Failure Prediction in Off The Road Tire using Fea Technique

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Abstract:- All over the world; mining operations, roadways, and large infrastructure project growth encourages to development of increased activity and demand Tire industries to raise output of their operations. This report is an assessment of finding out the failure of large size tires with an assessment of operational data and experimental data collected from field. The conclusion of the assessment with compendious remark is being very helpful for the tire to sustain and perform in horrendous condition. The inspection of material properties from recalled tire shows degradation in rubber compound and sum up of statistical data is referred to predict the theory of failure. Special purpose tire are use to carry higher loads at higher speeds up to 65 km/h in that case least temperature generation of tire is required for safety of tire from bursting, ply separation due to blister generation while rolling. "Even though consumers can simply and quickly check the air pressure and temperature of their tires, it becomes a neglected practice by many, That's too bad, because the four patches of rubber that come in contact with the road surface are vitally important to the performance of the vehicle. They are key for acceleration, lateral traction and braking grip."

Keywords*: Rubber degradation, Temperature Prediction, Finite Element Analysis, OFF THE ROAD Tire (OTR Tire), Failure prediction*

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1. INTRODUCTION

Giant tires are necessary for heavy mining operations, large infrastructure project and roadways growth vehicles and other Off-The-Road (OTR) vehicles. All over the world heavy growth encourages Tire manufacturers for the robust design and increased durability of tires which in turn decreases the operating cost of the OEM vehicles. These Giant tires are engineered to save money and increased productivity. This report is an assessment of finding out the failure of large size tires by analyzing operational data and experimental data collected and analyzed in laboratories on recalled tires. The conclusion of the assessment with compendious remark is being very helpful for the tire to sustain and perform in horrendous condition.

OFF THE ROAD tires works for heavy mining and construction operation to handle the most extreme load, Earthmover tires works for 24X7 in all weather condition. Tires are the most prominent rubber articles both with respect to importance as well as volume of production. Tire acts as a rubber spring that provides riding comfort, steering response, traction and braking. Now a day, temperature prediction in OTR Tire became one of the important aspects related to tire performance characteristics where maximum working flexibility must be achieved along with high efficiency, stability, Handling and Riding comfort.

This study is basically a continuation of the work of Tönük. The findings and the recommendations from his study forms the main set of goals for this study. As such, a completely new FE model is recreated by using efficient modeling techniques such that accurate, reliable and short solution times will allow study on tire cornering characteristics for a wide range of vertical loads and slip angles. Further, the study is extended to cover the analysis of the self aligning torque

2. LITERATURE SURVEY

Tire is one of the most important components affecting vehicle dynamics in more than one aspect. In particular, tire's cornering characteristics have a key role in determining directional control and stability, in short vehicle handling. As the characteristics of a tire is a result of its complex construction, consisting of many dissimilar material properties, carcass construction, and breaker belt configuration, its modeling is an extremely difficult process.

Until recently, experimental means were practically the only way to obtain tire cornering force characteristics. However, recently, the use of the Finite Element Analysis (FEA) has opened the possibilities of modeling and simulation of tires, for studying and improving many aspects of tire functions including the cornering behavior.

There exists a significant number of different tire models in literature; each can be classified according to the methodology used, scope of the study or tire parameter studied. Three main approaches are used to investigate tire behavior; analytical models, semi-analytical studies and Finite Element Method (FEM).

Tire dynamics studies can also be categorized depending on the scope. The first category is concerned with the lateral forces generated in the contact patch. These models are relevant in the handling analysis of vehicles. The second category deals with the vertical and longitudinal forces generated in the tire, and these are used for ride and performance analysis of vehicles, respectively. The studies in third category are on analyzing noise, vibration and harshness.

Figure 1 represents the traditional tire development process with a new tread pattern. After the first trials have been tested, some improvements are usually needed, and new moulds must be ordered. Usually the whole process takes several loops, huge amount of money and couple of years. On the other hand, though the convergence of this iterative process is not mathematically guaranteed, engineers and designers are typically satisfied after 2-3 loops.

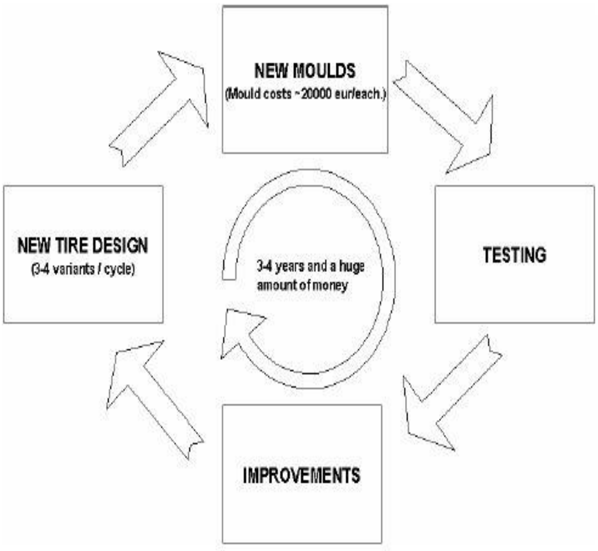

Figure 1. Traditional tire R&D process

In future, however, we see that virtual environments will become more and more important for designers and some physical testing will be performed with the modern simulation tools instead of traditional methods. We also see that the need for physical testing will not decrease; with simulation methods we will just be able to provide more information for designers, make better trials for physical testing and therefore provide safer tires with improved performance for consumers needs. Although these modern tools seem to be very attractive, some remarks have to be pointed out.

First of all, tire is relatively challenging application for FEM-simulations. Complex 3D-geometry of tire tread pattern combined with nonlinear materials, orthotropic structure and nonlinear contact boundary conditions, for example, leads to extremely difficult analysis and usually analyst ends up with a nonlinear analysis with huge amount of degrees of freedom. In this kind of situation a robust solver with ability to handle such complex models is definitely appreciated. A cross section of a studded winter tire is presented in the Figure 2.

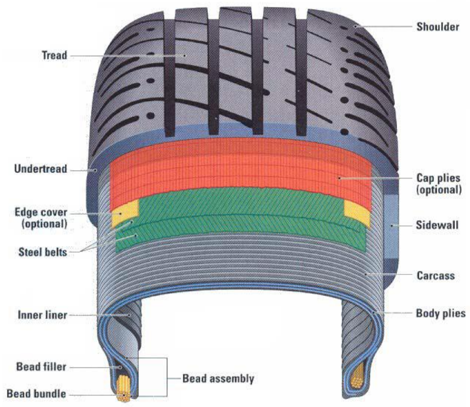

Figure 2. Constructional features of tire

Secondly, during last ten years the performance of computer hardware has been increased very rapidly. At the same time a lot of work has been done with robustness and capabilities of commercial finite element codes. These two things have together made possible for today's engineers to analyze and handle huge models with very nonlinear characteristics in reasonable time. Despite the rapid improvement in the computational performance some approximations are still needed and therefore an analyst who has good engineering skills in both physics and mathematics are important for successful simulations.

3. Finite Element Tire Design using ABAQUS

ABAQUS provides many nice features for tire modelling. For example, one may use embedded element technique in order to reduce the analysis time, but still obtain accurate results enough e.g. for tire lateral stiffness simulations. Other useful feature is steady state transport-capability, which enables some steady-state-handling simulations. Third, but not least, is the expandability and flexibility of ABAQUS code: with user subroutines one can define almost arbitrary user materials, contacts etc.

Fatigue and durability properties of tires are extremely important and form a fundamental basis for a sustainable safety. Due to complex stress field, cyclic loading and heat generation near the belt edge areas a designer sometimes sees fatigue damage called belt edge separation. This phenomenon is especially important in applications like commercial vehicle tires. It is very common that the vehicles using these tires are fully loaded and usually driven at maximum speed so tires under these cars are susceptible for belt edge separation.

Usually tire engineers evaluate the fatigue properties of a specific tire on test drum, under certain loading, speed and temperature conditions. The problem is, that such test is very time consuming, expensive and requires physical trials. In practice designers avoid belt separation by reducing the belt width, for example. Unfortunately this kind of modification reduces also the handling properties of tire and is therefore not recommended.

Types of finite elements that have been used include axi-symmetric hybrid elements with twist for purely rubber structural components, axi-symmetric surface elements with a twist for modelling of carcass and belts and axi-symmetric solid elements for modelling of the bead wire. 3D FE tire model (Fig. 3) is obtained by rotation of axi-symmetric model around tire axis. Dense mesh is created only in the vicinity of tire footprint, as described in [14].

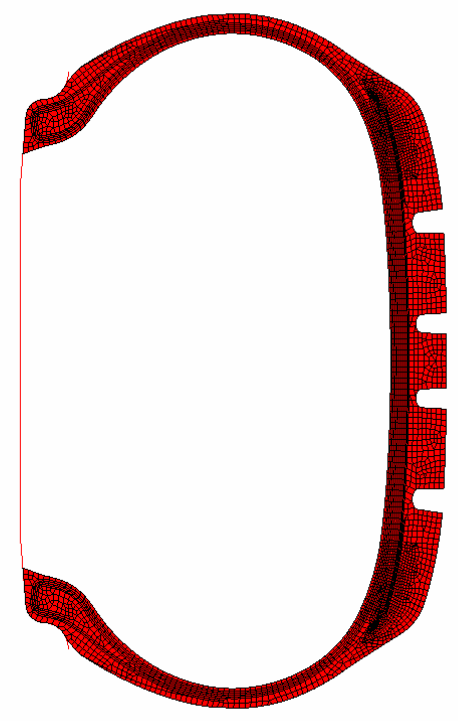

Figure 3. Axisymmetric FE-model after inflation

3D finite elements, which represent the equivalents to the corresponding axi-symmetric ones, are created during the rotation of axi-symmetric model. In this way, the 3D FE model is composed of: 8 or 6-noded hybrid elements that represent rubber, 4-noded surface elements for modelling of carcass and 8-noded solid elements used to model the bead wire.

The tyre model was developed by assuming that the inflated tyre is connected or fixed to the rigid rim through common nodes on the rigid rim. The tyre model was subjected to loading in two sequential steps. The initial loading was caused by the tyre inflation pressure, which was assumed to be uniform within the tyre. The inflated static tyre is then subjected to normal loading through the application of a specified normal deflection of the tyre at the contact region.

The main results of the research can be seen in figure 4, which represents the shear stresses in rubber around belt edge area. The conclusion is that the belt separation is caused mainly due to shear stress component. This shear stress is mainly caused by the deformation of the steel cords. When these cords are deformed in the footprint area, a shear stress is generated because of the angle in steel cords. Cyclic loading arises when tire is rotating.

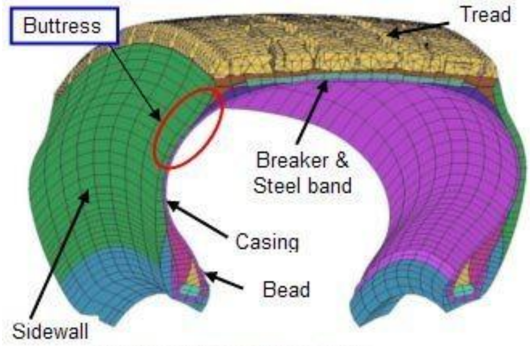

Figure 4. 3D Finite Element Model

4. 3D Tire Model visualization and Validation

ABAQUS breaks the simulation into a number of time increments and finds the approximate equilibrium configuration at the end of each time increment using the Newton-Raphson method. In this numerical technique each step is restarted from the solution of the preceding step. Consequently, the effect of the loading in a previous stage on the current stage (e.g., inflation pressure on loaded shape of the tyre) is easily taken into account. Details of the complete mathematical description of this methodology and its numerical implementation can be found in literature.

Figure 4 shows the finite element mesh of the tyre. In this model, C3D8H and SFM3D4R elements were used. C3D8H is an 8-nodded 3D brick element with constant pressure for the definition of the rubber parts. Reinforcement materials in ply, belts, and cap ply are modelled using rebar layer in surface element SFM3DR which is a 4-nodded quadrilateral element in 3D space. Total number of elements and nodes are 26497 and 32410, respectively.

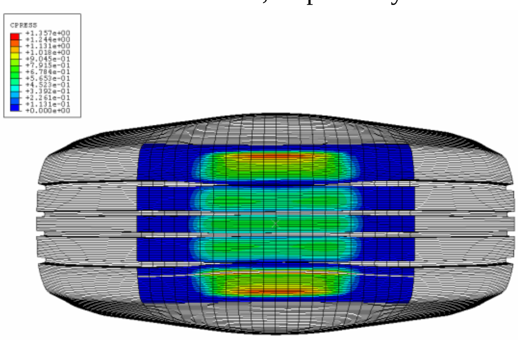

Figure 5. 3D Footprint result of Tire

The results of the simulation can be seen in figure 5, which represents the footprint area of the tire after loading. The conclusion of the footprint is remarkable to identify contact pressure coming onto the ground after loading.

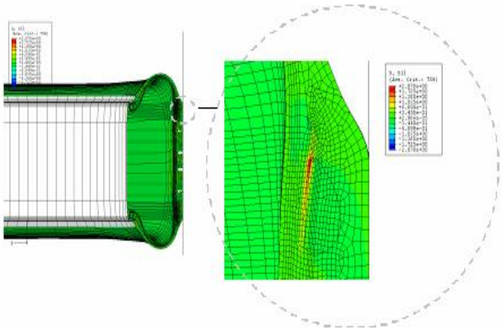

Figure 6. Shear Stress at of Tire

The main results of the research can be seen in figure 6, which represents the shear stresses in rubber around belt edge area. The conclusion is that the belt separation is caused mainly due to shear stress component. This shear stress is mainly caused by the deformation of the steel cords. When these cords are deformed in the footprint area, a shear stress is generated because of the angle in steel cords. Cyclic loading arises when tire is rotating.

5. PROBLEM FORMULATION

The analyses performed so far were based on the assumption of a frictionless contact surface. In order to consider the effect of the friction, the analyses were repeated assuming the well-known Coulumb's friction law with a friction factor of 0.7 between tread and road surfaces.

A finite element model for the simulation of the steel belted radial tyre under static load was introduced. This model includes the details of the tread pattern and thus the contact interaction between tread blocks and contact surface road can be examined.

These calculations were also repeated for similar tyres with simply ribbed treads. Comparing the results of contact pressure, interlayer shear stress, TSE, and SED, one can conclude that the belt angle of 20o gives the optimized values of selected design parameters. Furthermore, comparison the results of the tyre model with complex tread pattern and the simply ribbed model reveals that, although tyre deformation can be computed with reasonable accuracy by means of simply ribbed models, second order variables such as contact pressure, stress and strain energies should be calculated on the basis of the models in which the details of the tread blocks and other geometrical complexity in tyre configuration are taken into account.

6. OBJECTIVES AND CONCLUSION

ABAQUS seems to be a substantial tool to simulate such challenging and complicated applications as tire. ABAQUS solvers can handle nonlinear materials, nonlinear geometry and complicated contacts, for example uneven treaded tire in a very robust way. We can see some favourable or superior position and great advantages of using such modern simulation tools as ABAQUS. ABAQUS can be rapidly implemented into R&D-environment.

7. REFERENCES / BIBLIOGRAPHY

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