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Identification of the torque strut force load

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Abstract. A torque strut is member used as a fixing element of the car drive unit. Because a breaking of its metal part during the tests occurred, the measurement of forces applied to the strut during real usage in the car was required. The paper describes the load measurement methodology and it also explains the causes of a strut failure.

Introduction

A torque strut is member used as a fixing element of the car drive unit. It is placed between a gearbox and suspension subframe. It provides a flexible transmission of the forces that are generated by a torque of the engine. It consists of metal and rubber parts (Fig. 1 left).

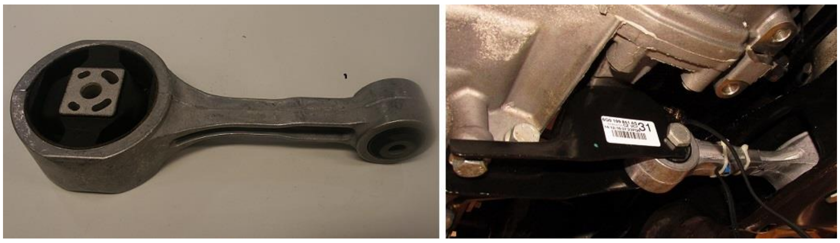

Fig. 1 The torque strut (left) and its mounting in the car (right)

Each new torque strut type has to be tested and its final tests are carried out in a real car (Fig. 1 right). Simulation of inappropriate launch of the car is one of these tests. It consist in a fast releasing of a clutch under revolutions that limiter allows. This process is repeated several times for the first and reverse gear. The car “jumps” and torque strut is loaded by high force peaks. The first gear generates tensile stress and the reverse one generates compressive stress.

One of the torque strut types was very often broken during this test. Thus it was necessary to determine the real loading force acting in this strut and to compare it with expected value of this strut design. The torque strut real loading during its real usage in the car had to be measured.

The real force measurement methodology

If the torque strut is assembled in a car, there is no space for standard force sensor (Fig. 1 right). Therefore, it was decided to measure the force by the strut relative elongation ε because both values are proportional according to Young's modulus E (Eq. 1) (of course only before the material yield point attainment) [1].

$$E = \frac{\sigma}{\varepsilon} = \frac{F}{A \cdot \varepsilon} \tag{1}$$

where σ is the normal tension, F is the loading force and A is the cross-sectional area

Because the Young's modulus and the cross-sectional area may be considered constant, the force can be determined from the relative elongation (Eq. 2) which can be measured by strain gauge sensors.

$$F = E \cdot A \cdot \varepsilon \qquad (2)$$

Two strain gauges sensors 1-LY41-6/350 [2] were glued to the opposite sides of the strut at its smallest cross-section place (Fig. 2 left). Then the strut was placed into the calibration device, loaded by the axial force 10 kN and the strain gauge signals were calibrated to the force.

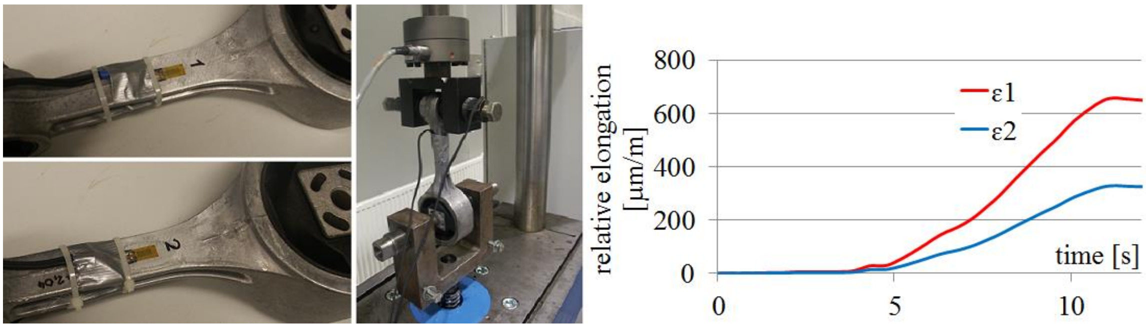

Fig. 2 The torque strut with strain gauges, its calibration and calibration result

This calibration showed first unexpected results (Fig. 2 right). Signal from one strain gauge was greater than from the second one. If the symmetry strut is expected, both signals should be practically identical during the strut axial loading.

The real force measurement result

The torque strut with the strain gauges was assembled to the car and test described above was performed. Six launches for first and reverse gear were carried out. Test results are summarized in the Fig. 3.

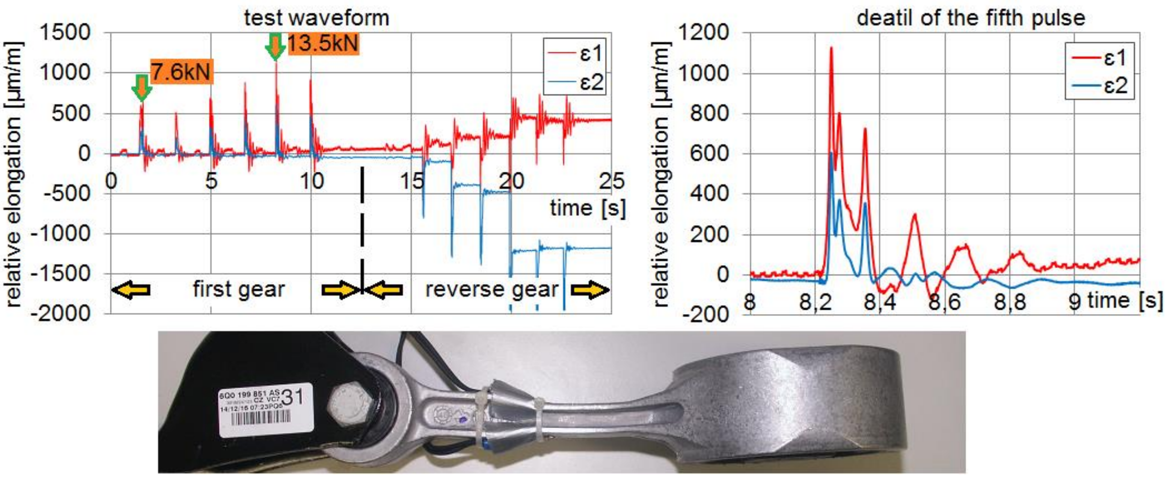

Fig. 3 The torque strut test results

Strain gauge signals showed same trends as the calibration, one was higher than the other one. Already after the fifth launch (the force peak was about 13.5 kN and the relative elongation 1117 μm/m) the strain gauge signals did not return to the zero value, the strut was permanently deformed and its material yield point was exceeded (see the waveform detail in the Fig. 3 right). One signal remained positive and the other one negative value, the strut was bent. It was unexpected result because the strut is loaded by tensile force in the first gear. The strut bending was gradually magnified during the next launches in reverse gear that create compressive loadings. Based on this result it was decided to check the strut cross section.

The strut cross section checking

The torque strut exhibited during calibration different values of voltage and therefore different deformations although strain gauges were placed symmetrically. The causes may be various, for example a defect of material, the load applied out of symmetry axis or asymmetric cross-section. For this purpose, the cut-outs from strut applicable for image analysis were created. The strut was divided by cuts perpendicular to the separation plane into two parts and finished by the milling to ensure the flatness of the cut with sufficient roughness. Then, the images was prepared using a microscope Nikon Eclipse LV100 and subjected to measurement using image analysis system NIS-Elements. One sample from a tested (T) and a new (N) strut were prepared. The wall thickness and the size of the area left and right rib were measured at four points (Fig. 4). The results can be found in the Tab.1. There are also shown the percentage difference between measured parameters of the thickness and the area of the left and right ribs.

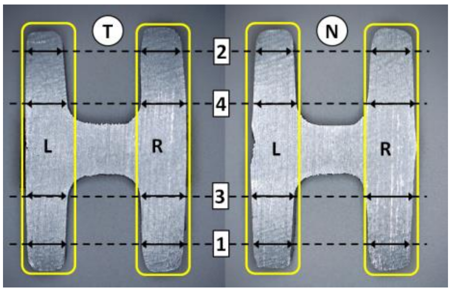

Fig. 4 The strut cross sections, check areas and lines (tested strut left, new strut right)

Tab. 1 The strut dimension check results

dist. [mm]	tested strut (T)					new unused strut (N)				
area [mm^2]	dist.1	dist.2	dist.3	dist.4	area	dist.1	dist.2	dist.3	dist.4	area
rib L	3.120	3.027	3.520	3.467	65.34	3.093	3.160	3.613	3.587	67.01
rib R	3.360	3.413	3.867	3.773	72.65	3.480	3.414	3.613	3.933	75.03
difference	0.240	0.386	0.347	0.306	7.32	0.387	0.254	0.000	0.346	8.02
[%]	**7.7**	**12.8**	**9.9**	**8.8**	**11.2**	**12.5**	**8.0**	**0.0**	**9.6**	**12.0**

The cause of unusual result was revealed - the strut casting is poorly manufactured and the cross-section is asymmetrical. Left area is about 12 % smaller than the right one. The wall thickness differences are significant and probably it is a reason of different unexpected behavior that leads to the bending strut. The torque strut was then redesigned in accordance with these findings and the new type of the strut was identically tested.

The redesigned strut real force measurement

The new strut type was tested identically as the first one. Two strain gauge sensors were glued to the opposite sides of the strut and calibrated by the 10 kN force. No unexpected result was achieved during the calibration, both strain gauge signals were almost identical (Fig. 5 right). It indicated the symmetrical strut casting.

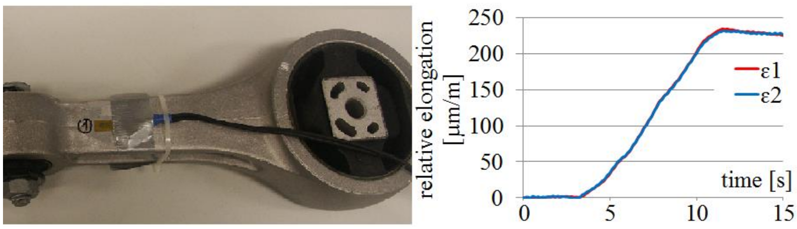

Fig. 5 The new type of the strut and its calibration

Than the strut was assembled to the car and the same test was repeated five times so that approximately 25 force peaks for first and the same for reverse gears were generated. Both strain gauge signals returned to the zero value after all tests, no permanent deformation was measured. Test pulses were different because their size and shape were influenced by the car driver (Fig. 6).

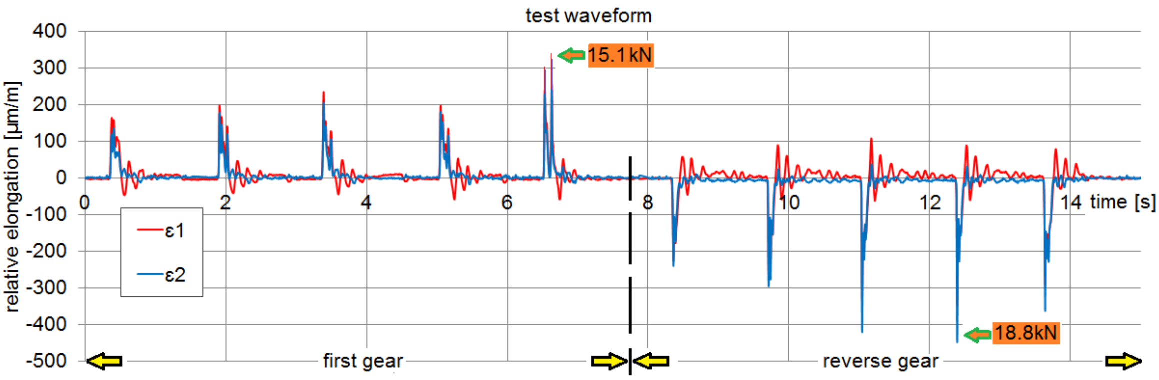

Fig. 6 New redesigned strut measurement example

Therefore the force peaks average value was calculated and the maximal values of the relative elongation and force were determined for both load direction. The absolute maximum of force peak was 18.8 kN and it caused relative elongation 439 μm/m (Tab. 2). The strut material yield point was exceeded by the relative elongation about 1117 μm/m during the first strut type testing. If we assume that the material of both the struts is the same and the strut new type maximum relative elongation is only 439 μm/m, the normal stress acting in the new strut is at safe level and critical material yield point will not be reached.

Tab.2 Test peaks summarization

	force peaks average value	maximum force	maximum rel. elongation
first gear	9.83 kN	**15.1** kN	**352** μm/m
reverse gear	14.64 kN	**18.8** kN	**439** μm/m

Conclusions

Test results showed that the first strut type cross section was undersized, its deformation was permanent after the force pulse of only 13.5 kN. In addition, its casting was poorly manufactured, it is asymmetrical and it causes the strut bending deformation. All these errors were eliminated during the new strut type design. The cross section area was increased and both halves of its casting are symmetric. No permanent deformation was observed during its testing, although the force peaks ranged up to 20 kN, the redesigned strut is safe for use.

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[2] Y Series Universal Strain Gauges, information on http://www.hbm.com/en/0364/strain-gauges-for-stress-analysis.