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Modification of a test bench for testing torsional stiffness

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ABSTRACT

Described modification concern a test bench for testing torsional stiffness. The bench was created to analyze behaviour a middle part of a new type of an active stabilizer. The middle part was was replaced by two or four profiles with rectangular cross-section which are constantly connected with not-changed parts of stabilizer (with its arms). Specially designed mechanism is responsible for changing stiffness and it performs it so that the profiles are expanded in the middle of sample on the same distance in opposite direction. An article contains brief description of mentioned test bench and one of a few issues which were revealed during investigations – weak accurancy of obtained results. It was determinated that modification in the area of the bench drive and change in recording system should allow on increase accuracy. After modifications became able to observe a phenomenon of changing torque behaviour, from linear to nonlinear, during twisting expanded sample.

***Keywords*:** active stabilizer, torsional stiffness, test bench, rectangular cross-section, modification, torque issues

1. INTRODUCTION

1. 1. Vehicle stabilizer bar

Anti-roll bars improve driving comfort, steerability and safety. They limit the tilting of the body during driving around a curve. Tilting is a consequence of the centrifugal force. Little body roll is beneficial for accurate and safe driving. Too much of it can cause loss of steerability and, thus, might lead to a side slip and often a roll-over of a vehicle [1,2].

Classic (rod) anti-roll bar is an appropriately formed torsion bar characterized by constant stiffness, selected by the vehicle manufacturer [3]. Its value is described by the following formula:

$$K_s = \frac{M_s}{\alpha} \qquad (1)$$

where:

M_s [Nm] – torsion torque
α [deg] – torsion angle

In an anti-roll bar called active, stiffness can vary in certain range, fluently or gradually. The devices changing stiffness are generally costly constructions, with a complex structure. They require additional actuators, for instance: hydraulic, pneumatic, mechanical or mixed [4].

1. 2. A new design of stabilizer bar

Mentioned drawbacks of described active anti-roll bars influenced on creation of the concept of new type of stabilizer with fluent adjustment of torsional stiffness. It is protected by patent application no 2016P00954 FR Unlike from classic anti-roll bar which normally acts on a torsion, additional bending stresses were introduced. They change a resultant stress state and, as a consequence, also expected torsional stiffness. Hence, bending-torsional stiffness is considered [5]. The developed concept (Fig. 1) assumes that the middle part of the anti-roll bar consists of a packet two or four profiles (1) with rectangular cross section each. They are expanded by specially designed mechanism (2), which is powered by electric starter (3). [6]

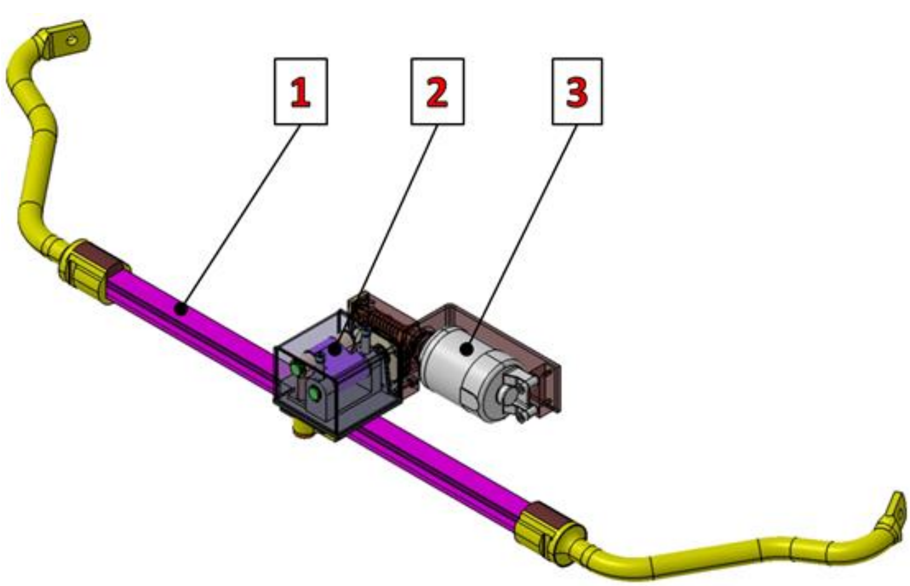

Figure 1. Conception of variable torsional stiffness stabilizer.

1. 3. A test bench for testing torsional stiffness

The test stand for determining stiffness characteristics of twisted elements should provide reproducible, easy to write and edit, research results. For multitude samples in different sizes, packetized in a variety of configurations the bench shall enable on a quick disassembly and reassembly of the unit in which tests are conducted.

The test bench is equipped with two sensors: torque and incline (providing a measure of sample twist). Analog signals are directed to the measuring card National Instrument NI 9215 BNC type, which forwards them in a digital form to the PC. Special software allows to record measurement results and to their subsequent processing for the purpose of further analysis.

Figure 2a shows the test bench. It consists of five main units. First is a computer set (1) for signal recording and data processing. The drive unit (2), is used to implement twist a sample (Fig. 2 presents old, currently not used system equipped with hydraulic drive). The unit equipped in lever causes the rotation of particular elements of the bench. They are connected each other in a series and they are respectively: torque meter MI50 (3), bi-articulated shaft and a set of testing profiles (minimum of two) which are mounted in a special test unit (5). Number (4) indicates an inclination sensor (which is a part of the test unit).

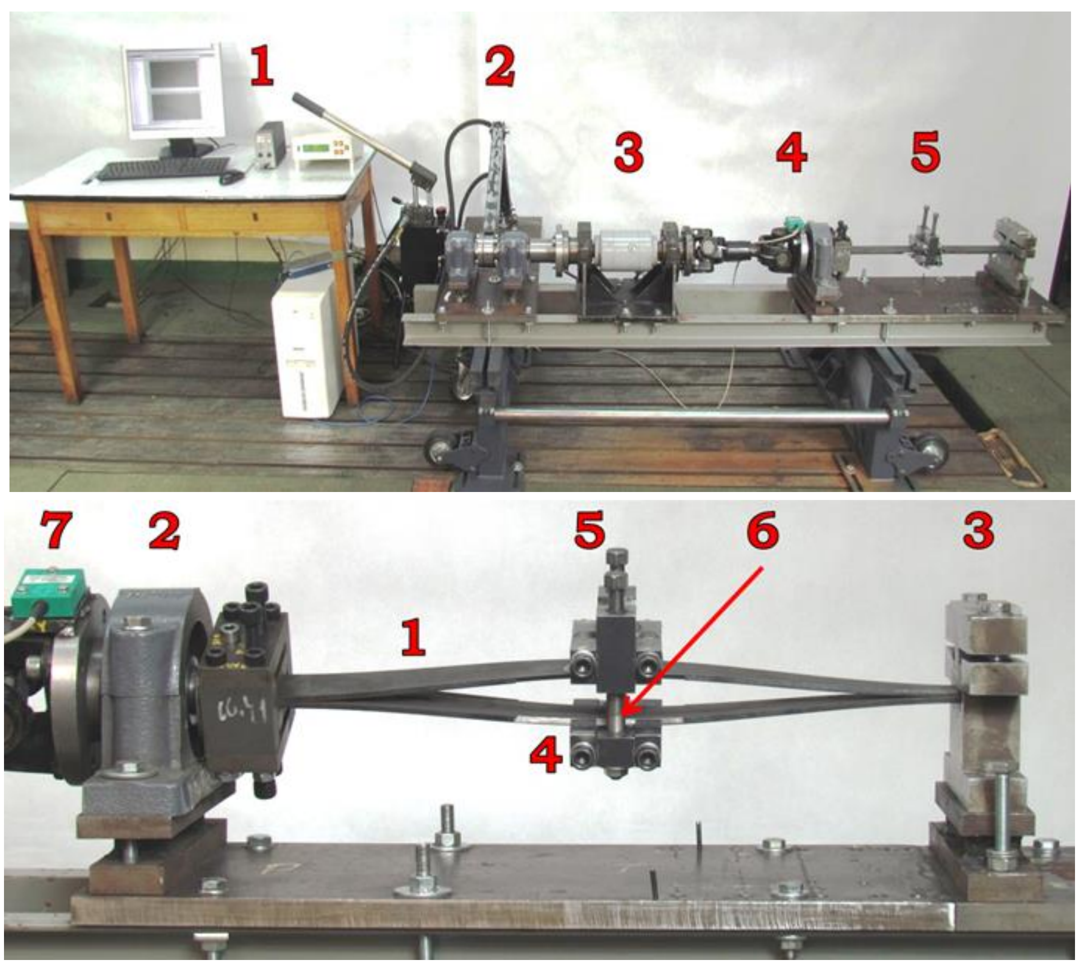

Figure 2. A test bench for testing torsional stiffness.
a) Pictorial view, **b)** Test unit at working position.

The test unit is shown in Fig. 2b. It has two supports: fixed (3) and movable (2). The fixed support is placed in an extreme position of a bench and it aim is to permanently immobilize a sample (1). The movable support acts as a base on which is mounted an inclinometer (7) Posital Fraba type ACS0802SV20HE2PM (tilt sensor). It allows on profiles rotate and on their axial shortening and lengthening during twisting and changing expand. An expanding mechanism (4) consists of two halves. Each of them is mounted on a corresponding profile in a way which prevents movement. Test elements are extended in the middle of their active length, by distancing both halves from each other. The distance is adjusted by wrenching two screws M12×1 (5) into the upper part of mechanism. These screws presses on two sliding pins (6) which are fixedly mounted in the lower part of mechanism. In this way, both halves move away from each other on an equal distance in relation to the longitudinal axis of the examined profiles.

1. 4. Samples

It was expected to carry out a series of studies of profiles with variable amount (from 2 to 4 pieces in sample) and following varieties in torsion length: 428, 478, 528 mm, width: 22.5, 30, 35, 40, 45, 50, 55, 60 mm and height: 3, 4, 5, 6 mm. Figure 3a shows an exemplary test element – two profiles welded at its ends with following dimensions of singular part 4×40×650 (torsion length 528 mm). All samples were cut from metal sheet 50HF and during performing process hardened up to 46-48HRC. Beveled edges, presented in Fig. 3b, were used to provide permanent attachment with expanding mechanism.

(a)

(b)

Figure 3. The test kit before hardening process.
a) upper view, **b)** a perspective view of central part with beveled edges.

1. 5. Test procedure before modification (for hydraulic drive)

Profiles presented in Fig. 3 were installed on the bench and there were conducted seven series of tests. In each series there were recorded torsion angle and torque generated for the nine following angle positions: 0°, 3°, 6°, 9°, 12°, 15°, 18°, 20° and a maximum angle for which allowed a stroke of hydraulic actuator (approx. 21,5°). In each series, the distance between both halves of extending mechanism were adjusted from 0 mm up to 30 mm with the 5mm stroke. Total test duration for singular sample lasted approx. 2 hours.

2. MATERIALS AND METHODS

2. 1. Test bench modification

The modification goal was to receive more accurate characteristic of changing torque in function of sample twist, so as to obtain full spectrum of change in torque during test. After test bench adaptation the goal was achieved.

An old drive system consisted of hydraulic actuator powered by manual pump. Characteristic obtained with this solution is presented in Fig. 4. As may be seen there are points which were selected in order to draw changing torque graph (Fig. 4). The solution is characterized by following features:

- Weak ability to perform accurate torque graph
- Long test-time
- Long data processing time
- Difficulties on test bench customization

Due to listed cons came up an idea to rebuild test bench, so as to make tests easier and faster. There were two ways to obtain it. First, to change manual pump to mechanical and second to elaborate a new drive system. After analysis of advantages and disadvantages both solutions and taking into account its implementation possibilities it was decided to select a new one system. Mechanical pump installation would generate too high cost (buying hydraulic station) and difficulties in its customization with control software.

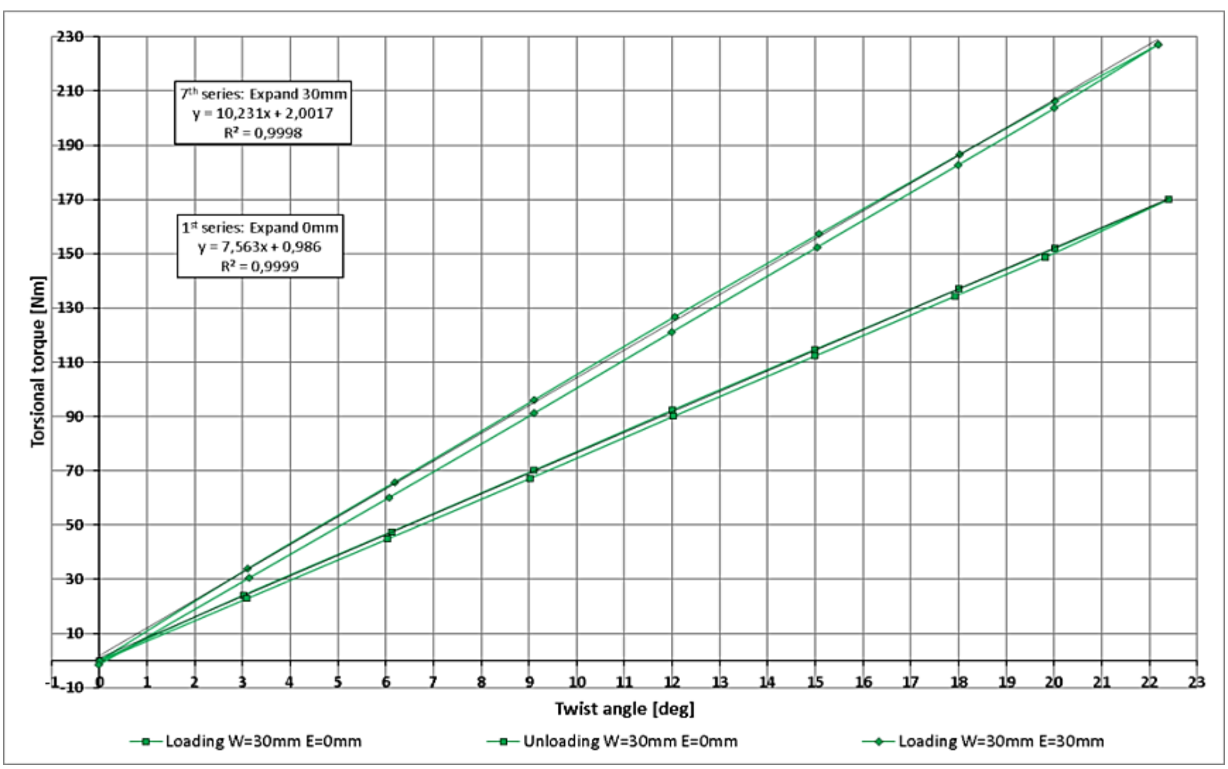

Figure 4. A graph of varying torsional torque for a set of two twisted profiles with dimensions 4×30×650 (twisted length 478 mm).

It was decided to exploit a serial DC electric motor which generates high torque. After determination of requirements it was selected XNPK18LPL/P30 motor with 18 Nm torque. An adaptation project has been made and its result is presented in Fig. 5. It consists of DC motor housing (1) which is rotatable mounted in support (2) on two special screws with pins at its ends (3). The motor powers rolling screw (4) which has a nut (5) which is rotatable installed in lever (6). To prevent retreat lever to its starting position, after twisting sample, the screw-nut gear is self-locking. Due to occurring friction and possibility to damage it should be lubricated by solid grease.

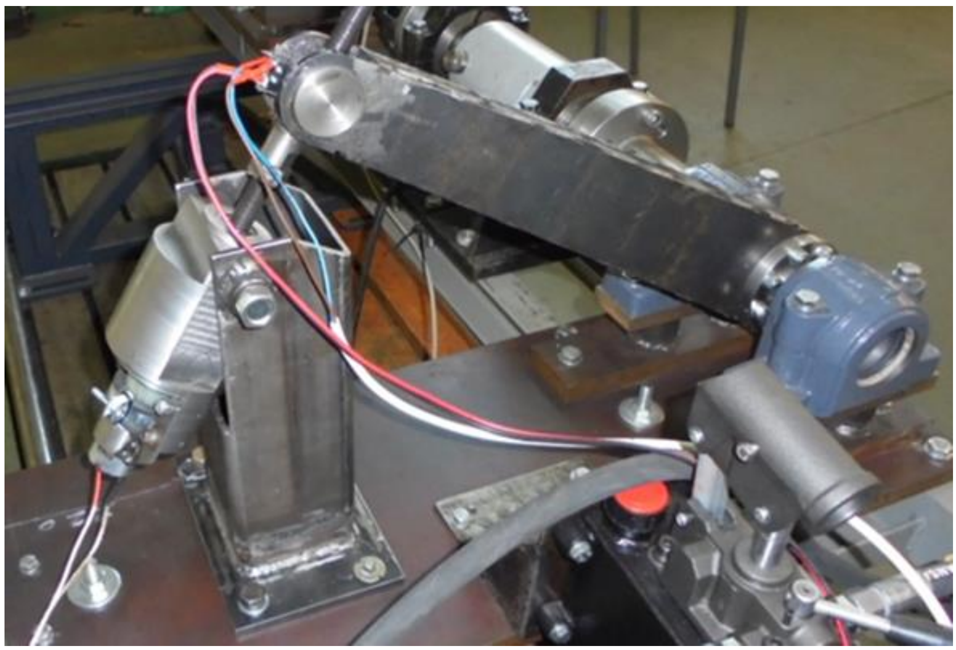

Figure 5. New electric drive.

2. 2. Test procedure after modification (for electric drive)

Sample, after installation and customization, was subjected to seven series of tests. For each of these there were recorded generated torque and incline angle during twisting from 0 to approx. 22°. After every series a distance between two halves of expanding mechanism was increased for 5mm from 0mm up to reaching 30 mm and the procedure was repeated. Total test duration for singular sample last approx. 0,5 hour.

2. 3. Modification results

Modification results in a form of torque graph which is presented in Fig. 6. Due to multiplicity of recorded points it is possible to observe changing torque in function of twist angle as a curve. It's character is well mapped by 1st and 2nd order trend line. First order is suitable for profiles which are not expanded and second for each expanded case.

The modification allowed on reveling phenomena of varying torque from linear to non-linear behavior during expanding sample. For better explanation may be said that the curve start bending and while expand increase, the radius decrease. Analysis of the loads shows that the vital role may have bending around an axis which is parallel to a shorter edge of the rectangular cross section of expanded profile, which occurs in addition to bending around an axis which is parallel to a longer edge of the cross section (during expanding) [7,8].

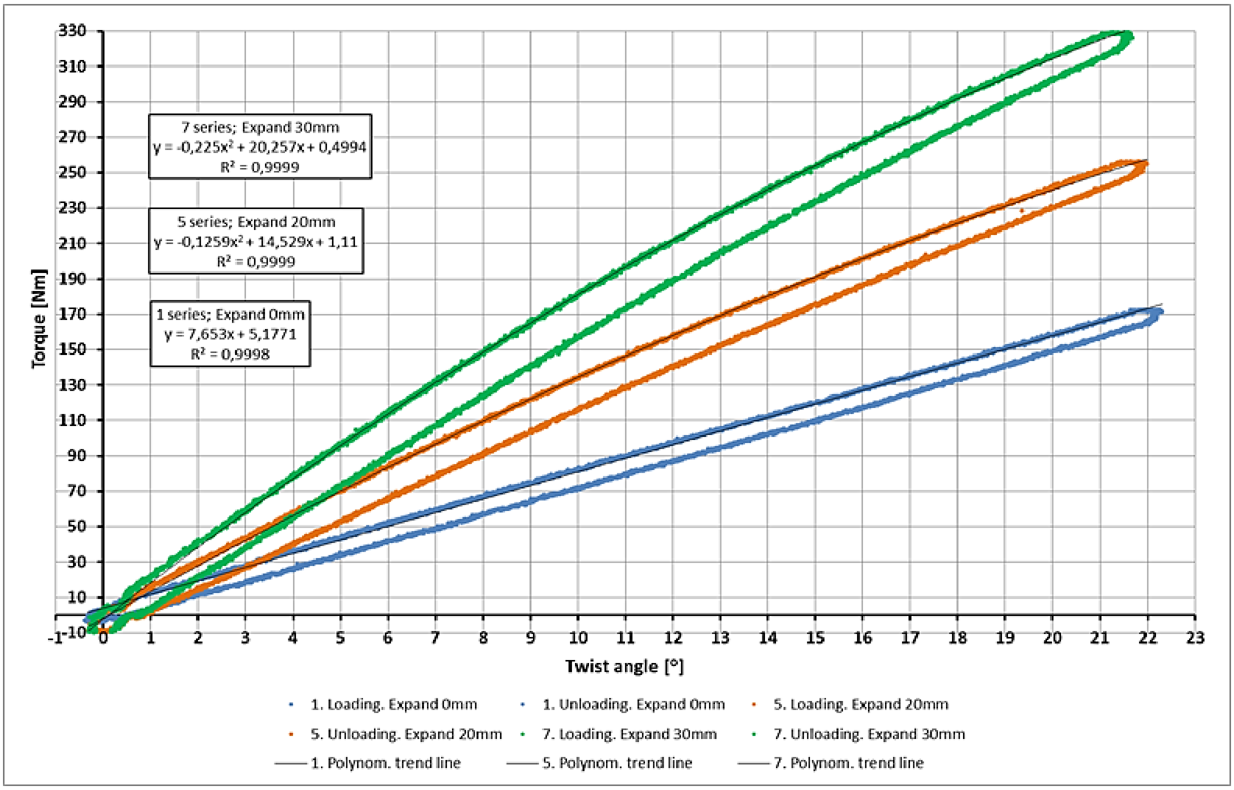

Figure 6. A graph of varying torsional torque for a set of two twisted profiles with dimensions 4×60×650 (twisted length 528 mm).

3. CONCLUSIONS

Test bench modification fulfill all assumed functions. It provides to following conclusions:

1) Test bench modification allowed on making tests faster. For singular sample test-time decreased from approx. 2 hours up to approx. 0,5 hour and for data processing it decreased from approx. 4 hours up to approx. 0,5 hour.
2) Thanks to that it was received more accurate graph of torque in function of sample twist (Fig. 6) it was revealed phenomena of varying torque from linear to non-linear behavior during expanding sample.

The scope of further work will include an investigation of more experimental profiles, so that an obtained results enable for development of a theoretical relationship describing the change of torsional stiffness during expanding profiles. Moreover will be made theoretical analysis to explain phenomena of varying torque from linear to non-linear behavior during expanding sample. Additionally it is planned to create a digital model and test it by using finite element method by the use of ANSYS 16.2 program. Properly constructed model will allow to analyze more samples in various combinations with selected dimensions. It will allow also on reduction of the costs of its preformation, implementation and duration of the research.

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