mentioned decreases. This of course doesn't exclude a reduction of the procurement costs, see below, and/or if new market shares are won by better O-ring solutions. Under this aspect it can be said, better = cheaper, until one has reached the point that users do not even notice the sealing element O-ring because there are simply no problems with it. This means that the lifetime of products is not limited by O-rings as long as these products are used in their intended applications or operating conditions.

What Makes O-Rings Cheaper in the Overall Balance?

First, a look at the procurement costs should be taken here. The introduction of injection molding for O-rings by means of Italian development support has made it possible to dramatically reduce the manufacturing costs of O-rings. The beginnings in the 1980s were troublesome because the rubber industry was not yet ready, but in the meantime, injection molding has become the standard production technology for large-volume orders for O-rings, which does not have to be a limitation from an application technology point of view. However, there is an even greater temptation for manufacturers to reduce manufacturing costs at the expense of quality by reducing cycle times. For O-rings, this means money can only realistically be saved if they are adequately specified, especially with regard to formulation properties, degree of vulcanization and surface quality. If this is the case, there are no concerns about procuring O-rings globally. This often means turning back the wheel of manufacturing technology by 20 to 30 years and having O-rings manufactured again by the compression process in low-wage countries. However, the cost assessment must take into account the fact that it is often a laborious process to bring an O-ring supplier with little know-how and market experience to an appropriate state-of-the-art. In the long run, however, this can lead to significant cost savings. Almost all O-ring manufacturers produce or outsource production to low-wage countries. If the technological possibilities with regard to specification, qualification and series testing of O-rings are used, see above, there is certainly still considerable potential for savings. However, the technological lead in O-ring production in Germany, Italy, France and other industrialized countries should not be underestimated in the cost balance. The significantly higher quality standard in production will certainly lead in the long term to significantly lower quality costs for customers through complaints processing and production downtimes. In order to make right decisions in this regard, a certain competence concerning O-rings is indispensable. This means that well qualified employees in purchasing and quality assurance should be able to differentiate sufficiently here. Sufficient qualification of design and development personnel can lead to better, less susceptible constructive O-ring designs /15/ and help to ensure that O-rings are adequately specified. This will eventually have a positive effect on the cost balance, too, see **Figure 1**. The first four causes of failure mentioned there cause nearly 50% of the failures and could have been avoided with appropriate qualifications.

Conclusion

This presentation demonstrates how the market supply of O-rings and helpful services has changed in recent years. The challenges of the future are to exploit this potential, which means to turn it into good or better O-ring solutions. And better O-ring solutions will in most cases also lead to cost savings. Better and cheaper solutions will also be possible for O-rings in many cases.

Ranking List of the Failure Causes for O-Rings

1. **Defects in the design of the groove (114 x = 20.1%)**
2. **Assembly error (54 x = 9.5%)**
3. **Ozone damage caused by pre-assembled NBR O-rings (50 x = 8.8%)**
4. **Wrong choice of material or formulation (50 x = 8.8%)**
5. **Chemical corrosion (47 x = 8.3%)**
6. **Temporary overheating (40 x = 7.1%)**
7. **Flow defects/ cracks (36 x = 6.4%)**
8. **Swelling/ shrinkage (32 x = 5.6%)**
9. **Abrasion (31 x = 5.5%)**
10. **Explosive decompression/ explosive overheating (23 x = 4.1%)**

Figure 1: The most frequent failure causes of O-rings

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