USING OF COMPUTATIONAL MODELLING TO LONG-FIBRE COMPOSITE

Jan KRMELA*, Miroslav MÜLLER, Vladimíra TOMANOVÁ***, Soňa RUSNÁKOVÁ*****

* University of Pardubice, Czech Republic
** Czech University of Life Sciences Prague; Czech Republic
*** Trenčín University of Alexander Dubček, Púchov, Slovakia

Abstract. The article deals with using the computational modelling to long-fibre composite structures with an elastomer matrix. These structures are included into tire for transport means e.g. radial tire for passenger vehicle as steel-cord belt plies. If good approach will be applied to the computational modelling of tire composite parts then good results are obtained. The good models must include all necessary inputs as geometry, material parameters of reinforcement and elastomer matrix, loading conditions etc. Then models represent actual states of composite structures, used in automobile tire-casing. The attention will be paid to the steel-cord belt plies which are composite structures with elastomer matrix and reinforcing steel-cords. The outputs from the computational modelling of tire long-fibre composite will be using as inputs to the computational modelling of the tire as whole.

Keywords: composite, long-fibre, tire, FEM

1. Introduction

The object of author Krmela is long-fibre composites consisting of an elastomer matrix (a rubber) and steel-cord reinforcements [1]. These composites are used in radial tire carcass [2] as two-layer steel-cord belt (figure 1) as example. The steel reinforcements can be in the form of wire and twisted wire. Detail of structure of belt plies, which is used in tire tread, is presented figure 2.

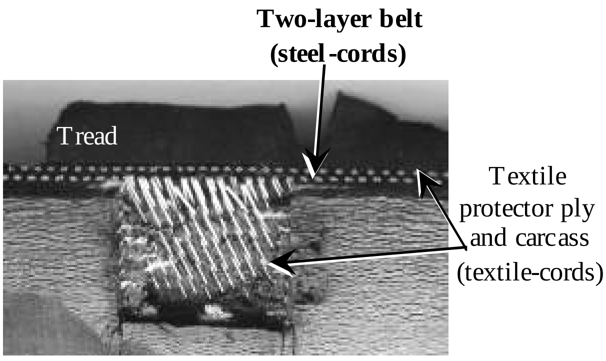

Figure 1. Composite structures used in the area of tire crown

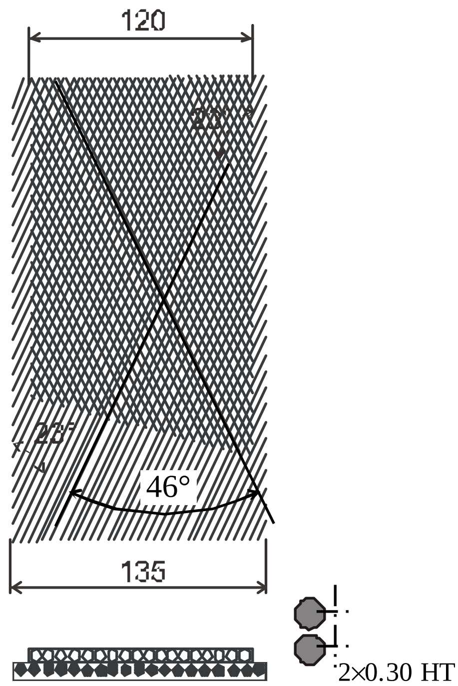

Figure 2. Structure of tire steel-cord belt plies of Matador 165/70 R13 [1]

The objective of this paper is creation of computational models of two-layer belt.
This paper is a part of a long-term scientific project dealing with systemic approach to computational modelling of complex single-layer, two-layer and

multilayer long-fibre tire composite structures with elastomer matrix (figure 3).

2. Computational models of tire steel-belt

The computational models must respect all input parameters presented on the figure 3.

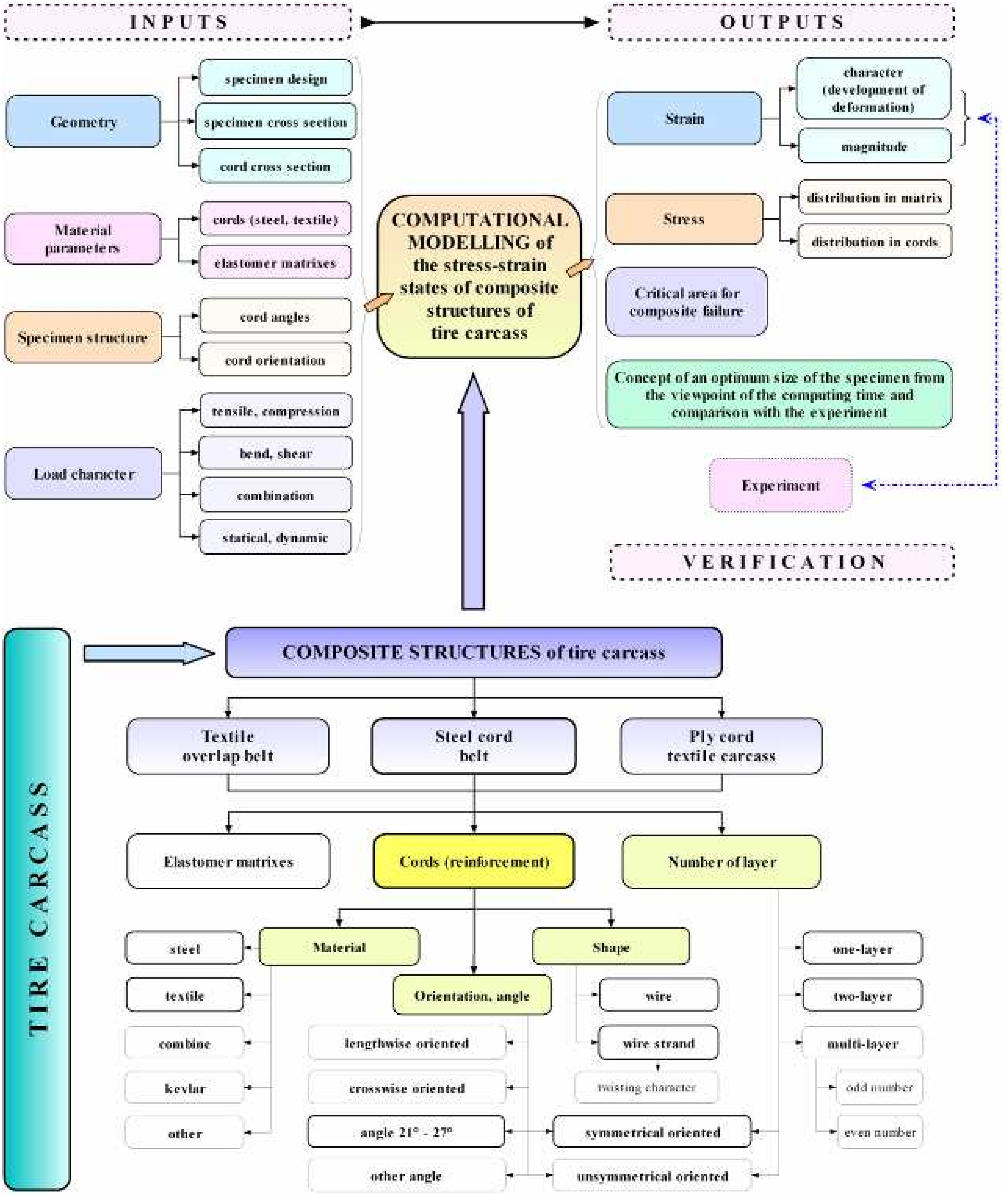

Figure 3. Diagram of necessary inputs for computational models of composite structures and corresponding outputs

The computational models of the stress-strain analyses of steel-belt should represent real state of the steel-belt of the automobile tire casing that will be loaded in several of ways.

For verification of the computational models is necessary to perform static experimental modelling of composite specimens [3].

The computational models were created by Finite element method (FEM) program system ANSYS with different cord-angles and orientation between plies as presented figure 4.

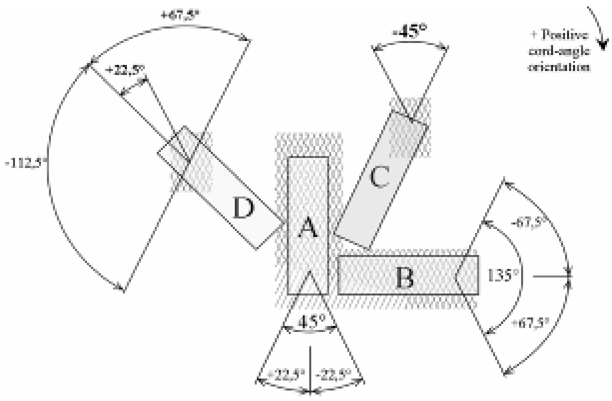

Figure 4. Design of cord-angles of computational model of steel-cord belt [4]

The half of the meshing model of symmetrical belt mentioned above on the figure 2 with size 100x25 mm [5] after tensile test is on the figure 5. The elastomer matrix is described by Mooney-Rivlin hyperelastic material model with parameters C10 = 0.451 MPa a C01 = 0.242 MPa. Steel reinforcement is described by linear isotropic material model. Basic simulations [6] of statically uniaxial tensile and bend tests were executed.

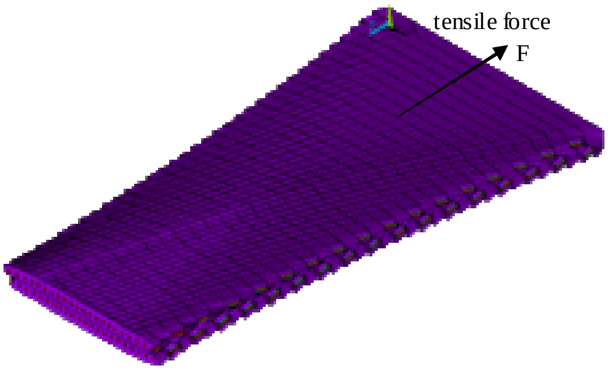

Figure 5. Computational model of steel-belt of Matador 165/70 R13

Example output from strain-stress analyses of symmetrical belt presented figure 6 whereon distribution of stress in cords displayed.

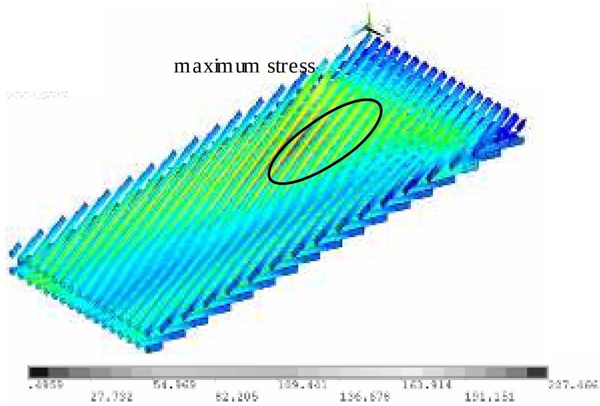

Figure 6. Distribution of stress in cords (half of symmetrical belt model)

Figure 7 presents other computational model of steel-belt plies with unsymmetrical oriented -67.5°/+22.5° cords (cord angle between layers is 90°) as example.

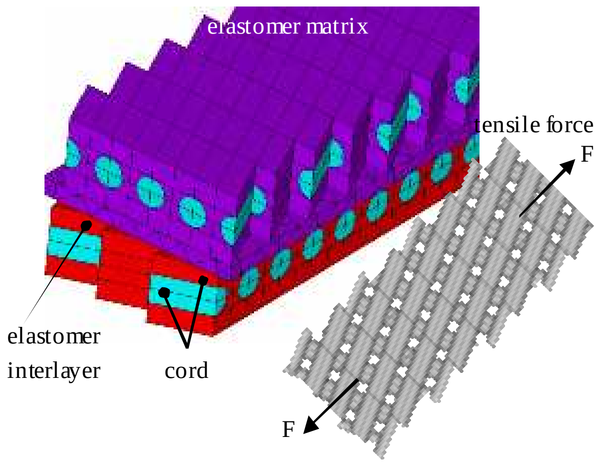

Figure 7. Design of model for unsymmetrical oriented two-layer steel-belt [1]

3. Computational model with adhesive bond

In complicated computational model of steel-belt, the character of interlayer at the border of matrix-reinforcing materials is taken into the consideration. In available literature, there is not so much attention devoted to topic of adhesion bond into tire composites for the computational modelling.

Figure 8 shows the way of adhesive bond incorporation in way of considering the replacement by third material. The model of half of one steel-belt layer with the reinforcement formed by compact wire is being concerned. Original border of cord-matrix (i.e. steel-cord diameter) is illustrated with dash line. This model based on higher-level knowledge with inclusion of all input data.

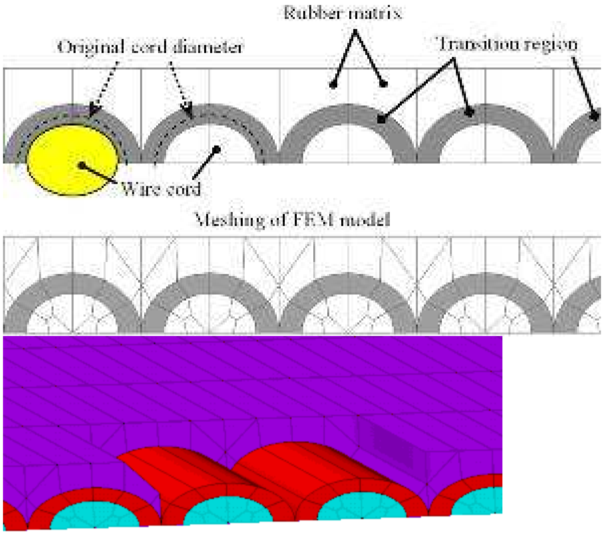

Figure 8. Design of computational model of steel-cord belt (half of one-layer with orientation angle 30°) with adhesive bond [7]

Generally, for creations computational models of composites structures is necessary to have a good knowledge about:

- structure of tire-casing as whole;
- steel-belt which used into radial tires;
- adhesive bond metal-elastomer, which obtained by metallography observation of reinforcements-matrix transit;
- material parameters of matrix and reinforcing cords. These parameters will be obtained by experiments;
- influence of degradation process – corrosion effect on composite materials from micro and macrostructure point of view.

Only this way we can derive high level computational models which include all input information and, simultaneously, models that are to be open for further usage.

Then will be possible these models used for statically tests under combined loading states (combinations tensile with bend) - that are to be approximated tire real state during tire operational loading (predicate about real deformation behaviours of steel-cord belt).

4. Conclusion

The outputs from the composite structures modelling will be used as inputs into the modelling of the dynamic states of tire composites structures and the strain-stress analyses of the tire.

Obtained outputs of modelling of composites can be used for geometry and cord-situate optimalization. The purpose of the optimalization is to obtain demanding characteristics of composites (stiffness in individual directions) for predicting e.g. demanding working deformation behaviour of tire as a complex.

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