Influence of truck tires explod on the level of professional risk in servicing truck wheel

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Abstract The article deals with a problem of minimization of levels of professional risks while servicing truck tires and wheels. In the process of removal of a truck wheel a worker can sustain a serious or fatal injury caused by the explosion of an inflated truck tire. The explosion of an inflated truck tire can result in affecting of complementary offloading’s on clamps cast spoke wheel. The mathematical model description of move of a disk wheel and values of reactive forces arising from the explosion of an inflated truck tire are presented. The equations of move of a disk wheel at its removal under the influence of reactive forces are solved. Results of numerical modelling of stresses arising on clamps cast spoke wheel during the explosion of the inflated truck tire are presented. The maximum normal stress arises in the stub basis can lead to free move of wheel and in a place of contact of a disk of a wheel high tangential stresses to destruction of a nut is positioned.

Keywords truck tires, explosion of an inflated truck tire, stress-strain state

1. Introduction

In spite of current achievements in the field of decrease of professional risks at service of a motor vehicle repair in the last decades, which provide decreasing number of injuries, issues of safety while servicing truck tires and wheels are still relevant. Extensive researches of the reasons and mechanisms of explosion of volumes under pressure, including wheels of a vehicle [1], are known. In a direction of minimization of risks of accidents and injuries connected with wheel operations it is necessary to relate investigations of the mechanism of heat exchange as one of principal causes of explosion of the tire of a wheel [2]. The researches connected with regulation and prevention of build-up of pressure in tire truck volume by help the gas outflow through small apertures and tubes [3] is interest. It is necessary to point out in a direction of researches connected with foam filling tires and developing new materials [4]. Investigation connected with designing and optimization of wheel assembly [5] are known.

The basic emphasis to avoid all risks of accidents and injuries is given to an exception of separation of a multi-piece rim, lock ring and movement of the removed wheel at explosion of the tire. However, at unscrewing nuts and sliding disk of wheel over stud and during this operation a truck tire can be exploded.
2. Researching

Truck tire as a body of variable mass is presented. The aperture from which the gas outflow is carried out, was constant. To accomplish this task, the equation of reactive force, \( R \), (1), as a result of explosion of an inflated truck tire, and equation of wheel moving (2) for unscrewed nuts were obtained. Regression equation of gas consumption on explosion of tire based on the results obtained in the STATISTICA software product [6] in (1) and (2) is presented.

\[
R = (-37 + 2 \cdot 36205 \cdot t - 3 \cdot 16045736 \cdot t^2) \left(\frac{k - 1}{k - 1} \mu \right) \left(\frac{P_2}{P_1} \right) \left(\frac{RT}{V} \right) \delta \phi
\]

where \( t \) – time, sec; \( k \) – coefficient, for multinuclear gases \( k = 1.29 \) [7], [8]; \( R_m \) - universal gas constant, \( R_m = 8314 \text{ J/kg} \) [7], [8]; \( T \) – temperature gases in tire, \( T = 293 \text{ K} \); \( P_2 \) – atmospheric pressure, \( \text{Pa} \); \( P_1 \) – pressure in tire, \( \text{Pa} \); \( \mu \) – molecular mass of a gas mix in the tire, \( \mu = 28.9 \text{ kg/mole} \) [7], [8]; \( V \) – volume of tire, \( \text{m}^3 \); \( d \) – radius between center of bolt hole and center of disk, \( \text{m} \); \( \delta \) – distance between center of bolt and bolt hole, \( \text{m} \).

The computational schema of moving is introduced in Fig. 1. MATLAB software product was used as a research tool, which enabled solution of equation of wheel moving – the coordinates and velocity of center mass of wheel [9]. The numerical modeling of the stress state of wheel assemblers was used in ANSYS. Values of stresses and deformations allow estimating Probability of destructing of wheel elements [10], [11].

![Figure 1](image_url)  
**Figure 1.** The schema of wheel, where G - weight of wheel, N – force of normal reaction, F - friction.

Geometric dimensions, mass of units, pressure, molecular mass of a gas mixture in a tire were taken as source data for the program. The solution of equation (2) was implemented by Runge-Kutt method in software product MATLAB. Initial condition: \( \phi = 0 \); \( \dot{\phi} = 0 \); \( t = 0 \). Wheel with tube-type steel
disk in radius, \(D\), and pressure in tire 3000 Pa is studied. The maximum angle, \(\phi\), of rotation of a disk of a wheel on studs makes 0.074 rad.

3. Results

The equations of move of a disk wheel at its removal under the influence of reactive forces (2) are solved. On Fig. 2 the graph of the value of the angle of rotation for different values of the time, is presented.

![Figure 2. Time history of angle of rotation of disk wheel.](image)

Figure 3 shows the graph of the value of the angular velocity for different values of time. Figure 4 presents the change of reactive force in time. While analyzing the results of decision of equation of wheel moving it was shown that the value of angular velocity in the end of free rotation is 24.324 rad/sec for the less 0.014 sec, the maximum value of reactive force in initial time the gas outflow is more then 210000 N and quickly reduce.

![Figure 3. Time history of angular velocity of disk wheel.](image)
Figure 4. Time history of reactive force.

The computational domain of the wheel is shown in Fig. 5. Numerical simulation was performed on the module Explicit Dynamics environment ANSYS. Conditions of contact - Penalty at which equal and opposite forces are calculated for model nodes were received. The material properties are Young’s modulus $E = 71000$ MPa, Poisson ratio $\nu = 0.33$, initial yield $\sigma_{y0} = 275$ MPa, and hardening modulus $E_T = 500$ MPa [12]. The solution control was made on: method Lagrange/ALE – automatic, Method for Euler Strain rate calculation – weighted, method for Euler pressure calculation – average, ALE/Euler energy - total.

Figure 5. The model of truck wheel.

In the result of numeric simulation the distributions of directional deformations, shear and normal stresses on the wheel elements is received. The directional deformation on axis OX, OY of the stud is presented in Fig. 6. Figure 7 shows the values of the shear stress and normal stress.
Figure 6. Time history of directional deformation on axis: 1 - OX; 2 – OY.

Figure 7. Time history of normal and shear stress: 1 – normal stress on axis OX; 2 – shear stress in plane OXY; 3 – shear stress in plane OYZ.

Figure 8 shows the values of normal elastic stain on the stub.

Figure 8. Time history of normal elastic strain: 1 – on axis OX; 2 – on axis OY; 3 – on axis OZ.
On Fig. 9, and Fig. 10 shows distribution of normal stress by axis OX, and shear stress in plane OXY.

![Figure 9. Normal stress in axis OX.](image)

![Figure 10. Shear stress in plane OXY in the stud.](image)

It follows from Fig. 9 what the maximum value of normal stress in the stud (more 700 MPa) exceeds the permissible metal yield limit (350 MPa).

**Conclusion**

While analyzing the results of mathematical modeling it was shown that the maximum normal stress arises in the stud basis by axis OX. Thus deformations on an axis OY are 11% more than on axis OX, that characterizes a significant bend and as a consequence high value of shear stress in the place of contact disk with the stub.

The simulation performed by using the finite element method has shown that in the case of the explosion of an inflated truck tire the internal stress in the metal alloy of stud becomes critical. The most dangerous cases are associated with defects, arising in processes of work truck wheel, because they can form new mechanism destruction, for example, the damage of the stud threads can arise the free sliding of nut on the stud with big velocity. Therefore, further research will be made based on using the available numerical model and the formation typical defects in wheel assembler.

The use of the Finite Element Method with the research tool which enabled to solve of equation, for example module Explicit Dynamics environment Ansys and MATLAB, allows predicting mechanism of destruction and value of danger effecting on a worker.

The most rational way for reducing the risk of accidents during the process of truck wheel service is regular checking all metal surfaces of a disk, nuts, studs and surface of tire.

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