An engineering model for the prediction of pantographing in rubber tire moulding

Benoit Debbaut

ANSYS Belgium s.a.
avenue Pasteur 4, B-1300 Wavre, Belgium
benoit.debbaut@ansys.com – www.ansys.com

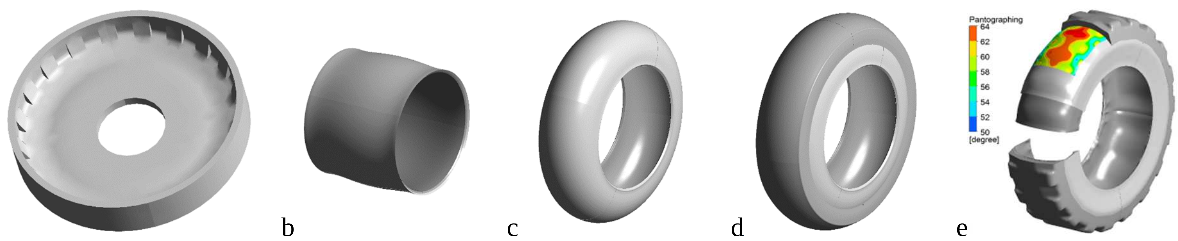
ABSTRACT

A key stage in the rubber tire manufacturing process is the moulding. Layers of rubber are assembled in order to make the unvulcanised tire: some of those layers are reinforced with fabric cords or wire cords. The unvulcanised tire is then placed into a curing mould, where inflation and heat are applied in order to give the final shape to the tire, including the tread patterns and markings. During inflation, the relative orientation of reinforcement sets of cords or wires changes. This is usually referred to as pantographing, and it may affect the end-use properties of the tire. It is therefore important to get a picture of the possible changes of orientation of reinforcement sets during inflation.

Describing the individual components of reinforcement sets would probably be too complex. A macroscopic model after the fashion of orthotropic elasticity is more reasonable [1]. Reinforcement wires oriented along a given direction confer an orthotropic property to the compound: the compound exhibits a specific strength along the direction of orthotropy. From this physical consideration, one can easily develop a constitutive model where the contribution of the reinforcement cords or wires is superimposed to the (isotropic) contribution of the compound [2].

Let us consider the manufacturing of a rubber tire whose shape will be given by the mould shown in Fig. 1(a). At the beginning, the carcass and a rubber layer are in a cylindrical configuration as seen in Fig. 1(b); reinforcements along the axial direction are embedded into the carcass. Axial displacement is imposed at the edges of the cylinder in order to obtain a torus, as shown in Fig. 1(c). Subsequently, two reinforcement belts and tread are placed on the torus, as shown Fig. 1(d). Reinforcement in the belts have an initial orientation of +40 and -40 degrees with respect to the symmetry plane of the tire. Placing both reinforcements belts on the torus already generates a preliminary pantographing.

The unfinished tire is now placed into the mould for final inflation and curing. A pressure is applied in order to guarantee a good contact between the tire and the mould, so that the tread markings are properly shaped. Although overall deformations produced by the inflation pressure remain moderate, they can locally be significant. In particular, this concerns the reinforcement belts, whose reinforcement directions can vary. After inflation, one can evaluate the amount of pantographing by considering the scalar product between the reinforcement orientations of both belts. In Fig. 1(e), we display the distribution of angle between both reinforcements sets. As can be seen, the local distribution ranges from 52 to 64 degrees, and to some extend it is also the finger print of the required tread patterns.



a b c d e

Fig. 1. Simulation of tire manufacturing: mould (a), initial preparation of the carcass and side walls (b), deformed torus after axial motion of the edges (c), unfinished tire after placement of reinforcement belts and tread (d), tire after moulding and pantographing or local distribution of relative angle between cords of reinforcement belts (e).

REFERENCES

[1]. S. G. Lekhnitskii, *Theory of elasticity of an anisotropic elastic body*, Holden-Day, 1963.
[2]. B. Debbaut, “A simple model for wire reinforced polymer and rubber”, *Rheol Acta*, **54**, pp. 403-409, (2015).