

Testing Equipment for Fatigue Tests of Steel Cords

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Abstract:

The contents of the paper point out the necessity of combining the theoretical and experimental approaches in the investigation of tyre load in vehicles.

The models are planar and they model the cross-section of the tyre enabling the consideration of the bottom load and the internal pressure in the tyre, as well as the influence of the lateral force.

The paper presents the findings, the formulations necessary for solving the task obtained in the experimental model tests and serving as a basis for comparison with the results obtained from purely theoretical approaches, e.g. by the method of finite elements, with identical load conditions.

Introduction

The steel cords reinforcing motor vehicle tyres are unevenly loaded in time as the tyre is in operation and in contact with the road surface.

The conditions for conducting and evaluating experimental tests that would model the considered loading of the steel-cord-reinforced tyre have been defined as follows:

- cyclic loading of the decaying compression type with the sinusoidal functional dependence of the increase in the loading force on time, this loading being exerted in the axis of the test specimen,
- frequency of the loading force is to be controllable within the range of 10 Hz to 30 Hz,
- deformation of the specimen (compression) should be controllable up to 30% of the length of the specimen,
- the angle between the non-deformed clamped part of the specimen and the part being deformed must be constant, amounting to 15° or 20°,
- a possibility should be available of conducting the tests under different thermal conditions within the temperature range between 0°C and 100°C, and the given temperature should be constant in the entire course of a particular test,
- the testing equipment should allow for testing several test specimens at a time,
- the shape and dimensions of the test specimen should be identical to those used in tests according to the Slovak technical standard STN (Determination of rubber-to-cord adhesion after dynamic deformation by Henley method),
- the fabrication of test specimens and preparation thereof prior to the test should conform to the regulations set out in standard STN,
- the basic result of the fatigue tests conducted under the conditions set out above shall be the determination of rubber-to-cord adhesion, the relative decrease in rubber-to-cord adhesion and comparing the results obtained under the conditions described above with those obtained in tests according to standard STN.

To be able to conduct these experimental tests, it was necessary to design simple test equipment for cyclic loading of the test specimens.

The design of the test specimen and the manner of clamping thereof

The test specimen shall be fabricated in accordance with the currently valid standard STN (Determination of rubber-to-cord adhesion after dynamic deformation by Henley method).

If the test specimen is to be loaded with cyclic loading of the decaying compression type with the sinusoidal functional dependence of the increase in the loading force on time, and this loading is to be exerted in the axis of the test specimen, then this type of loading is different from that applied in dynamic tests as set out in standard STN where the loading force is exerted upon the test specimen in the middle of its length. For this reason it was necessary to modify the method of clamping of the specimen, as well as the entire system of the loading mechanism of the test specimen.

The system of clamping of the test specimen has been designed as is shown in Fig. 1. Both ends of the test specimen **1** will be clamped in the designed clamp. Structurally the clamps consist of four parts, namely of the base body **2**, the fixing sleeve **3** and of two identical fixing segments **4** and **5**. The clamps are designed so as to enable easy clamping of the specimen, an unambiguous transfer of the load upon the specimen, and that they meet the conditions of loading. It was also kept in mind that parts of the clamp should be simple enough to fabricate without special effort.

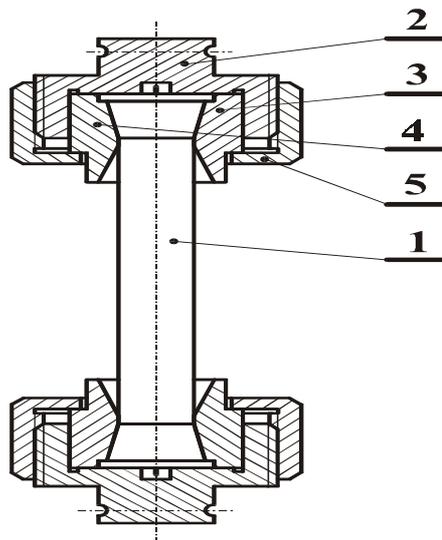


Fig. 1

One end of the test specimen will be inserted into the clamp throat entrance with a recess in the clamping segments **4**, **5**. The segments, together with the specimen, will be inserted into the accurate cylindrical opening in the base body **2**. The sleeve **3** will be slid onto the smaller external surfaces of the clamping segments, the sleeve being subsequently bolted and tightened. Thereby the clamping of an end of the specimen itself is completed. A cylindrical surface with a groove is formed in the main body, which enables to subsequently insert the specimens into the specimen-clamping device in the testing equipment. The designed clamping system ensures accuracy and axial alignment of the clamping of the specimen. It also enables to define the angle of incidence of the material between the clamped and the

deformed part of the specimen, and the stem of the specimen near the clamped part may be deformed only by the angle given by the conical surface in the clamping segments. It will be possible to fabricate the clamping segments with various angles of the cone and thus to simulate different angles of incidence during the test. At the same time, the conical recess will enable that the specimen be deformed in the direction where the resistance of the tested material to deformation is the least. Moreover, the designed system of clamping enables to vary the loading of the cord itself. As is seen in Fig. 2, a cylindrical cavity is formed in the middle of the base body, whose diameter is greater than the diameter of the cord. Thus, during the compression of the specimen, the loading force will not be exerted directly upon the cord and deformation of the cord, if any will be caused indirectly, through the deformation of the rubber. If the base body is fabricated without this cylindrical cavity, the loading force will be exerted upon the cord directly, and hence it will deform the cord directly. It is assumed that these differing methods of loading will be found useful especially in steel-cord reinforced specimens.

The design of the clamping device

The following requirements must be met in the design of the clamping device:

1. high precision and sufficient rigidity of the clamping device
2. possibility of clamping a number of specimens in the clamping device
3. maximal structural simplicity
4. highest possible service life and reliability of the designed structure
5. easy fabricability of components

With a view to meeting the conditions of experimental tests and the conditions set out above, it has been decided to use a normalised guide stand in the structure of the clamping device which can be adapted to the conditions of cyclic loading by simple modifications. The advantage of using normalised guide stands is the fact that the upper, movable part of the stand travels in the guideway made up of a sleeve and a column. The movement of the upper part is thus conducted along a precisely defined path. The precision of the movement depends on the structural type of the guideway used in the design of the stand, which can be sliding guideway or linear motion guideway. The wear of the guideway and the service life of its component parts also depend on the type of the guideway.

The guide stand conforming to standard STN has been used in the present design of the test equipment. This guide stand is equipped with circular work surfaces with the diameter of 200 mm. The upper **2** and the lower **3** faceplates must be fixed onto the work surfaces of the stand in a precisely defined position. Using pins ensures accurate positioning of the faceplates on the work surfaces of the stand. The faceplates are fastened to the work surfaces with bolt joints. Seven test specimens with the clamping heads **1** mounted will be inserted into the openings of the faceplates. The position of the clamping heads on the test specimens will be fixed by stud bolts **4** in both the upper and the lower faceplate. The tips of the stud bolts fit in the groove formed in the base body of the clamping head. In the stage of fabrication of the faceplates and of fixing thereof onto the components of the guide stand, it is necessary to ensure that the specimens, the clamping heads and the openings for mounting of the clamping heads in the upper and the lower faceplates are axially aligned. Identical loading of all test specimens will be achieved only on meeting this condition.

An overall view of the complete aggregate for the loading of test specimens is shown in Fig. 2.

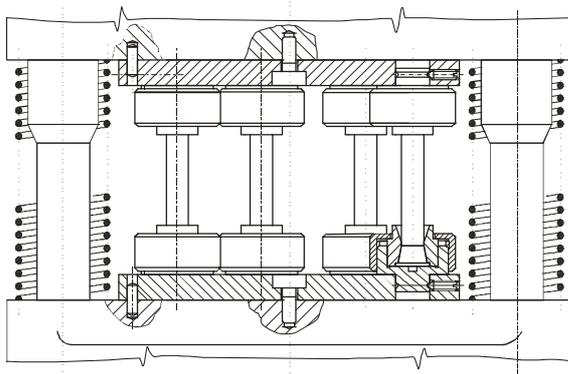


Fig. 2

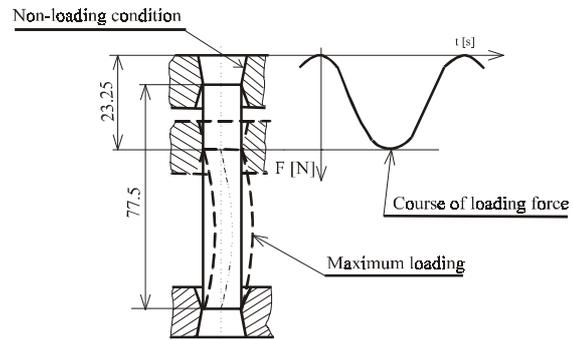


Fig. 3

The design of the loading mechanism

The function of the loading mechanism is to ensure the conditions, defined in the introduction, for conducting the experimental tests.

In order to make it possible to continuously vary the frequency of the loading force, it is advantageous to use an electrical motor with a semiconductor speed control as the drive of the loading equipment.

There are a number of mechanisms enabling transformation of rotary motion into translator's motion. From the point of view of achieving a maximum design simplicity of the loading mechanism, cam mechanism appears to be the most advantageous. Its disadvantage, however, rests in the fact that it does not allow a continuous variation of the feed and hence it would be necessary to design and fabricate a new cam for each degree of deformation of the specimen. On the other hand, its advantage is the fact that even in various degrees of deformation of the specimen it is not necessary to additionally set the test specimen-loading node. This, however, will hold true only if all cams to be used in conducting testing in selected degrees of specimen deformation possess an identical radius of the non-stroke part ($r = \text{const}$).

Analysis of deformations in the test specimen

The method of the application of load to the specimens by force whose magnitude varies periodically along the sine curve is shown in Fig. 3. The maximum deformation of the specimen is 30% of the functional length of the specimen (77,5 mm), which constitutes the specimen's deformation of (23,25 mm) at the maximum frequency of force variation of 30 Hz. Loading tests are conducted on two types of specimens: on specimens with no steel cord and on specimens reinforced with steel cord of $\varnothing 1$ mm which is cured in the centreline of the specimen.

Two finite-element models have been created to calculate great deformations. The model with no steel cord is shown in Fig. 4 and the model with steel cord of $\varnothing 1$ mm is shown in Fig. 5. The material constants for rubber and steel cord, which have been used in the calculation, are in Table 1.

Tab. 1

Material	ρ [kg.m ⁻³]	E [MPa]	m	G [MPa]
Rubber	1255	8,2	0,488	2,8
Steel cord	7800	2,1	0,33	0,8

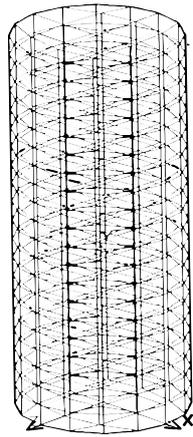


Fig. 4

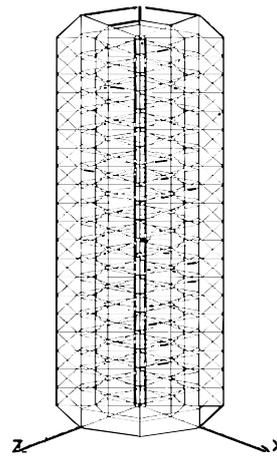


Fig. 5

Specimen No. 1 with no steel cord is substantially more flexible than the steel cord reinforced specimen No. 2.

This is corroborated by the calculation of shifts (Fig. 6 and 7) at an identical loading force. In order to verify the results of calculation, it is necessary to perform experimental measurements and subsequent evaluations on a greater number of specimens and to modify the calculation accordingly. Items involved here are the actual marginal conditions of the clamping of the specimen, properties of adhesion between steel cord and rubber, magnitude of the loading force and its frequency, the shape and diameter of the steel cord, etc. The testing machine enables to clamp the specimen so as to allow to move the steel cord out of the specimen or not, as necessary. The shifts in Fig. 7 are calculated for such compression of the specimen, which will allow moving the cord out of the specimen. The shift is given in metres.

Conclusion

The theoretical and experimental model tests enable to select the most suitable version in solving the problem of loading the tyres of transport vehicles. The test results may be utilised in developing new models and true to shapes of tyres. The test results may also be used in comparing the efficiency of different testing methods.

Acknowledgements

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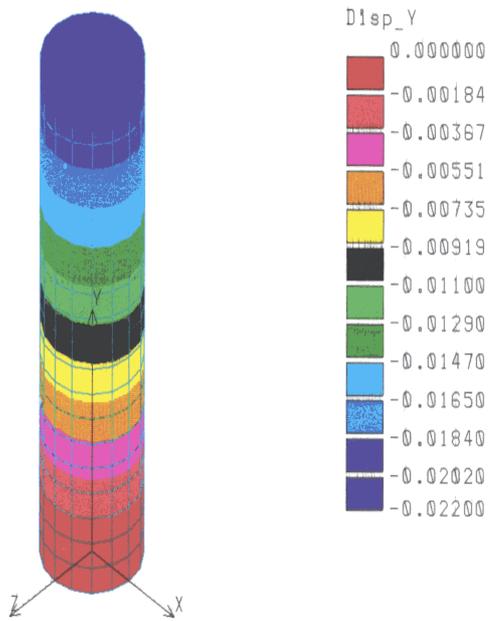


Fig. 6

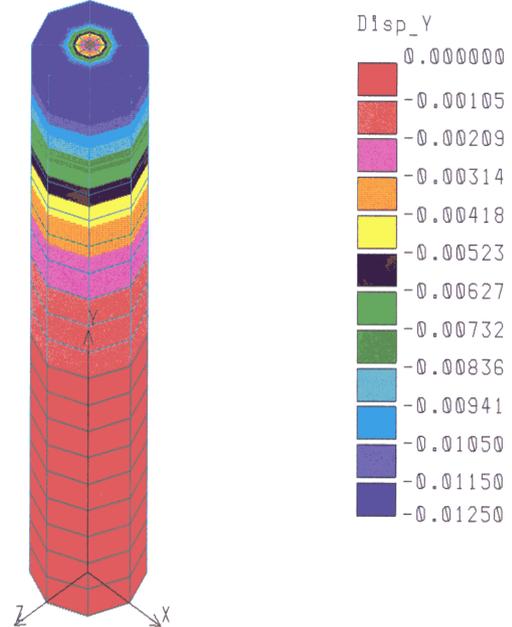


Fig. 7

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