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Finite Element Analysis of the Impact of Scratches on the Tire

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Abstract. The performance of the tire has an important effect on vehicle running safety, and in the actual use of the tire will inevitably encounter a variety of complex and harsh conditions, it is easy to make the tire scratches, so to study the effect of scratches on the performance of the tire is very important. In this paper, the geometric model of tire scratches is established by SolidWorks, and then imported ANSYS Workbench to build finite element model of the tire and the ground. And the finite element analysis was carried out on the tire model with scratches, comparison different parts of the scratch on the tire under the standard air pressure and static load, strain and deformation analysis of different effects. Analyzing them the effects and the damage of the tire has certain guiding significance safe use of tires.

The Establishment of Finite Element Model of Tire Scratches

In recent years, the population of cars in our country has grown and grown with the rapid economic growth. As it is a typical structural component between road and a car as well as a support and force transferring component, a tire plays an important role[1]. The performance of the tire has an important influence for safe driving of the vehicle. While serving in the tire during, poor road conditions are encountered inevitable, at this time it often happen tire sidewall, especially the tread was scratched by sharp objects or bumps. This paper is to explore the impact of scratches on the safety performance of the tire. Thanks to the development of FEA and computer technology, the analysis of tire structure have been improved greatly, they have developed from too simple theory, such as Netting Theory, Membrane Theory, Laminate Theory, to FEA theory[2]. Lau, Liu Feng, Yangxue Gui[3] by a finite element model 9.00 R20 radial tires study the contact problem tire and the ground. In this paper, the load and the constraint conditions of the no scratch tire and the tire with scratch are respectively applied, to see the distribution of the strain, stress and deformation under different load, to compare between different the two, to explore the impact of tire scratches on the tire.

Model SolidWorks

In this paper, a few cases of tire scratches were established by SolidWorks. One is to set a scratch in the middle of the two tread, the other is to set a scratch on one side of the three patterns, the horizontal position is located at the center point of the left pattern and the tire shoulder. Cross section of tread scratch is rectangular round the tire, and the model is shown in Figure 1.

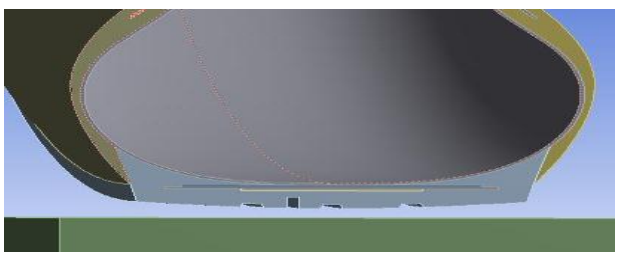

Fig. 1. Scratches in tread of tire

The cross section of scratch in the middle of the tire sidewall is rectangular and round tire, and the model is shown in Figure 2.

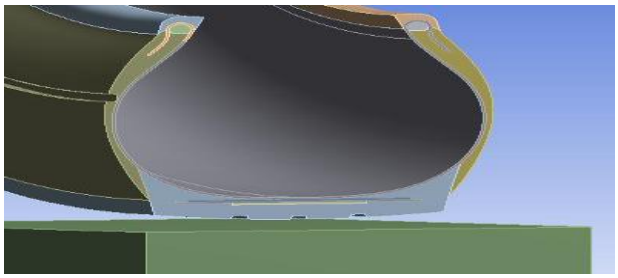

Fig. 2. Scratches in sidewall of tire

Set Workbench

Three-dimensional model is imported into ANSYS WORKBENCH, complete meshing. Based on multiscale finite element analysis theory [4], the material of the tire is made of composite material and single material. The single material included rubber and steel cord, SOLID186 element was used to simulate rubber's property, and SOLID45 element was used to simulate steel cord's property. Applied load and boundary conditions

Apply Constraints

Because the bead area and the hub of tire have no relative displacement, this paper does not established the hub model, and this paper does not studied the rotation condition of the tire, so the contact areas of bead and hub of tire is seen as fixed, applying a Fixed Support. Due to the symmetry of the tire, only half of the tire model is established, it is to be applied frictionless Support in the two cross section.

Apply Inflation Pressure

Load tires are often used in twin, according to GB/T2977-2008, the inflation pressure is set to 0.84kPa. The direction is perpendicular to the inner surface of the tire and point to the outside of the tire.

Load on the Tire

Simulation of the static load, Simulation of the tire contact with the road conditions, are four ways[5]. Practice has proved that four kinds of loading is the same thing, to achieve the same effect. The last one is one of the easiest convergence, the minimum computing resources consumed. So the method is that the wheel does not move, and the displacement of the tire is applied to the rigid body on the ground floor, because a certain load of the tire will always cause a fixed sinking amount, as shown in Figure 3.

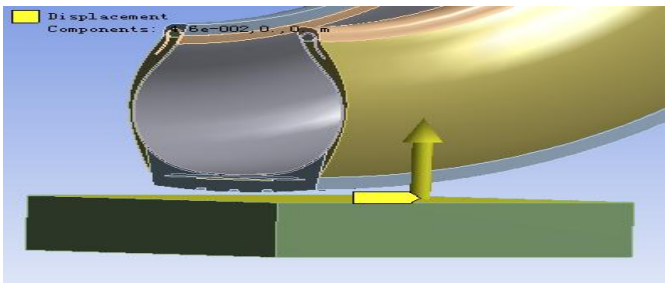

Fig. 3. Apply ground displacement

The Solve of Finite Element Analysis

Setting the number of steps in solving Analysis Settings are the three steps, the first step is the tire

inflation process, the tire section always changes during the process of inflating, in order to ensure the air pressure is perpendicular to the inner surface of the tire the first step is to set up 40 sub-steps, to select Interative in the solution method. The second step is the process of quick access to the tire after the inflation completed, the process is set up to 5 sub steps, and the other options are the default setting. The third step is that t the tire and the ground contact process, this step is the most cost of computing resources and the most difficult to converge. The contact options of Type Solver choose to enhance the Lagrange method as a contact algorithm. Setting sub-steps is 50, the contact mode selection is Frictional, the friction coefficient is 0.6; Normal Stiffness Factor is set to 0.1 in order to speed up the convergence; Because the road stiffness is much larger than the tire, so the Target Bodies project is to choose the road, the Contact Bodies project is to choose the tire tread. You can choose to solve after the setup is completed.

Study on the Result of Finite Element Analysis

Study on the Stress

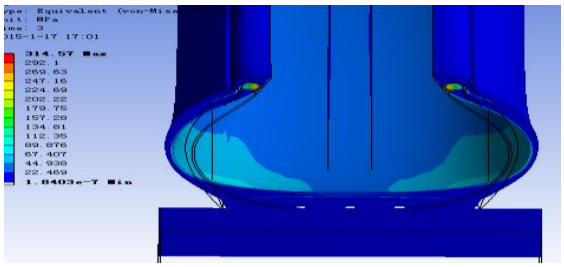

Fig. 4. Von-Mises stress without scratch

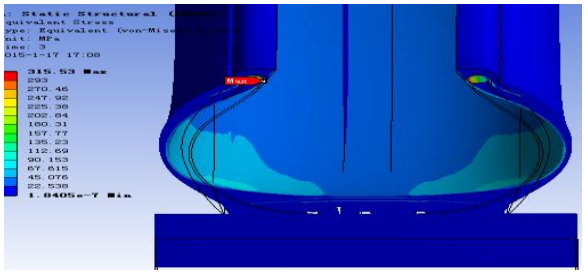

Fig. 5. Von-Mises stress with scratch in middle tread

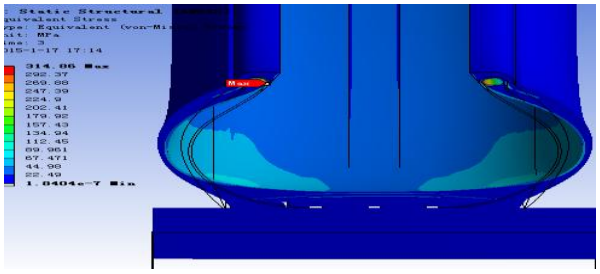

Fig. 6. Side tread scratch Von-Mises stress

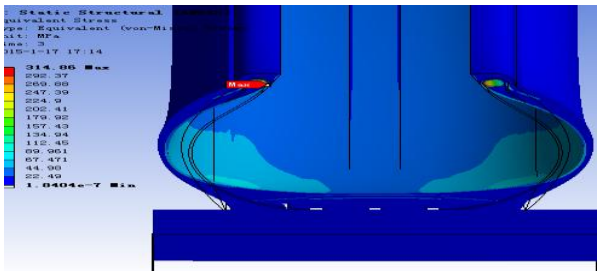

Fig. 7. Sidewall scratch Von-Mises stress

As can be seen from the above four picture, the overall stress distribution of the tire is almost symmetrical distribution, the impact on the stress distribution of scratches is very small; the tire maximum stress located on the matrix and bead wire contact area of ground, the tire maximum stress were 314.57MPa, 315.53MPa, 314.86MPa in the Figure 4, 5, 6, it can be considered that tread scratch has no effect on the tire maximum stress, and maximum stress reaches the 341.62MPa in figure 7, This shows sidewall scratch of the tire has great influence on maximum stress.

Study on the Strain

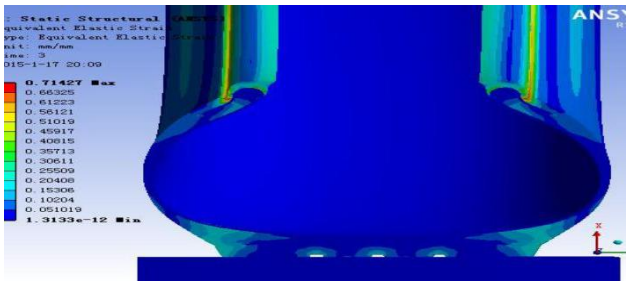

Fig. 8. Strain without scratch

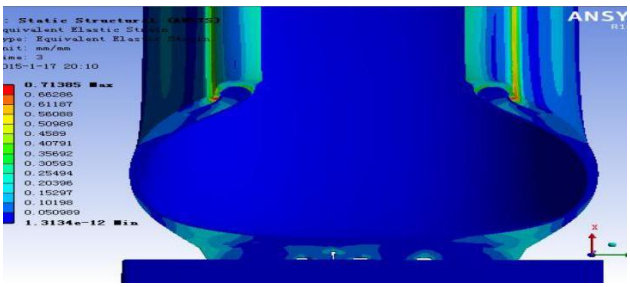

Fig. 9. Strain with scratch in middle tread

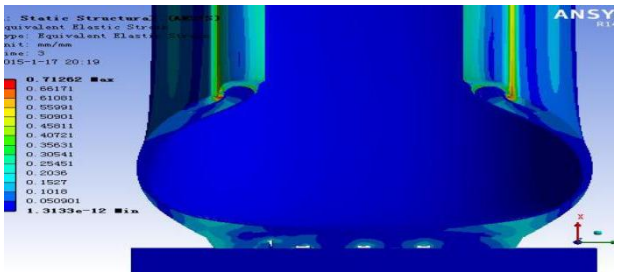

Fig. 10. Strain with scratch in side tread

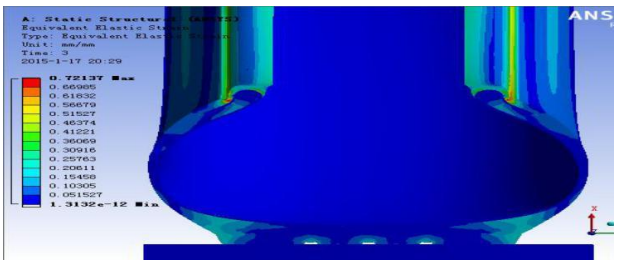

Fig. 11. Strain with scratch in sidewall

It can be seen from the strain diagram, the tire with scratches, the whole of the strain and complete tire strain diagram change is little, it remains substantially symmetrical in general, only in the part of the scratches are different. Strain around the scratch for two scratches of the tread will increase significantly, for example, Figure 8 and Figure 9 Comparison, the maximum strain value around the scratch is 0.196, the strain value of the same position on the whole tires was 0.021, the maximum strain value of scratches is 9.3 times of that without scratches, and the difference is very big. But in

slightly away from scratch, such as the same position around the left first tread pattern, the maximum value of no scratch tire is 0.168, the value of scratch tire is 0.132, strain value far from the scratch is basically the same.

Study on the Deformation

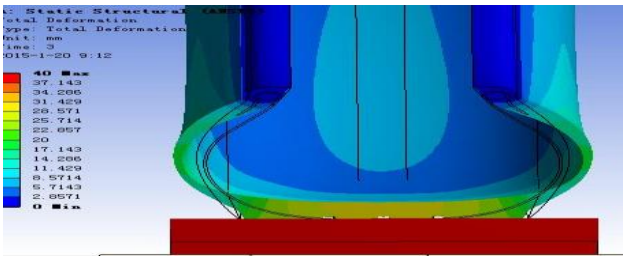

Fig. 12. Deformation of tire without scratch

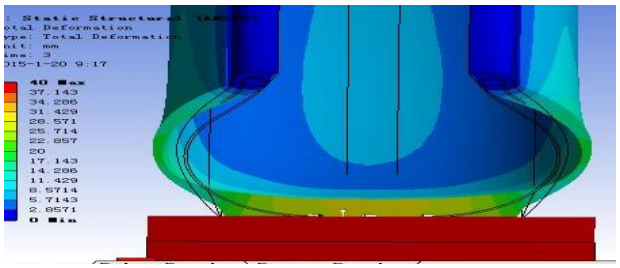

Fig. 13. Deformation of tire with scratch in middle tread

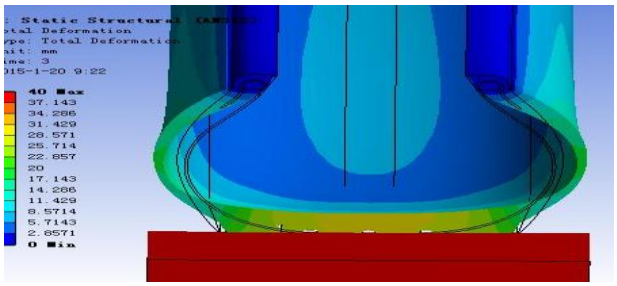

Fig. 14. Deformation of tire with scratch in side tread

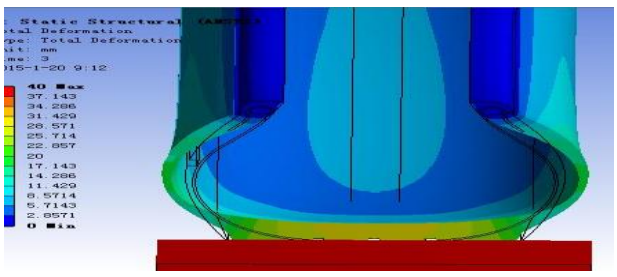

Fig. 15. Deformation of tire with scratch in sidewall

It can be seen that the deformation of the tire is generally symmetrical under the four kinds of cases. It can be considered that scratches will not affect the overall deformation of the tire.

Conclusion

This paper discusses the impact on the scratches of a tire. The stress, strain and deformation of the tire with different scratch are studied under the standard inflation pressure and static load. The following conclusions can be obtained through the study: the tread scratches have little impact on the stress of the tire, to a certain extent, the sidewall scratches increase the maximum value of the stress of the tire; No matter whether it is the tread scratches and the sidewall scratches, the strain around the

scratch is much higher than without scratches.

The analytic efficiency is improved by combining the SolidWorks and ANSYS, tires with cracks is a common issue, the finite element analysis of this situation can offer some valuable guidance to tire's safety.

Acknowledgements

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