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# THE COMPUTATIONAL MODELLING OF TIRE

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**Abstract.** The article deals with the computational modelling of the strain-stress analyses of radial tire for passenger vehicles. The Finite Element Method (FEM) using the program system ANSYS is applied to the computational modelling. The tire is complicate composite structure which consists of textile-cords, steel-cords and elastomer parts of tire carcass. For computational modelling of tire is necessary knowledge about experimental modelling of tire from macrostructure and microstructure.

**Keywords:** tire, fem, strain-stress analyse

## 1. Introduction

Tire as the element assuring good interaction between car and road must meet critical safety criteria at high speeds. This is incidentally also a question of assigning the correct type of a tire to a car and to its operating conditions (tire only for road operation, for off-road, combined operation as well as for summer or winter conditions).

The passenger vehicle radial tire consists (e.g. cross-sections are on the figure 1) of elastomer parts and composite structures with textile cords (especially PA 6.6 and PES textile fibers are used) and steel-cords which can be in form of thin wire or wire strand with different constructions [1]. The composite structures applied into tire (figure 2) with different cord-angle, material of cords, numbers of layer (single-layer or multi-layer) are:

- textile tire carcass,
- overlap textile belt,
- steel-cord belt.

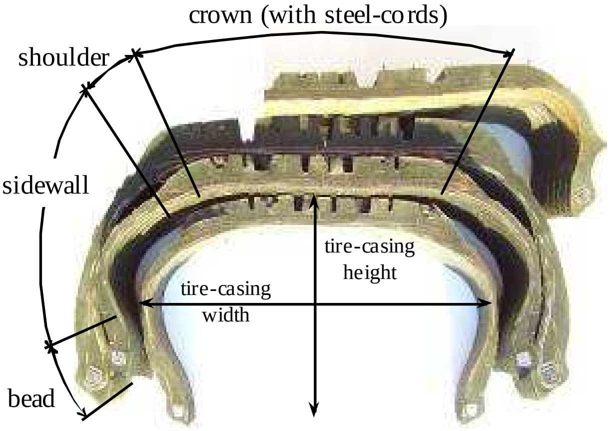


Figure 1. Cross sections of tire-casing

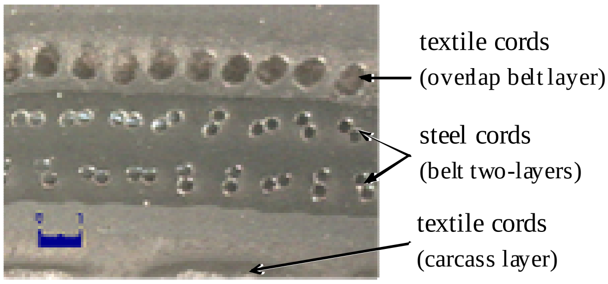


Figure 2. Structure of tire in the middle of tire crown

The tire is during the operation exposed to combine loading as from a mechanical (statical, dynamic) as a temperature point of view (local heating in subzones, global heating in the tire-tread area permeating into the tire during breaking).

This is why the use of computational modelling is applied also to the field of tires (design modification – change of inclination angle of reinforcing fibres, number of reinforcing layers, materials of cords, etc.) of purpose namely increasing of tire safety during the operation of a vehicle at high speeds. The computational modelling of the tires as an entity allows solving various ways of loading as well as to assembly the models at the various levels.

The work of the author over a long period is devoted to radial tires for passenger vehicles and particularly to their computational and experimental modelling [1 ÷ 6].

In order to be able to adopt a comprehensive approach to the state of the art trend of computational modelling, it is necessary to have good knowledge of the function of wheels with tires, different types of tires, their design, structure, range of materials, operating conditions, characteristic behaviour at particular modes of loading and knowledge of more details and data. All these can be considered as input parameters absolutely necessary for computational modelling of tire without which present modelling engineers cannot manage.

This contribution is devoted to compiling computational models of the tire casing at the static level (strain-stress analyses) to determine deform-loading features in a way so the models will include all necessary input parameters, which complexly describe the tire and interaction of the tire-casing with the road. Therefore, at the same time those models could be, after e.g. meshing simplifying and adding other input parameters of dynamic load, used as a basis for computation complex dynamic tasks. Just in this way the computational models on high level can be obtained and would include all input information and same models to be opened for further usage (e.g. thermodynamic tasks, etc.).

It is necessary experimental tests of tires for verification analyses between experiment and compute.

## 2. Static tests of tires for computational modelling

Knowledge of the extent of resistance of tires to various modes of loading and effects of the environment is gained from tests of strength and life – in other words from destructive tests. Also basic statical deformation characteristics of tires can be obtained from a device called statical adhesor (figure 3), which is available to author. The statical adhesor also enables measurement of data from the contact surface under defined conditions – shape of obstacles, vertical loading and inflation pressure.

It is possible to obtain outputs from experiments on statical adhezor:

• radial deformation characteristic (by vertical tire force loading),

• torsion deformation characteristic (slip curve by twist moment),

• size and shape of contact area and distribution of contact pressure,

at following conditions:

• loading (vertical),
• tire pressure (under-inflation, overinflated tire, specified pressure),
• size of radial deformation,
• shape of obstacle etc.

Figure 3. Statical adhezor with contact area detail

## 3. Static computational models of tire

Compiling static computational models was requested by solving many difficult tasks, challenge was mainly in setting material parameters and their correct description (question of proper material models choice). It is necessary to bear into the mind that material parameters are not constant values, but depend on temperature parameters etc. Further, on, the elastomers have non-linear characteristics and cannot be described by only two parameters – Young model of elasticity and Poisson factor as is being presented also in specialized technical literature.

The compiled computational model for determining the deformation states of tire Matador 165/70 R13, which includes all necessary input parameters presented on the figure 4, is shown on figure 5 as example. The Finite Element Method (FEM) using the program system ANSYS is applied to the computational modelling.

Reinforcement parts of the tire are made up of the areas, which are described as orthotropic models of material behaving such so-called rebar features [1]. Material factors for their description were obtained based on the computational modelling of on-purpose splitted the tire parts so based on detail models of e.g. steel-cord belt. It is due to non-possibility of detail incorporation of reinforcement cords into the computational models of whole tire so it is necessary to alternate the belts and the textile-carcass.

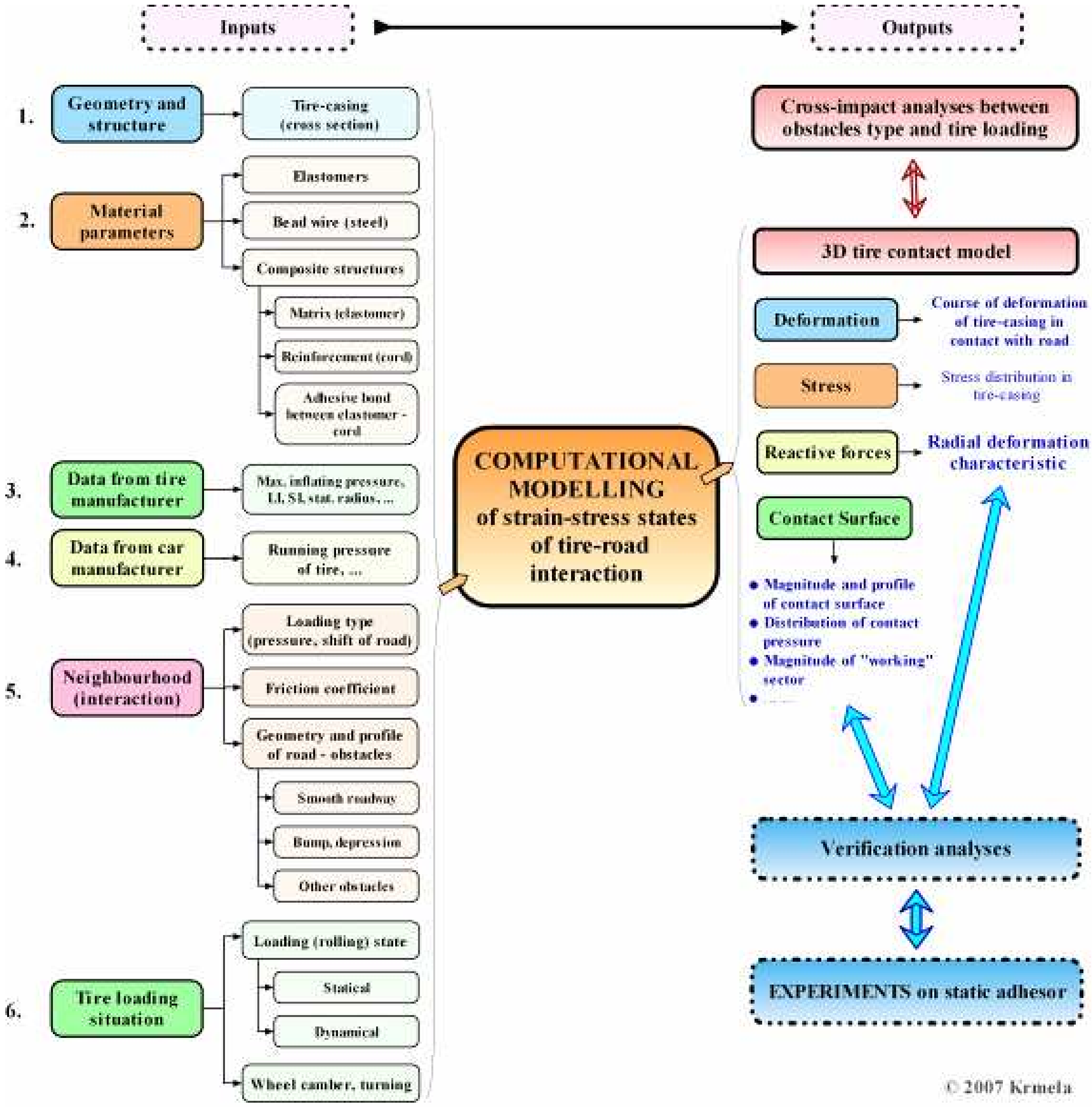


Figure 4. Necessary inputs to computational models of tire

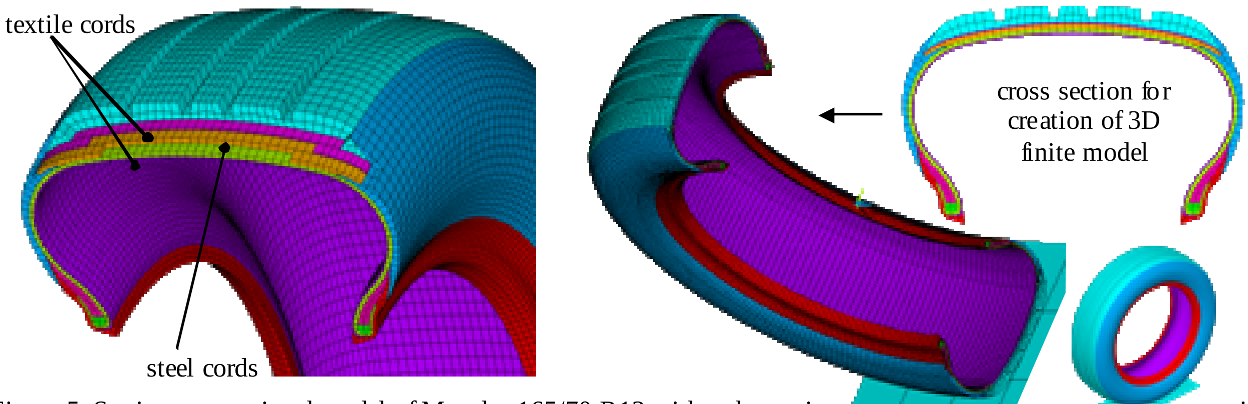


Figure 5. Static computational model of Matador 165/70 R13 with orthotropic material and rebar element for composite structures and hyperelastic material model for elastomer parts of tire

Presented computational model shows good results at interaction of the tire with the chosen road surface bumps [6] while the effect of vertical static force counting with the weight of the car.

The outputs from computational modelling presented figure 6 as example. The maximum value of contact pressure is at the end of steel-cord belt layers. The presented computational model of tire has good verification with experiment on statical adhesor by deformation characteristic.

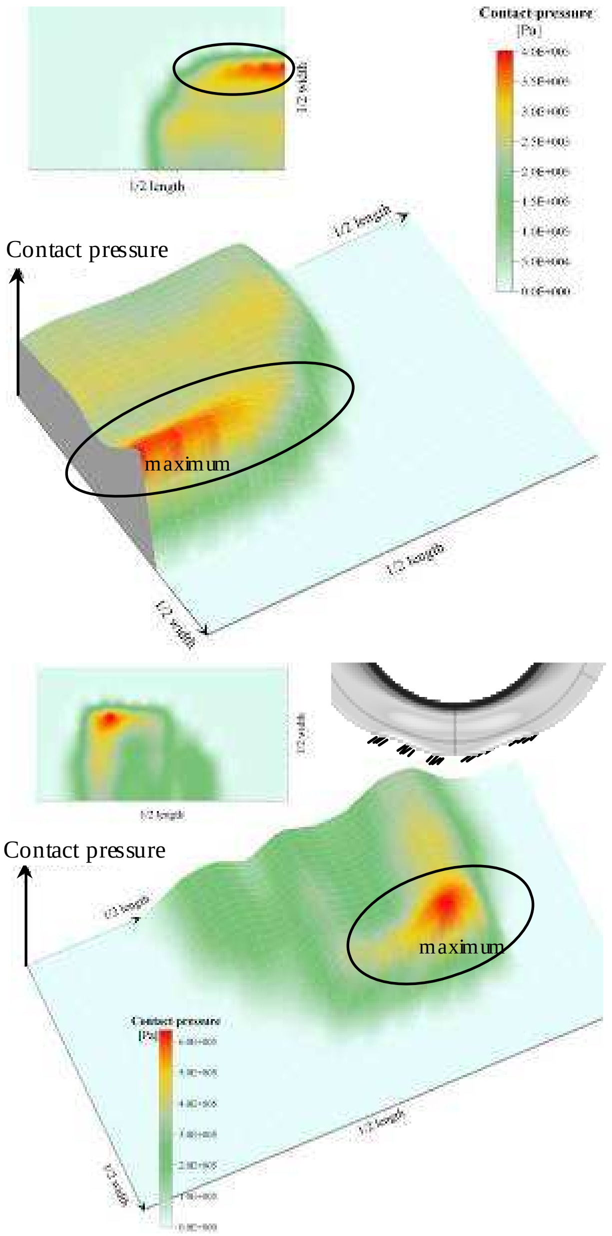


Figure 6. Distribution of contact pressure in contact surface on smooth roadway (above) and on concave obstacle for "great" radial deformation (c. 20 mm)

There is an assumption that after extension by the dynamics and implementing further modifications of the model, the definition of realistic blocks, the model will pass the computation also at the solving of dynamic loading states.

## 4. Conclusion

This contribution was originated based on experiences with computational modelling of the parts of the tire, which are so demanding from material as well as combined load point of view. It will be very important which way to be chosen by an engineer to compile correct computational models of the car tires, which would be proper for dynamic load states. At the same time, those models need to be opened for different way of loading states and allow the solving not only stress-strain states but as well as modal analysis, thermal fields questions, rolling mode et al.

In available literature, there is not too much attention devoted to this topic.

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