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OF ELASTOMER COMPONENTS

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Tensile Test on O-Rings

Why and how?

Many users of O-rings think that the material characteristics determined during initial sampling on test plates also apply to the individual seals. Unfortunately, this is not the case in most cases. For a variety of reasons, real gaskets have worse characteristic values than those determined under ideal laboratory conditions on test plates. To ensure that this factor does not lead to seal failures in practice, testing the actual mechanical properties of ring-shaped seals is a good way of ensuring and confronting material reality.

1. Importance and Purpose of Tensile Testing on Rings

The tensile test on rings and especially on O-rings is primarily carried out for ***quality assurance*** reasons. The tensile test provides information about the formulation quality (evaluation of the absolute values, strength of the material, determination of formulation changes). For example, it is not possible to detect an exchange of the polymer of compounds with different molecular weights and/or a different molecular weight distribution (e.g. high-viscosity press mix by low-viscosity spray mix) by infrared spectroscopy (IR), but only by tensile testing and possibly by long-term compression set tests. Furthermore, the tensile test provides information on subsequent changes compared to the prototype condition. This is often the

simplest way of detecting possible changes to the initial sample condition in the event of complaints.
In addition, the standard deviation (e.g. premature tearing due to joining lines, tears, notches, degree of cross-linking[1], etc.) provides information on the processing quality.
Due to these diverse results, a tensile test on O-rings or finished parts ensures the quality much better than if only the recipe quality on dumbbell bars is determined.

Moreover, the tensile test on rings also secures ***practical applications***. This can be particularly helpful in the case of components subjected to particularly high physical stress, e.g. by assembly expansion (>100%), abrasion or gap extrusion.

2. Influences on the Test Result

Knowledge of the causes why real seals have different test results than standard specimens is very helpful for a safe and lasting seal application. When designing and ordering a gasket, sensible limit values for the actual sealing rings can be agreed with the manufacturer at an early stage and weak points in the vulcanization or manufacturing process can therefore be identified and not only afterwards as a result of damage.
The following points only deal with special features in the tensile testing of rings, other causes of influence on the general tensile test of elastomers (e.g. test temperature, compound composition, Mullin effect)[2] are not dealt with here.

2.1 The Influence of Processing

In the case of some O-rings, due to poor processing, it is not the strength value of the material that is determined, but the lower strength of the joining line (= confluence point of the rubber compound in the production of the O-ring in the injection mold) at which the O-ring tears. This problem depends on the material (e.g. certain acrylate rubbers), the tool and the process parameters. The joining line can usually be detected in advance by a visual and strain test or by relatively large scatter in a tensile test. Typical for the scatter in tensile tests of O-rings are 5-10%-points standard deviation related to the mean value of the elongation at break or the tensile strength.
An important characteristic of good processing is the achievement of the optimum degree of vulcanization. However, there is no generally valid optimum, but this must be determined depending on the intended application of the elastomer component. If, for example, the tear resistance is the most important material parameter for the finished product, a different degree of crosslinking or a different crosslinking density must be aimed for than if, for example, a low

[1] Der optimale Vernetzungsgrad ist sehr gut durch die Zugfestigkeit zu bestimmen. Siehe hierzu Abb.1 dieses Fachartikels!
[2] Weiterführende Informationen können im Kap. 5.2 folgender Publikation nachgeschlagen werden: BLOBNER, U. und RICHTER, B.: Fachwissen Prüfverfahren für Elastomere: Zugversuch: Prüftechnische Grundlagen und Empfehlungen für die praktische Anwendung, Ausgabe 10/2014, Onlinepublikation: https://www.o-ring-prueflabor.de/files/fachwissen-zugversuch_10_2014.pdf

compression set were the most important component property. This can be seen in the following diagram **(Fig. 1)**:

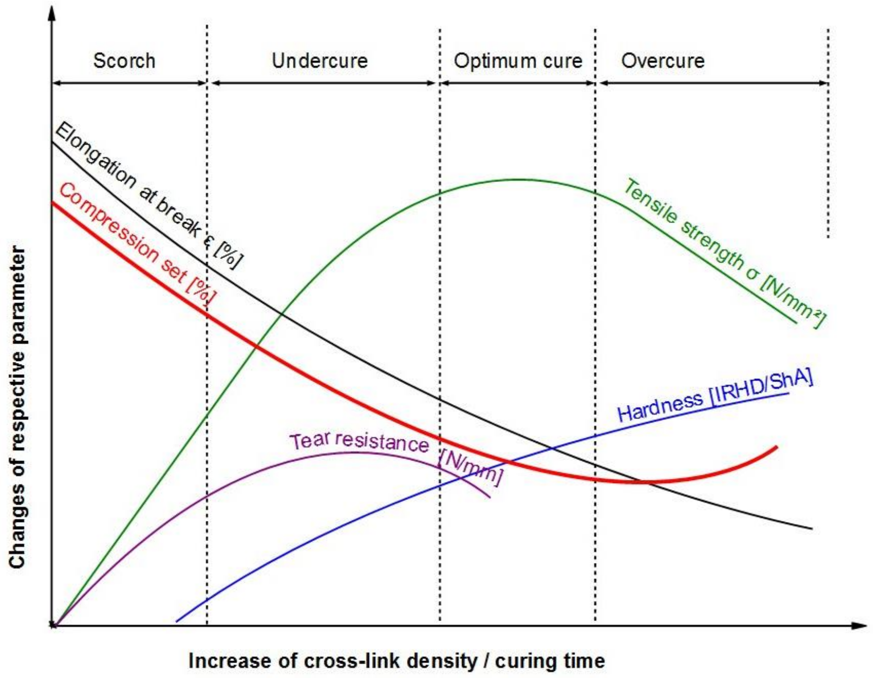

Fig. 1: There is no ideal degree of cross-linking: Depending on the application, the optimum cross-linking density must be defined by the optimum of tear resistance, tensile strength or compression set.

2.2 Influence of the Cord Thickness

Interestingly, the different cord thicknesses of O-rings mainly have an influence on the strength values (tear or tensile strength), hardly on the elongation at break, and virtually none on low stress values[3]. This can also be seen in **Fig. 2** below.
NAGDI describes the influence of specimen geometry on tensile strength as follows and gives indications of the causes for this behavior: "In general, the rule applies: the larger the initial cross-section or the larger the volume of the specimen, the lower the tensile strength. This dependence 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". [4] Even in the most carefully produced elastomer compounds, there will be such "flaws" or inhomogeneities. "The sum of all such inhomogeneities, such as defects in the regular structure, foreign inclusions, filler agglomerates, vacuoles, cracks, is called the microstructure of the substance. Each inhomogeneity causes a strong local stress concentration in its immediate environment during deformation processes. The "most dangerous" inhomogeneity then becomes the starting point of the fracture."[5] This explains why the real strength of elastomer compounds is often two to three orders of magnitude below the molecular strength.[6]

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[3] vgl. ECKER, R.: Mechanische-technologische Prüfung von Kautschuk und Gummi in: BOSTRÖM, S (Hrsg.).: Kaut-schuk-Handbuch , Band 5, Stuttgart, Verlag Berliner Union, 1962, S. 119
[4] NAGDI, Khairi: Gummi-Werkstoffe Ein Ratgeber für Anwender, Ratingen, ²2002, S. 290
[5] vgl. ECKER, R.: Mechanische-technologische Prüfung von Kautschuk und Gummi in: BOSTRÖM, S (Hrsg.).: Kaut-schuk-Handbuch , Band 5, Stuttgart, Verlag Berliner Union, 1962, S. 120
[6] Ebd., S. 119

REECE[7] gives a very compelling example of this: when testing tensile test rods, it was found that smaller shoulder rods had higher tensile strengths than larger shoulder rods, but the dispersion of the results also increased considerably. If one assumes that the fracture origin - as described above - begins at flaws, it is logical that a small shoulder bar has fewer flaws than a larger one or no critical flaws. He now developed the thought experiment that one should think of two small test rods put together. Assuming that two small test specimens tear under different loads, a larger dumbbell rod composed of both small test specimen tears at the lower load. The higher and better load value is thereby eliminated, which also reduces the dispersion of the results. In addition to this phenomenon described above, there is a second influencing factor which Iman NAZENI[8] presented at a lecture conference of the German Rubber Society in 1960 in Berlin using the example of test rods. Thinner test rods had higher strengths than thicker test rods. He explained this with a better compaction of the compound during the production of thin test specimens. Similarly, it can be assumed that with thin-walled elastomer components or O-rings with a smaller cord thickness, pressure transmission in the manufacturing process is better than with O-rings with a larger cord thickness or with thick-walled components. This results in fewer flaws and the material is less susceptible to tear initiation or propagation due to better compaction.
In practice, the conclusion was confirmed that large-volume test specimens have lower tensile strengths in tensile tests on O-rings from the same formulation: O-rings with a small cord thickness (e.g. 1.78 mm) have significantly better values than O-rings with a large cord thickness (e.g. 6.99 mm) (see **Fig. 2**).

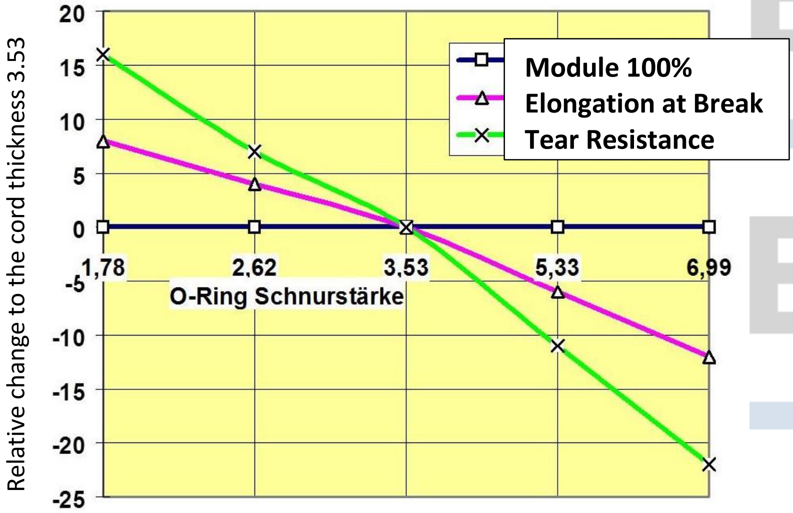

Fig. 2: Relative change of the stress value σ100%, of the elongation at break and tensile strength as a function of the cord thickness of O-rings [9]

With these findings it is now possible to understand and explain the observation described at the beginning of this section that cord thickness mainly influences strength values, but not

[7] REECE, W.H.: The Strength of Vulcanised Rubber in: Transactions of the I.R.I (Institution of the Rubber Industry), 11, 1935, S.320f.
[8] NAZENI, Iman: Einfluss der Dicke der Prüfvulkanisate auf die Messwerte der Zerreißfestigkeit beim Standard-Prüfverfahren nach ASTM, vorgestellt auf der Vortragstagung der Deutschen Kautschuk-Gesellschaft, Berlin, 1960 (Übersetzung: SCHOON, Th. G.F.)
[9] Die Daten zur Erstellung des Diagramms wurden entnommen von: Parker Hannifin, O-Ring Division: Effect of O-Ring Cross-Section and Rate of Pull on Physical Properties in: Technical Bulletin, ORT-021, 11/30/92

tension values. The strength values indirectly give a statement about the frequency of defects which can lead to a rupture, while the low stress values are only material characteristics where possible previous damage (micro ruptures etc.) has no influence.

2.3 Influence of the Pin Diameter

Particularly with smaller O-ring diameters, it is technically no longer possible to apply these to lubricated and ball bearing or driven rollers before the tensile test. The sealing ring is then placed on lubricated half-shells (**Fig. 3**) or rigid pins (**Fig. 9**). There are even - as already described above - standards[10] which generally require testing on fixed mandrels, even for larger O-rings (see **Table 1**).
In an internal investigation, the O-Ring Prüflabor Richter was able to prove that in this case the influence of the pin diameter had no effect on the results. As the comparison of the median values showed, the differences determined were in the range of random scattering.

Test Specimen O-Ring	EPDM (18,77 mm x 1,74 mm)		
Pin Diameter [mm]	**2**	**3**	**5**
Tear Strength [N/mm]	15.29	14.81	14.44
	16.22	15.43	14.87
	15.57	15.58	16.15
	15.28	15.16	15.76
	15.61	14.74	16.00
Mean Value [N/mm]	15.59	15.14	15.44
Median Value [N/mm]	**15.57**	**15.16**	**15.76**

Tab. 1: Investigation of the influence of different pin diameters on the tensile strength of an EPDM O-ring (70ShA) at a test speed of 500mm/min.

2.4 Influence of Test Speed (100, 200 und 500 mm/min)

Depending on the test standard, test speeds of 100, 200 or 500 mm/min are required. A rule of thumb in most cases is that for smaller O-rings a lower test speed is also required.
In the experience of the O-Ring Prüflabor Richter, however, different test speeds had little or no influence on the results as long as they were within the above-mentioned range (see **Tab.2**). The following table shows an example of this for an EPDM material:

Test Specimen O-Ring	EPDM (18.77 mm x 1.74 mm)	
Test Speed [mm]	**200**	**500**
Tear Strength [N/mm]	15.17	14.44
	14.99	14.87
	15.78	16.15
	15.90	15.76
	15.77	16.00
Mean Value [N/mm]	15.52	15.44

[10] Volkswagen AG: Konzernnorm PV3973 (Ausgabe 2010-11): Elastomer-Runddichtringe Bestimmung von Zugfestig-keit, Reißdehnung und Spannungswerten im Zugversuch, Unterpunkt 4.1.4, S.2f.

Median Value [N/mm]	**15.77**	**15.76**

Tab. 2: Investigation of the influence of different test speeds on the tensile strength of an EPDM O-ring (70ShA) with a pin diameter of 5mm

2.5 Influence of lubrication or slip intensification of rings or mounting pins/rolls before tensile test

Most test standards require either driven rollers or lubrication of the ring and mounting pins in the tensile test.
It is undeniable that lubricating the ring or mounting pins produces more reproducible test results and higher strength and elongation values.
Table 3 below is the result of testing 100 O-rings in the O-Ring Prüflabor Richter with an inner diameter of 6 mm and a cord thickness of 2 mm. The O-rings were placed on 3mm pins and pulled at a speed of 200mm/min. They were made out of FKM material with a hardness of 80 ShA. This diagram clearly demonstrates the influence of a lubricant.
The standard deviations (in % of the mean value) have been reduced from the dry state from **11** or **12%** to **6** or **5%**, the mean values of the tensile strengths have even increased from **10.1** to **12.9 MPa,** and the elongation at break from **120** to **156%**. These results show that the influence of using a lubricant in the tensile test must be evaluated more highly than the other parameters (strain rate/pin diameter). A silicone oil is recommended as lubricant

Test Specimen	**Tensile Strength [N/mm²]**				**Tear Strength [%]**			
	$\bar{x}$	**x_{max}**	**x_{min}**	**$\sigma_{\bar{x}}$ [%]**	**$\bar{x}$**	**x_{max}**	**x_{min}**	**$\sigma_{\bar{x}}$ [%]**
O-Ring 6x2mm dry	**10.1**	13.2	7.8	**11.8**	**120**	153	91	**11.1**
O-Ring 6x2mm lubricated	**12.9**	15	9.5	**6.1**	**156**	171	117	**4.6**

Tab. 3: Internal comparison of tensile strength and elongation at break on lubricated and dry FKM O-rings (80 ShA), test speed 200mm/min

3. Size of the O-Rings

Although the sizes of O-rings are standardized, there are innumerable deviations from them. This is probably the most popular form of sealing technology and is used both in miniature applications from cord thicknesses of approx. 0.8 mm and less and in large machines and fittings up to cord thicknesses of 20 mm. From a cord thickness of approx. 10 mm, suitable strips for the production of dumbbell bars (e.g. type 3 or S3A according to DIN 53504: March 2017) can be obtained from the O-ring cords by splitting machines. These can then be used again for testing on standard specimens.
The tensile strength test on whole O-rings refers in practice to O-rings with smaller cord thicknesses (< 10 mm), most frequently on O-rings with an inner diameter of less than 30 mm and cord thicknesses < 5 mm.

ASTM D1414 and DIN 53504 provide guidance for the testing of O-rings. Using the prescribed rollers as holders for the O-rings and their minimum spacing, it is possible to calculate which diameter can still be tested in accordance with the standards:

The ASTM D1414[11] allows, as the smallest standardized roll, those with a diameter of 9 mm, whose centers should be moved together up to a distance of 19 mm. The rollers should be mounted on ball bearings. This results in a minimum inner diameter of the O-rings, which can still be tested according to standards, of

$$\mathbf{d_{i\,min}} = 2 \times 19 \text{ mm} + \pi \times 9 \text{ mm} = 66.3 \text{ mm} / \pi = \mathbf{21.1\ mm}$$

This means that O-rings from approx. 21 mm inner diameter can be tested with this roller arrangement. The prerequisite, however, is that the ring can be placed on the rollers without stretching.[12] A roller should either be driven at a certain speed or the contact surfaces of the two rollers should be lubricated with an oil ("castor oil").
For O-rings with a diameter smaller than 25 mm, the ASTM allows smaller pin diameters without drive (subitem 8.1). The ASTM does not provide a minimum dimension.
DIN 53504[13] refers to the German Association of the Automotive Industry (VDA) and lists 3 minimum dimensions in **Table 3**. The smallest O-ring specified there has an inner diameter of 34.8 mm.
As explained above, there are no exact standard specifications for testing small O-rings. Special test fixtures are required, as shown in **Figures 3 to 5** below.
The usual accuracy of the length change measurement is one tenth of a mm or better. Therefore, the accuracy decreases for very small O-rings, since potential measurement errors have a greater percentage impact on the final result. The testing of very small O-rings (di < 3 mm) is possible, but requires a lot of testing experience and special care in the execution in order to achieve reproducible results. The O-Ring Prüflabor Richter uses either half shells (**Fig. 3**) which allow the test pins to be brought closer together, or special needles for micro O-rings (**Figs. 4 and 5**).

Fig. 3: Half shells for reproducible testing of small O-ring diameters: Custom-made design of the O-Ring Prüflabor Richter

[11] ASTM – International: Designation: D1414 – 15(July 1, 2015): Standard Test Methods for Rubber O-Rings, S.2
[12] Ebd., S.2
[13] DIN 53504: Prüfung von Kautschuk und Elastomeren – Bestimmung von Reißfestigkeit, Zugfestigkeit, Reißdehnung und Spannungswerten im Zugversuch, Ausgabe: März 2017

Fig. 4: Micro - O-ring in size comparison with a finger

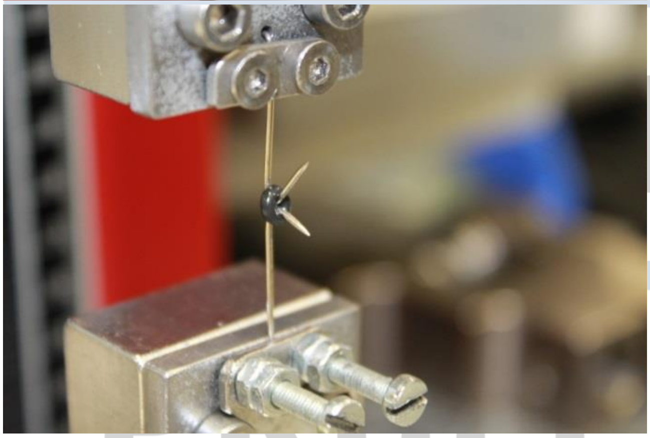

Figure 5: Tensile test of a micro O-ring with special needles as specimen holder

With very large O-rings (di > 200 mm), the problem arises that the travel of the tensile testing machine may not be enough. ASTM D1414 (subitem 8.2.1) allows sections of the O-ring to be tested in such a case. Similarly, sections of O-rings may be tested if the O-ring has been cut open for an ageing test. The unaged reference piece shall then be cut out of an O-ring in the same way.
However, the test result may only be used for evaluation if the section of the O-ring has not been torn at its clamping point. (Subsection 8.3.2)

The very practical Volkswagen test specification 3973 does not prescribe minimum or maximum sizes, but there are test mandrels matched to the inner diameter. This is shown in the following table:

O-Ring Inner Diameter [mm]	Test Mandrel Diameter [mm]
< 8	3
8 to 20	5
20 to 40	6
> 40	18

Table 4: Required test mandrel diameter of the VW PV 3973 [14]

[14] Volkswagen AG: Konzernnorm PV3973 (Ausgabe 2010-11): Elastomer-Runddichtringe Bestimmung von Zugfestig-keit, Reißdehnung und Spannungswerten im Zugversuch, S.3

4. Holding Devices and Clamping Methods for O-Rings and Standard Rectangular Rings

As mentioned above, O-rings are tested on rollers according to standard. These rollers should be ball bearing according to ASTM D1414 ("ball-bearing spools", subitem 8.1).
In order to avoid local stress peaks in the O-ring during the test procedure, which would significantly influence the test result, one of the rollers should be driven **(Fig. 6 and 7)**.

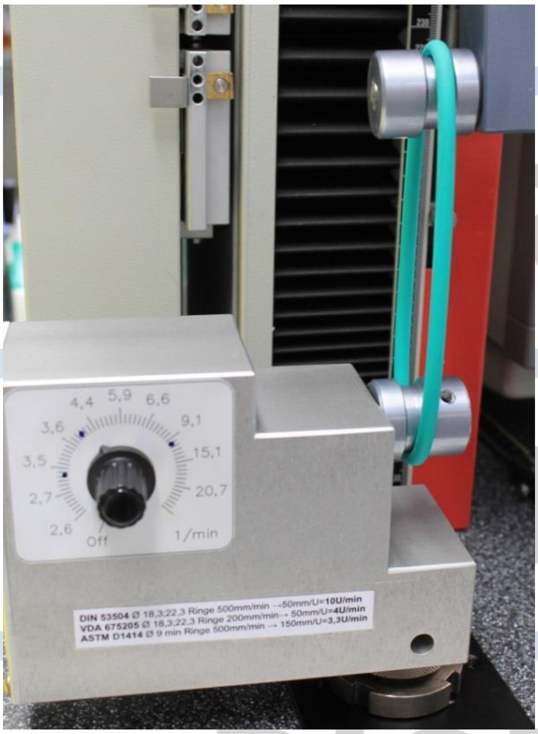

Fig. 6: Tensile test with driven roller: The drive unit can be seen at the bottom left of the picture. The rotation speed of the roller is variably adjustable, depending on the requirements of the corresponding standard.

Fig. 7: Tensile test of a small dark green O-ring with a driven roller and a smaller diameter.

However, it is also possible to use rollers without drive (**Fig. 8**) and instead lubricate the contact surface of the metal rollers (with castor oil) to ensure that the O-ring slides off during the tensile test. (Avoidance of notch effect, constriction in the contact area of the mandrel).
VW test specification 3973 (2010-11 edition) permits the testing of O-rings on mandrels (**Fig. 9**) and also prescribes the use of a lubricant (silicone oil).

Since the VW test specification mentioned describes a precise test procedure for tensile testing on O-rings, it is recommended that it be used preferably as a standard for tensile testing on O-rings. The content of this PV largely corresponds to current practice in the O-Ring Prüflabor Richter, which has been carrying out O-ring tensile tests regularly since 2000.

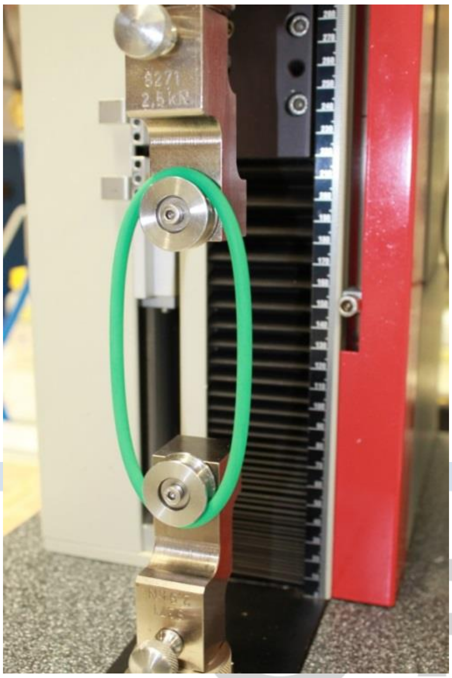

Fig. 8: Tensile test of an O-ring on ball bearing rollers (here not driven)

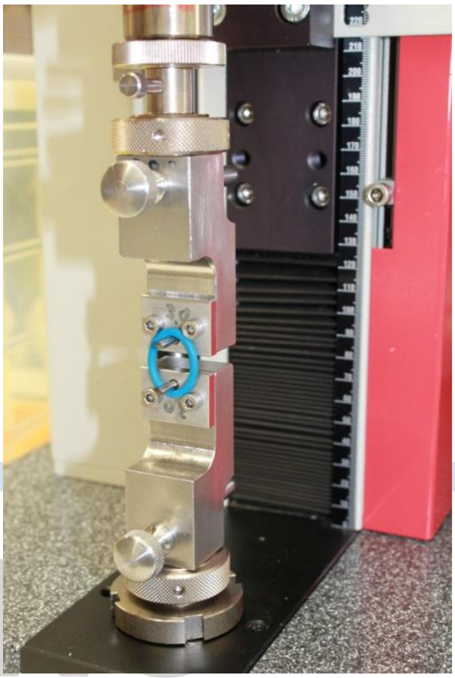

Fig. 9: Tensile test of a small O-ring: If the use of ball bearing rollers is no longer possible, oiled fixed mandrels are used in practice.

The ASTM D1414 also allows samples to be taken from cut O-rings. The danger exists that the specimen will tear at the clamping point. This is where the highest notch effect occurs and sometimes the seal is damaged, which can then form the crack initiation.
If the cut O-ring is correspondingly long, we recommend deflection specimen holders[15], in which the specimen is deflected on a curve shortly before the clamping area so that the force affecting the clamping point is reduced. This prevents tearing at the clamping point.
However, the O-Ring Prüflabor Richter has developed a simpler and practice-oriented local pretreatment method for the specimen (reinforcement in the clamping area), which in most cases already prevents tearing at the clamping point.

5. Test Speeds

ASTM 1414 (subitem 8.3.1)[16] requires a test speed of 500mm/min.
The Volkswagen PV 3973 standard (2010-11 edition) specifies a uniform test speed of 200mm/min for all O-ring sizes.[17]

[15] Example of a deflecting specimen holder of a manufacturer of tensile testing machines (website accessed on 03.07.2019): http://www.zwick.de/de/produkte/probenhalter-pruefwerkzeuge/spezial-probenhalter.html und http://www.zwick.de/de/anwendungen/textilien/faeden-garne-zwirne-rovings/zugversuch-an-zweifachzwirn.html

[16] ASTM – International: Designation: D1414 – 15 (July 1, 2015): Standard Test Methods for Rubber O-Rings, S.2

[17] Volkswagen AG: Konzernnorm PV3973 (Ausgabe 2010-11): Elastomer-Runddichtringe Bestimmung von Zugfestigkeit, Reißdehnung und Spannungswerten im Zugversuch, Unterpunkt 4.4, S.4

This is also the recommendation of the O-Ring Prüflabor Richter. In a large series of tests on O-rings with different dimensions, the best comparability of the results was shown at this test speed. This is because the dynamic influence decreases at lower test speeds, which means that tensile strengths are measured at slightly lower levels than at higher test speeds.

6. Calculation of the Results on Standard Rings (Problem of Different External / Internal Stresses)

In comparison to the tensile test on shoulder bars, the following problem occurs during the tensile test of O-rings: The inner diameter is subjected to a higher load than the outer diameter of the O-ring.

Internal comparative tests by the O-Ring Prüflabor Richter of EPDM, O-Rings with cord thicknesses of 3.53mm and S2 shoulder bars have shown comparable results for this pairing. However, this is often not the case in practice, since series O-rings are usually not as well vulcanized as test plates and, especially with larger O-rings (inner diameter > 50 mm), the probability of surface defects increases.

6.1 Different Calculation Methods of Results or Characteristic Values from the Tensile Test of Rings

The following considerations apply only to the calculation of rings clamped and tested by rollers or mandrels; O-ring sections clamped in jaws are subject to similar rules as tensile test bars.[18]

The calculation of the ***tensile strength*** is usually not a big problem. The force required for tearing is divided by twice the area of the ring cross-section (**Table 5**):
Although the calculation of the tensile strength is unproblematic, the evaluation of the result is more difficult. Due to the different stress distribution over the ring cross-section, it is not easy to determine an actual tensile strength. In most cases, tearing will start at the inner diameter of the ring because this is where the highest stress is applied.

For the standards quoted above (ISO / DIN / ASTM / VW-PV), the ***elongation at break*** of the rings is always determined with reference to the inner diameter.

When determining the ***stress value***, the standards differ more severely. In most standards, when determining the stress value, the strain is not referred to the inner ring circumference, but to the mean ring circumference. This results in a more realistic stress value[19], especially for larger cord thicknesses, than if it were related to the inner diameter, and the result of the

[18] vgl. ASTM – International: Designation: D1414 –15 (July 1, 2015)): Standard Test Methods for Rubber O-Rings, Unterpunkt 8.4.2.2, S.3
[19] vgl. ASTM – International: Designation: D412 – 16 (Nov 1, 2016): Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension, Unterpunkt 17.2.1, S.10

stress value is then largely independent of the dimensions of the ring. Furthermore, the results are better comparable with those obtained with test rods[20].
If the stress value of O-rings is a specified value, meaning that its test is explicitly required in a specification, it should be calculated using the mean ring circumference. If this requirement is not met, the stress value in practice is usually determined by means of the inner ring circumference for the sake of simplicity.

7. State of the Art for Good Tensile Strength and Elongation at Break Values on O-rings (ISO 3601-5)

Usually, certain tensile strengths and elongations at break are only required in specifications from seal users (e.g. industrial applications, automobile manufacturers, aviation, etc.). These values must then be determined on standard specimens produced under ideal conditions. More and more often, however, specifications or component drawings also contain material properties that must be explicitly tested on the O-ring. However, a seal user who is not very deeply familiar with this subject usually cannot evaluate whether these required values in company specifications correspond to the state of the art or not.
ISO 3601-5[21] is the first internationally valid standard that represents a good state of the art irrespective of external constraints or company traditions and considers the differences between tensile tests on standard specimens and O-rings. In addition, it also specifies nominal values for the tensile test of hot-aged standard specimens and O-rings.
The following **Table 5** shows impressively how the test values for the most important basic elastomers can deviate between standard specimens and O-rings in the delivered condition in order to still correspond to a good state of the art.

Required Properties	Test Specimen	NBR (S), 70	NBR (S), 90	NBR (P), 75	NBR (P), 90	HNBR 75	HNBR 90	FKM 70	FKM 75
Minimum Tensile Strength [MPa]	2 mm Test Plate	12	10	12	10	16	16	10	10
	O-Ring (24.99x3.53)	10	8	10	8	14	13	8	8
Minimum Elongation at Break [%]	2 mm Test Plate	250	125	150	90	200	125	150	150
	O-Ring (24.99x3.53)	200	100	150	90	200	100	150	150

Required Properties	Test Specimen	FKM 80	FKM 90	VMQ 70	EPDM (S), 70	EPDM (S), 80	EPDM (P), 70	EPDM (P), 80	ACM 70
	2 mm Test Plate	10	10	6	10	10	10	10	8

[20] vgl. International Standard ISO 37: Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties, Sixth Edition: 2017-11, Kapitel 5, c) 1), S. 4
[21] ISO 361-5: 2015-04: Fluid power systems- O-rings- Part 5: Specification of elastomeric materials for industrial applications

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Minimum Tensile Strength [MPa]	O-Ring (24.99x3.53)	8	8	5	8	8	8	8	7
Minimum Elongation at Break [%]	2 mm Test Plate	125	100	150	250	175	150	120	150
	O-Ring (24.99x3.53)	125	100	125	200	125	120	120	100

Tab. 5: Target specifications for tensile strength and elongation at break for both standard specimens and O-rings according to ISO 3601-5, which correspond to a good state of the art.
(NB: The numerical value behind the material stands for the hardness grades in IRHD-CM , (S) = sulphur cross-linked material, (P) = peroxide cross-linked material, the tests on the standard specimens (2mm test plate) are carried out according to ISO 37, the tests on the O-rings according to ASTM D1414)

With regard to these limit values for O-rings according to **Table 5**, it should be noted that these refer formally only to the dimension 24.99x3.53 mm and to ideally vulcanized O-rings produced in the laboratory for the definition of the formulation quality. Nevertheless, these limit values can also be achieved on series O-rings, but this would then have to be agreed between supplier and customer in addition to the requirements of ISO 3601-5. However, ISO 3601-5 regulates mandatory hardness and compression set values for O-rings.

8. Conclusion

The tensile test on O-rings is a relatively simple but very useful test method. What is for the hose manufacturer the ultimate finished part test in the form of burst pressure is for the O-ring manufacturer the tensile test of the O-ring. This type of seal is one of the few elastomer components which, due to their shape, are suitable for such a prefabricated part test without any major pre-treatment. As this is a finished part test (in contrast to dumbbell bars), it is also possible to make quick conclusions about the manufacturing process itself.
If the tensile test of O-rings is carried out in accordance with standards and correctly evaluated, important conclusions can be drawn from this. For this reason, this test method is state of the art in the automotive industry and could certainly help other industries to uncover defects in the formulation or manufacturing quality of O-rings.

A long version of this article, which also deals with the tensile test on standard rings and related difficulties, can be also found on our website