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Tensile Set –
Testing Principles and Differentiation from Compression Set Testing

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Test Standards Used: ISO 2285 (Ausgabe 01-2013), DIN ISO 2285 (Ausgabe 12-2013), ASTM D412 – 06a (Reapproved 2013) *(chapter 12.2 Determination of Tensile Test)*, ASTM D1414 – 94 (Reapproved 2008) *(chapter 9. Tension Set Test)*

The tensile set, like the compression test, is a possibility to obtain information on the relaxation behavior and on the cross-linking state of a test specimen after a defined temperature load by means of the re-deformation behavior. In special applications and with special sealing geometries, it is a helpful supplement to compression set testing.

1. Brief Description of the Tensile Set Test Procedure and It's Current, Valid International Test Standards

In the tensile deformation test, the specimen is stretched. It is either a constant strain or a strain under constant load. This article deals only with the first case, as it is the most important one in our daily testing routine.

The specimen is either an elastomer strip, a dumbbell rod or a ring. It is either a pure elongation in length (see **Figs. 1** and **2** with elongated Tensile Set standard specimens) or a radial elongation (see **Fig. 3** with elongated O-rings). The strain is usually 25% or 50% and is defined in:

- **Temperature stress** (e.g. 24h / 150°C)
  and
- **Cooling Procedure**[1]

Subsequently, the specimen is relaxed again. The permanent elongation or expansion is set in relation to the absolute elongation or expansion. The standard does not specify a standard length for the longitudinally stretched specimens. In most cases, however, 50 mm are used as the measuring length[2]. The advantage of tensile set dumbbell bars is that no additional holding clamps are required because the dumbbell bar can be easily hooked into the device. The length to be measured is marked on the dumbbell rod with marker pens[3].
Earlier standards required dumbbell bars with a measuring length of 100mm. Since then, mostly shorter measuring lengths are used and because, in many cases, there are not very large strains measured back with the tensile set, accurate and exact measuring devices are absolutely necessary[4]. The change in length is measured with an accuracy of 0.1 mm[5]. (The measuring device is in most cases a caliper, see **Fig. 1 and 2**).
The result of the tensile set correlates approximately with the compression set.

In the ASTM Standards ASTM D412 - 06a (Reapproved 2013) (chapter 12.2 Determination of Tensile Test) and ASTM D1414 - 94 (Reapproved 2008) (chapter 9 Tension Set Test) a tensile set test is described in the chapters mentioned in brackets, but only at room temperature and after a load of 10 minutes at 100% elongation (ASTM D 1414). This short-term tensile set does not occur in our everyday test routine and it is questionable whether the results can be reproducibly measured, since very small Tensile Set values will be obtained at room temperature and after such a short loading time. Furthermore, it is unclear what benefit this

[1] Methods A and C are analogous to the compression set according to ISO 815-1 (edition 02-2008). There are differences in the cooling method according to Method B: While ISO 815 (CR) requires cooling in the compressed state to room temperature within a time window of 30 to 120 minutes after removal from the furnace, ISO 2285 lacks this time window and the indication that room temperature must be reached. The Tensile Set standard only requires a cooling time of 30 minutes. In both standards (ISO 815 and 2285), the return measurement then takes place after relaxation at the end of the cooling time and a further 30 minutes waiting time in the relaxed state.
[2] vgl. BROWN, Roger: Physical Testing of Rubber, New York, [4]2006, S. 215
[3] vgl. DIN ISO 2285 (Ausgabe Dezember 2013), Unterpunkt 6.4.1, S.10
[4] vgl. BROWN, Roger: Physical Testing of Rubber, New York, [4]2006, S. 215
[5] vgl. DIN ISO 2285 (Ausgabe Dezember 2013), Unterpunkt 4.1.3, S.7

test method should have for the practical user.

Fig 1: Tensile Set: standard test specimen in initial position, still relaxed state (50mm)

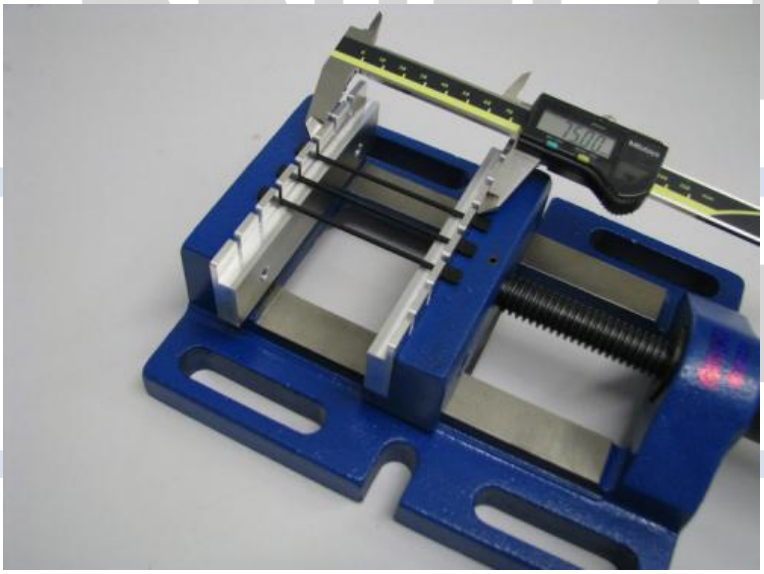

Fig. 2: Tensile Set: standard specimen in stretched condition, shortly before furnace loading (50% elongation at 75mm)

Fig. 3: Tensile Set on O-rings using a test mandrel in a laboratory furnace (radial elongation)

The Tensile Set E4 in percent is calculated as follows[6]:

$$E_4 = 100 \times (L_5-L_1)/(L_2-L_1)$$

E_4 = Tensile set [%]
L_1 = Unstretched initial measuring length [mm]
L_2 = Stretched measuring length [mm]
L_5 = Measuring length after the recovery phase [mm]

How does this permanent elongation emerge? It is a similar effect to compression set: first, the original network structure is partially destroyed by heat and stress (elongation or expansion). As a result, the restoring forces decrease. Secondly, new cross-links are created in the stretched structure. These new cross-links counteract a deformation back into the initial position. The permanent deformation - which we measure - represents an equilibrium of the two forces working against each other.[7]
If you would like more detailed information on the theoretical background of deformation set testing, we recommend the article "Expertise in Compression Set Testing" on our website.
The tensile set is usually used much less frequently than the compression set test.

2. Advantages and Disadvantages of Tensile Tests (Differentiation from Compression Sets)

What are the advantages and disadvantages of the tensile set and when should it be used?

[6]The designations and abbreviations in the calculation formula for the Tensile Set were taken from: DIN ISO 2285 (Ausgabe Dezember 2013), Unterpunkt 8.2 *Konstante Dehnung*, S.14
[7]vgl. TOBOLSKY, Arthur V. und Hoffmann, Martin: Mechanische Eigenschaften und Struktur von Polymeren, Stuttgart, 1967, S.285f.

- The tensile set is used almost exclusively on finished parts. In the case of O-rings with very small cord thicknesses, the measurement uncertainty is lower than with the compression set test method.
- On many sleeves, rod and piston seals, and radial shaft seals (on the sealing lip cut out with a knife) the Tensile Set is the only possibility to measure the degree of cross-linking.
- The procedure is simpler than compression set testing because a mandrel is easier to produce than planar plates and spacers. The method is therefore suitable for recurring dimensions if there is already the right mandrel.

Since, for example, a non-contact measuring machine for O-rings is not available everywhere in goods receipts of smaller companies, the accuracy of tensile set tests is not always as high as for compression set tests. Of course, this point does not apply to our accredited laboratory, as we have the appropriate measuring equipment. In addition, we also offer complete incoming goods inspections for companies.