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Study of strain-stress behavior when reconstructing rotary kiln tyres from floating to welded-in type

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Abstract. The paper provides modeling results in the CAD/CAE SolidWorks system with embedded FE-analysis package SolidWorks Simulation to study the hardness of floating tyres during their reconstruction into welded-in tyres.

1. Introduction
A relatively long operating period of technological drum (TD) supports indicated relatively low reliability of floating tyres (“F”), complexity of their mounting, service and repair. Therefore, the supports of operating TDs are modernized by replacing “F” tyres with welded-in tyres (“W”). Fig. 1 shows the design of “F” and “W” tyres, which are currently used for rotary TDs.

a) *b)*

Figure 1. Design of rotary TD supports: *a)* “F” tyres; *b)* “W” tyres

At present, the welded-in tyres are less practical to manufacture, have more complex design and hence, are more expensive in comparison with “F” tyres. The Department of Mechanical Engineering of Belgorod State Technological University named after V.G. Shukhov developed the technology intended for the onsite reconstruction of “F” tyres into “W” tyres [1, 2, 5]. This will provide for considerable cost reduction for the replacement of tyres, increase in their reliability and operating lifetime.

2. Optimal design of shaped grooves
It is suggested to install special shaped ring grooves on tyre faces and to make flaps for subsequent connection with TD casing. The earlier studies [3] show that an optimal design of such shaped grooves

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is an extended semicircle form with inclined bottom and top sides. The form, the size and the relative position of the formed ring grooves are shown in Fig. 2.

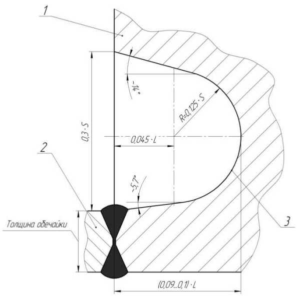

Figure 2. Design of ring shaped grooves on tyre faces during reconstruction

Since the tyre section form will be changed during reconstruction, there is a need to define an optimal form of such section thus ensuring smooth strain distribution in places of their further connection with casing, conditions of minimum hardness change and minimum reconstruction cost. The study was conducted by modeling in the *CAD/CAE SolidWorks* system with embedded FE-analysis package *SolidWorks Simulation* both for a particular dismantled tyre and for a tyre with casing elements and loads corresponding to operating conditions. The first task presents an interest from the standpoint of shaped ring grooves processing technology. The second task will, in general, allow assessing the possibility of practical application of such technology.

Since it is implied to treat surfaces in TD operating conditions, it is advisable to use a centerless scheme when a tyre, dismantled from a TD, is installed on support rolls of a special stand. Considering the heavy weight of a tyre, this scheme of installation may lead to its considerable deformations. It is obvious that in various zones, the deformation values will differ, which will allow, first of all, defining the value of potential deformation for its comparison with dimension tolerance and determining the optimal area of a processing tool placement against support rolls of a special stand.

Carbon cast iron was chosen from the embedded software library. To simulate the installation of a tyre on support rolls, a certain limit was set – fixed geometry of preliminary defined tyre boundaries on the outer roller face, corresponding to the contact area between a tyre and a roll. The boundary size is defined by the following formulas [4]:

$$a = 1{,}52\sqrt{\frac{p}{E}\cdot\frac{R_1\cdot R_2}{R_1+R_2}};$$

$$p = \frac{F}{S},$$

where a – boundary half-width, mm; S = 2000a – boundary area, mm^2; F = 280000 N – boundary applied force (its value is defined according to tyre weight m = 56000 kg); R_1 = 3050 mm – tyre radius; R_2 = 1700 mm – roll radius; E = 206000 N/mm^2 – Steel 35L elasticity modulus.

As a result of the calculations, the half-width contact area of a tyre with support rolls made a = 1.2 mm.

Since within the considered static task, the tyre is deformed under gravity, then the gravity is taken as a load value. Fig. 3 shows the designed models of tyres with the above-mentioned restrictions. Fig. 4 shows the finite element pattern of both models.

a) *b)*

Figure 3. Boundary conditions for tyre models: *a)* reference; *b)* reconstructed

Stress profiles are obtained through modeling (Fig. 4). The software program also makes it possible to define stress digital values at various areas of the studied objects (Fig. 5).

a) *b)*

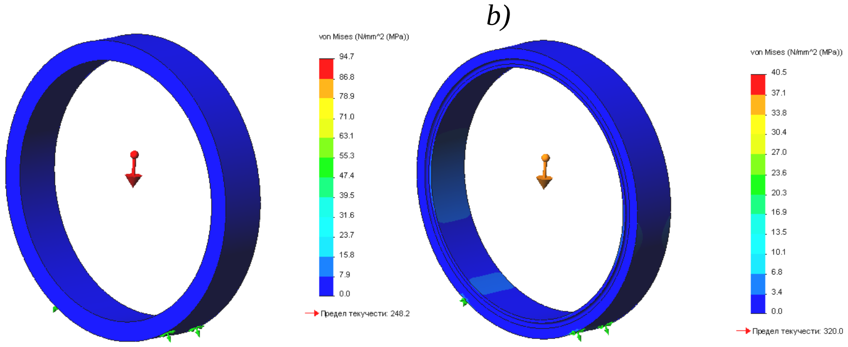

Figure 4. Stress profiles in tyres: *a)* reference; *b)* reconstructed

a) *b)*

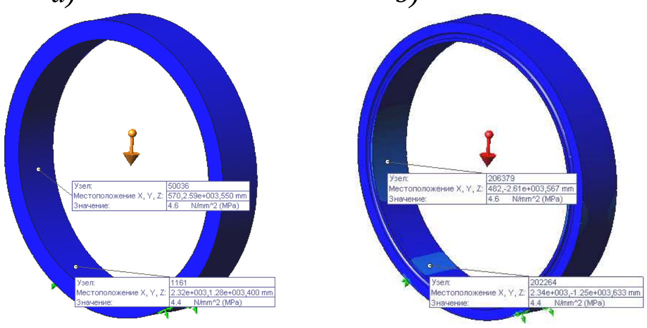

Figure 5. Stress values in certain areas of tyre models: *a)* reference; *b)* reconstructed

The analysis of obtained results shows that the formation of shaped ring grooves does not exert significant influence on tyre hardness, including mostly loaded sections. However, with respect to the first task, it is possible to make a final conclusion by drawing the displacement profiles of a tyre surface (Fig. 6).

a) *b)*

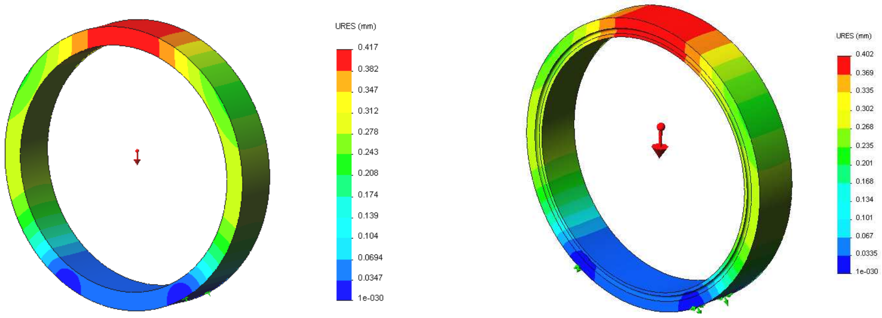

Figure 6. Displacement profiles of a tyre surface: *a)* reference; *b)* reconstructed

3. Study of tyre strain-stress behavior.

The analysis of displacement profiles shows that in both cases the biggest displacement is observed at upper tyre areas. Displacement values of a reconstructed tyre were even slightly lower, which is obviously caused by the reduction of a tyre weight. Thus, the formation of shaped ring grooves during reconstruction of tyres does not lead to considerable changes of their hardness; therefore the observed deformations exert almost no influence on processing accuracy. In the course of subsequent operation, the tyre loads significantly increase; therefore it is necessary to study potential changes of strain-stress behavior for such conditions. Fig. 9 shows reference tyre models with TD casing elements.

a) *b)*

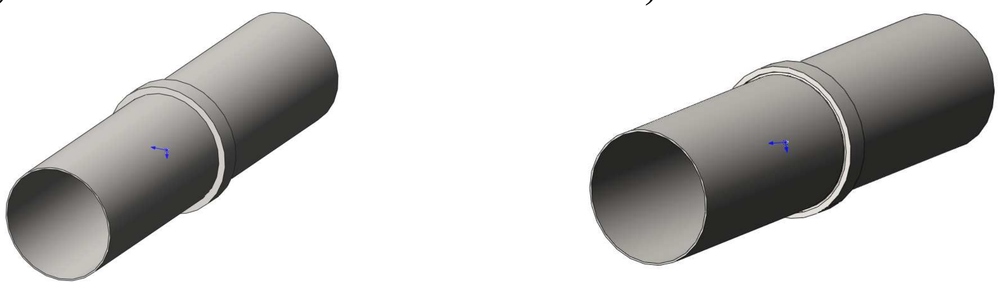

Figure 7. The concerned TD models with tyres: *a)* reference; *b)* reconstructed

Due to the increase in the tyre weight, the conditions of boundaries, which ensure contact between a tyre and a roll, also change. According to calculations, the half-width of a contact area made a = 1.9 mm. In addition, a fixed geometry at casing faces and the gravity, being the limit of a model, was also set (Fig. 8).

a) *b)*

Figure 8. Set limits for tyre models: *a)* reference; *b)* reconstructed

According to modeling, stress and displacement, profiles for reference and reconstructed tyres were obtained (Fig. 9, 10, 11).

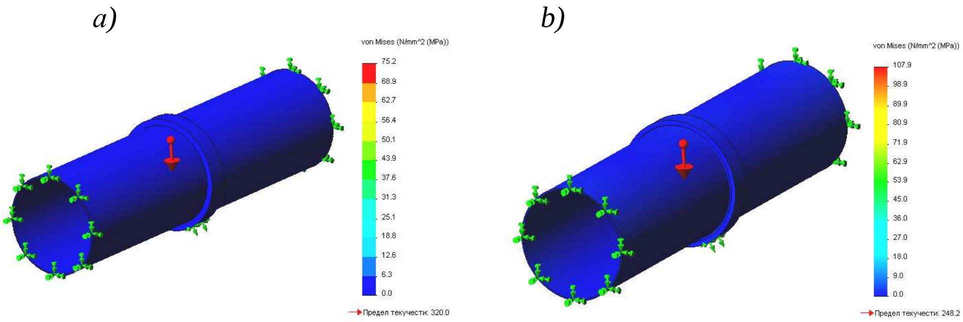

Figure 9. Stress profiles in tyres: *a)* reference; *b)* reconstructed

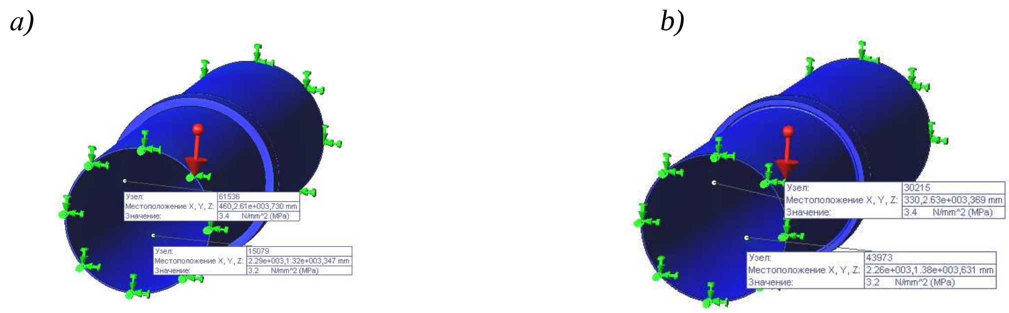

Figure 10. Stress values in some parts of the studied tyre models: *a)* reference; *b)* reconstructed

The study shows that the change of the tyre section as a result of its reconstruction, even if loads are increased to working values, does not lead to considerable changes of its strain-stress behavior.

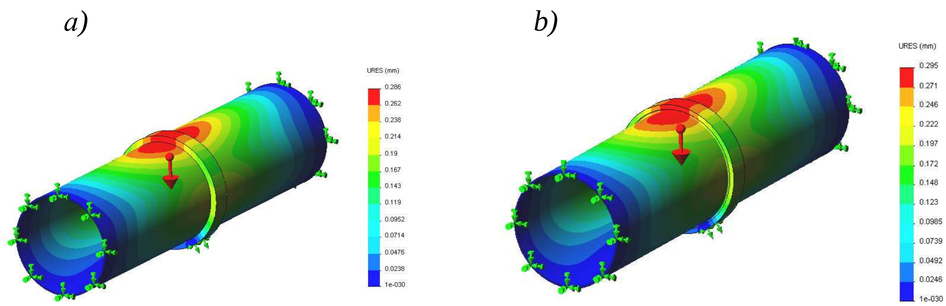

Figure 11. Displacement profiles of the studied tyre models: *a)* reference; *b)* reconstructed

4. Conclusions

Thus, the reconstruction of “F” tyres into “W” tyres due to formation of special shaped ring grooves on its surface does not lead to considerable changes of their strain-stress behavior. Therefore, the reconstruction of “F” tyres into “W” tyres in operating conditions with use of mobile equipment is quite possible.

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