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V. Geinitz / M. Weiß / U. Kletzin / P. Beyer

# Determining of parameters characterizing the functional and forming behavior of spring steel wire

### SESSION 7 - ENGINEERING DESIGN


### Abstract

The aim of the research project was to determine the tensile, torsion and bending characteristics and parameters on 9 example wires. The paper gives a review of the changes in wire parameters caused by tempering and presetting and the effects on the spring production and spring characteristic and function.


### Initial Situation and aims

The proper knowledge of the functional and forming behavior of spring steel wire is the basis for design and production of technical springs. The wire of the helical compression springs as most used springs is stressed with torsion stress. So the torsion yield point should be the basis of spring design. Due to the fact that the torsion test is not-standardized, the torsion yield point is unknown and the spring design had to apply the tensile strength. Because of its production cold-drawn spring steel wire is neither homogenous nor isotropic. Therefore it is problematically calculating the torsion or bending behavior of the spring steel wire from the tensile strength of the raw wire material.

The *E*-modulus and the shear modulus *G* describe the elastic behavior of the wire. Therefore *E* and *G* are required for calculating the spring function. The values for *E* and *G* given in the standard ($E$ = 206 N/mm² and $G$ = 81.5 N/mm² for patented cold-drawn spring steel wire and oil hardened and tempered wire) were measured long time ago.

Furthermore the elastic behavior of spring wire as well as the spring function is influenced by the spring production steps tempering and presetting. For this reason it is necessary determining the tensile, torsion and bending characteristics of the raw material and of spring steel wire after tempering and presetting. The results, stress-strain-curves and parameters, should be saved in a SQL database with Web-Interface.

## Procedure

The first task was to develop and adjust the experimental equipment for tensile, torsion and bending tests with small diameter spring steel wire. An algorithm had to be developed for analyzing the strain-stress-curves measured and evaluating the parameters like elastic modulus, shear modulus or technical yield point under torsion stress (torsion yield point).

Therefore a torsion test (fig.1) was set up and a rig was developed determining the shearing elongation (torsion elongation, fig.2).


Figure 1: Torsion test

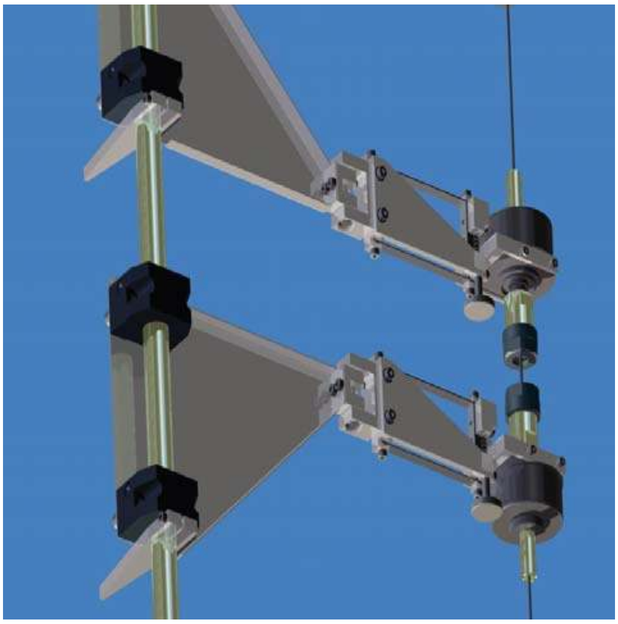


Figure 2: 3-D-Mechanical drawing of a developed rig determining the shearing elongation

The torsion and tensile parameters of spring steel wire were measured on 9 types of wire: oil hardened and tempered wire, stainless wire and patented drawn wire each with 3 diameters. Furthermore the influence of tempering and presetting to the torsion and tensile parameters of the spring steel wire was investigated.

## Experimental results

Figure 3 shows the torsion stress – torsion elongation- curve as a function of the tempering temperature of an oil hardened and tempered spring steel wire. The wire torsion behavior, the torsion strength and elongation, is influenced by the tempering temperature. Figure 4 and 5 show the torsion yield points $\tau_{t\,0,04}$ of 3 patented cold-drawn spring steel wires and oil hardened and tempered wire respectively with wire diameters of 1mm, 3mm and 4.5mm, which were tempered 60 minutes with different temperatures $T_A$. Because of its production the torsion yield point of the patented spring steel wire changes on a big scale.

In addition, the shear modulus which is used for calculating the helical spring function is changed with the temperature of tempering (fig.6).

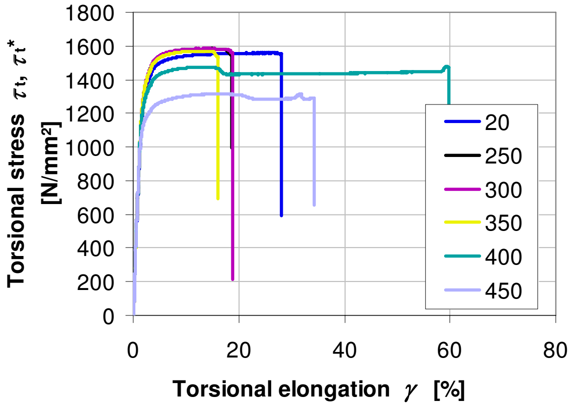
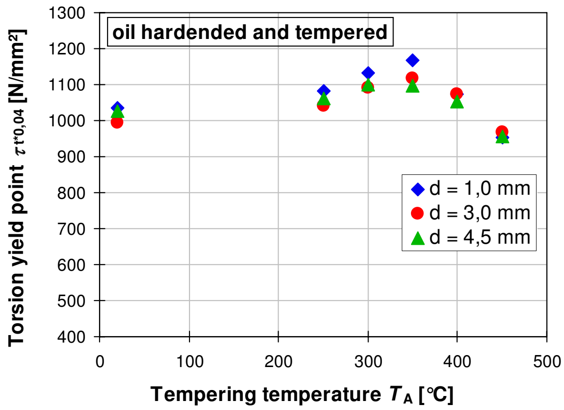



Figure 3: Torsion stress – torsion elongation- curve as a function of the tempering temperature [°C], oil hardened and tempered spring steel wire with *d*=3,0 mm



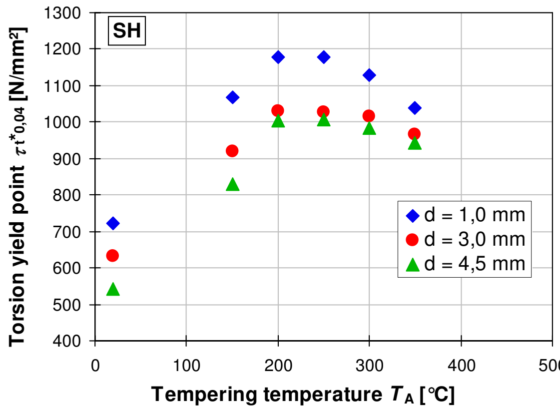




Figure 4: Torsion yield points of oil hardened and tempered wires with 3 different wire diameters tempered 60 minutes with different temperatures

Figure 5: Torsion yield points of patented drawn spring wires with 3 different wire diameters tempered 60 minutes with different temperatures

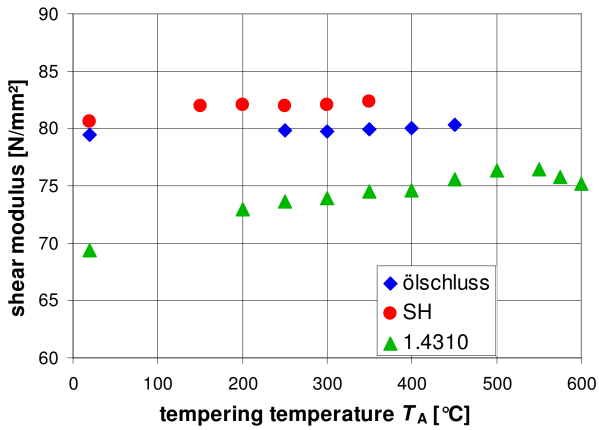



Figure 6: Shear modulus of 3 types of wires with $d$ = 3.0 mm tempered 60 minutes with different temperatures

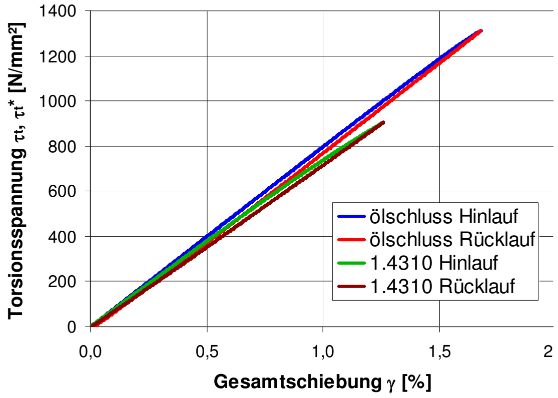



Figure 7: Torsion behavior of a wire after tempering and presetting determined with the loading and unloading torsion test

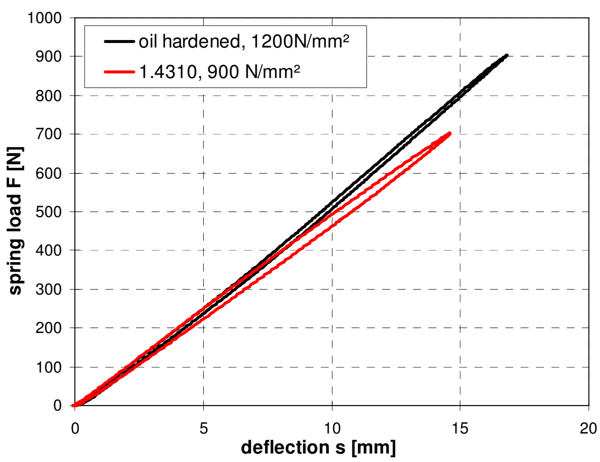



Figure 8: Spring characteristic of two high loaded springs made from 1.4310 and from oil hardened and tempered wire

The wire in a helical spring isn't loaded up to fracture. The wire torsion elongation in a helical spring with a very high deflection is less than 3%. The torsion test with alternating loading and unloading simulates the wire behavior in a helical spring. If the wire is twisted over the torsion yield point a plastic deformation in torsion direction occurs. This plastic deformation can be compared with the permanent set of the wire in a helical spring after the production step pre-setting (reduction of spring length). The alternating loading and unloading torsion test with a tempered and pre-setting wire shows the elastic properties of the wire in a tempered and pre-setting helical spring.

A very high-stressed helical spring and hence a large permanent set leads to a characteristic hysteresis in the spring load - spring deflection curve (spring characteristic, fig. 8).

## Summary

The results of the research project are already used by spring manufacturers. The tensile and torsion strain-stress-curves of the spring steel wires measured improve spring calculations with the finite element method. The parameters detected with the torsion test are used for the design of high-stressed compression springs.

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Besides the authors, the following members of staff at the Faculty of Mechanical Engineering of the Technical University Ilmenau have been involved in the research: Dr. Kersten Liebermann, Peter Beyer, Ina Bretschneider and Jürgen Remdt.

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