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THE IMPACT OF THE STEEL CORD CONSTRUCTION ON ITS DECLINE OF BREAKING FORCE AFTER FATIGUE TEST IN BIDIRECTIONAL BENDING CONDITIONS

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Preliminary Note – Prethodno priopćenje

In the paper the influence of bidirectional bending on breaking force of steel cord has been assessed. Tests were carried out under laboratory conditions on three types of cord. It was found that bidirectional bending of steel cord cause the deterioration of strength properties and weakening of steel cord as a result of its fatigue. The obtained results may find application in the wire industry while implementing the new production technologies of steel cord.

Key words: steel cord, fatigue strength, force, mechanical properties

INTRODUCTION

The progressive development of the automotive industry and the unrelenting demand for transport services, against whom it is committed to increasing demands caused that seeks to increase capacity cars, and thus increased the requirements for tire performance properties. An important group of steel products are steel cords which are used to reinforce car tires [1-3].

The design of the tire requires a material with high tensile strength and low elongation. The most important part of the tire's carcass - structural skeleton tires composed of one or multiple layers of steel cord [4]. Steel cord is a product of a wire in the form of strands or cables, which affects a significant effect on improving the quality and reducing the tire rolling resistance [5].

In the life of the tire affects its internal structure, and used to strengthen the so-called. reinforcement. All wires, strands and ropes used for the reinforcement of tires must meet very high technical requirements.

Tyre manufacturing companies try hard to reduce their production costs. Steel constructions, which not so long ago were produced in large volumes, e.g. 4 x 0,28, are being replaced with constructions of a smaller number of wires, such as 2 x 0,30. This is obviously associated with a lower price and mechanical parameters that surpass the values of the original multi-wire constructions.

All this resulted in a change in steel cords. Materials with a carbon content higher than 0,8% were stated to be used in order to attain high final strength in drawing wires, while retaining the fatigue properties of steel cords manufactured. Currently, there are high-speed tyre cords, in which the wire strength reaches a level of 4 000 MPa. These are so called ultra-tough steel cords.

M. Suliga, R. Kruzel, Czestochowa University of Technology, Czestochowa, Poland

Therefore, the study attempts to assess the impact of fatigue on the steel cord strength properties.

MATERIAL AND APPLIED DRAWING TECHNOLOGIES

The material for the study were the steel cords from C72 grade (Table 1). Were chosen three types of cords, the following structures:

- cord A - construction 3x0,15+6x0,27
- cord B - construction 2+2x0,25
- cord C - construction 2x0,30

Table 1 **Chemical composition of steel /wt%**

C	Mn	Si	P	S	Cr	Ni	Cu	N
0,76	0,55	0,21	0,008	0,012	0,02	0,02	0,03	0,02

Fatigue tests of steel cord were conducted on fatigue machine of his own design, made at the Institute of Plastic Forming and Safety Engineering, Czestochowa University of Technical, Figure 1.

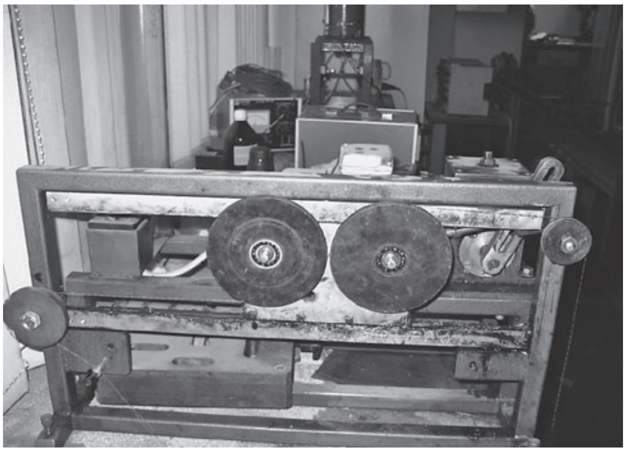

Figure 1 The fatigue testing machine

Fatigue tests consist of subjecting the sample to the cord quickly and complex cyclically changing loads, with values similar to those which occur in operational conditions. In order to play such conditions are built machine fatigue different structures [6]. To accelerate the process of progressive fatigue and shorten the duration of the test, the fatigue machines apply a small wheel diameter D relative to the diameter d of the cord and the substantial bending of the speed, expressed in the number of bends per unit of time.

For a full unidirectional inflection machine bending fatigue of the cord is meant the state of the bent and straightened to return to the initial state, and a full two-way meant shoulder transition from the bent state to the straight position, and then bent in the opposite direction. Frequency fatigue machine load changes is the number of cycles N per minute, ie full movement of the cord back and forth. During the test in the cord occur following stress:

- variable tensile stress,
- bending stresses caused by varying bending moments,
- varying the compressive stresses induced in the grooves of the transverse pressure of the wheels.

All stress variables are cyclical and cause some fatigue cord, manifested by cracking scrap wires with a characteristic fatigue and increasing elongation of the specimen.

RESULTS

Made cords were tested actual breaking force cord in its entirety (for adapted to the testing machine). Then, knowing the value of the breaking force steel cord matched the corresponding load, assumed to be between 0,3 breaking strength cord. After installing the steel cord load placed and mounted on a testing machine fatigue life. Table 2 shows the parameters of the fatigue test.

Table 2 **The parameters of the fatigue test of investigated cords**

Steel cord construction	Length of section / mm	Load / N
3x0,15+6x0,27	800	333
2x2x0,25	800	188
2x0,30	800	133

Each steel cord was subjected to a fatigue test, which lasted respectively 15, 30, 60 and 120 minutes. During the study period, the number of cycles, which should be understood by the number of full bi-directional hinges. Several times during the study counted the number of bends in relation to the unit of time, to give the result of 45 full bends / minute. The cord was double-push it at cyclically varying loads tension and turnover cord around its own axis. Next, the breaking force of steel cord was estimated.

For a more complete analysis of the impact of steel cord fatigue on its strength properties, in the study the approximating functions showing the relationship between breaking strength steel cord and the number of fatigue cycles were shown. The test results are presented in Table 3 and in Figures 2-5.

Table 3 **Results of breaking force measurements for particular cord types, with the number of fatigue cycles indicated**

Number of cycles N	Cord breaking force F, N		
	A	B	C
0	1 665,1	938,9	443,1
675	1 661,4	936,8	442,1
1 350	1 655,8	928,1	432,5
2 700	1 632,1	902,1	402,8
5 400	1 571,9	870,7	385,7

The study showed a gradual decrease in the strength of the cord subjected to a specific fatigue, which is confirmed by the calculated percentage differences in Table 4

Table 4 shows further that the decrease in strength of the steel cord under the influence of variable bending stress is not a linear one. With a small number of fatigue

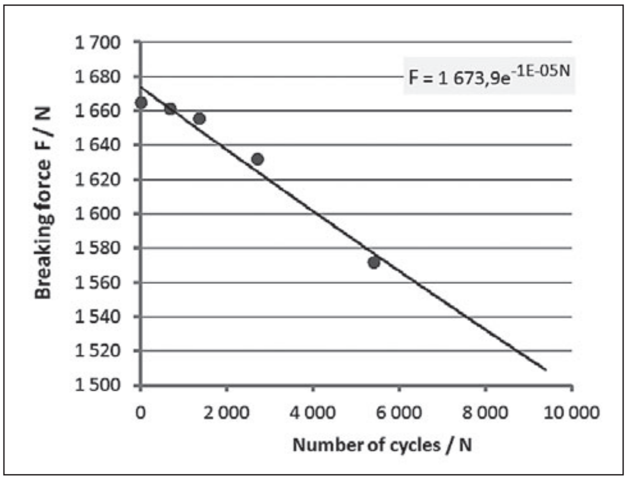

Figure 2 The diagram of the breaking force F decrease as a function of the number of fatigue cycles for the 3 x 0,20 + 6 x 0,35 design cord

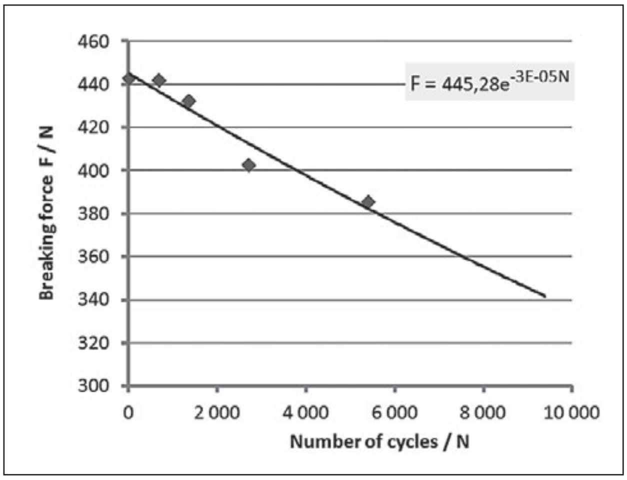

Figure 3 The diagram of the breaking force F decrease as a function of the number of fatigue cycles for the 2 x 2 x 0,25 design cord

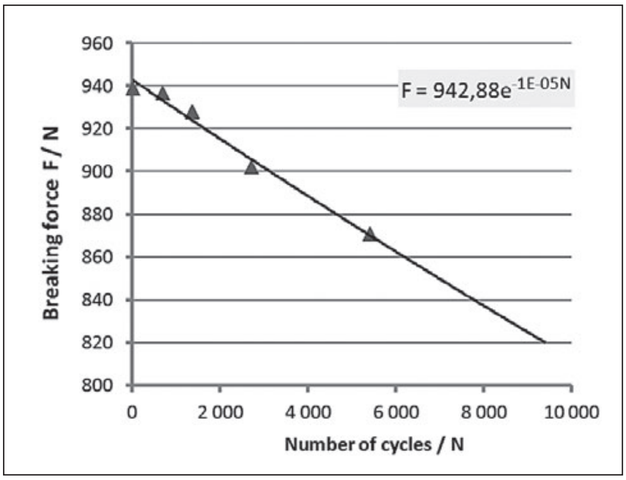

Figure 4 The diagram of the breaking force F decrease as a function of the number of fatigue cycles for the 2 x 0,30 design cord

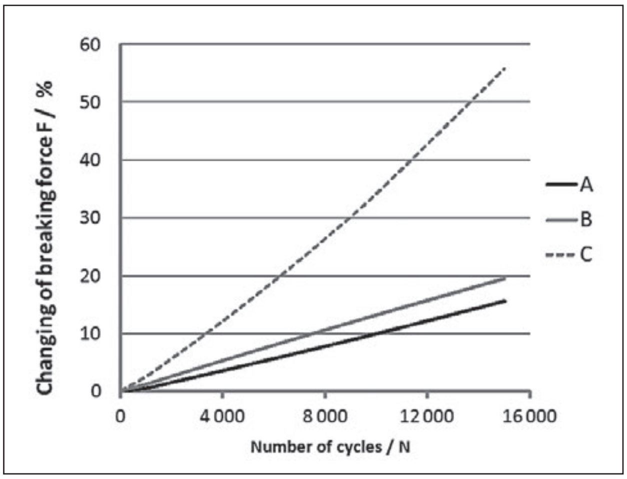

Figure 5 The percentage decline of breaking force as a function of the number of fatigue cycles for the design cord from A, B and C variant

Table 4 **The decrease of the strength of particular steel cords, depending on the design type and the number of fatigue cycles applied**

Steel cord construction	Percentage decrease in breaking force, depending on the number of cycles / %			
	675	1 350	2 700	5 400
3x0,15+6x0,27	0,2	0,6	2,0	5,6
2x2x0,25	0,1	1,2	3,9	7,3
2x0,30	0,2	2,4	9,1	13,0

cycles regardless of the type of test cord observed a slight, statistically insignificant decrease in breaking strength. At about 700 cycles of fatigue differences between cord Fm in the initial state and the cord after a fatigue test was approximately 0,2 %. However, after exceeding 1 500 cycles of fatigue observed a significant decrease in breaking strength. For 5 400 fatigue cycles, depending on the type of test there was a decrease of the cord strength in the range of 5 - 13 %. From Figure 5 shows that while significant elongation steel cord fatigue testing to more than 10 000 cycles causes a sharp decline in its strength, depending on its design differences can amount to over 30 %.

The largest decrease was observed strength steel cord for cord 2 x 0,30 construction. In contrast, the least impact on the strength of the cord was the test carried out on cord 3 x 0,15 + 6 x 0,27 construction (Figure 5). What confirms that way of cord coiled, the number of wires and their diameter have a major impact on the resistance of steel cord fatigue. Thus, it can be hypothesized that the appropriate selection of steel cord construction for a particular model of car tires should contribute to a significant improvement in its quality.

CONCLUSIONS

From the experimental studies carried out, the following findings and conclusions have been drawn:

1. Steel cord fatigue caused by bidirectional bending will affect the strength properties.
2. The decrease in breaking force of steel cord under the influence of variable bending stress is not a linear one. With a small number of cycles of 700, the differences in the strength properties of the cord are negligible. However, at 10 000 fatigue cycles there was a significant loss in strength of the cord, the differences ranged from 10 to over 30 %.
3. The method of cord coiled, the number of wires and their diameter have a major impact on the resistance of steel cord for his fatigue.
4. The use of steel cord of type 2x0,3 on the one hand allows to reduce production costs, on the other hand reduces its variable resistance to the stresses to which the cord is subjected to a vehicle tire during its operation.
5. The results can be applied in wire industry while the implementation of new production technologies of steel cord.

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Note: The professional translator for English language is Krzysztof Skorupa, Myszków, Poland