ATLANTIS PRESS
Advances in Engineering Research (AER), volume 105
3rd Annual International Conference on Mechanics and Mechanical Engineering (MME 2016)

Finite Element Analysis of the Effect of Cracks in Tire Shoulder

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Keywords: 11.00r20 Tire, Finite Element Analysis, Cracks in Tire Shoulder, Overload; Tearing Energy G, Life Prediction.

Abstract. You 11.00R20 tire shoulder suffered hyperthermia and periodic alternating stress will easily result in rubber aging and cracking, then the flaw generate in it. In this paper, based on ANSYS Workbench, a local sub-model of the 11.20R20 tire shoulder is established. And the stress, deformation and displacement of the sub models containing cracks are analyzed by FEA. The types of crack are distinguished in this paper, then tearing energy at crack should be calculated. Moreover, the crack life also be evaluated, so that we can estimate the effect of defect safety performance of tire

The Establishment of the Sub-Model

In this paper, AutoCAD and SolidWorks are used to build the geometry model of the 11.00R20 tire shoulder [1,2], then the geometry model is imported to ANSYS Workbench, and the finite element model of the tire is built in this software. In the process of building tire model, the geometrically non-linearity, the material non-linearity and the contact non-linearity are fully taken into consideration. When it comes to composite material, the ACP part, which is designed for analysing composite material component is used to build the mode of the tire. Finally the finite element model is built by assembling the rubber parts and composite material parts.

Based on multiscale finite element analysis theory [4], in the tire shoulder we set a radius for 2mm semi-circular three-dimensional crack, using 20 node SOLID186 unit. In ANSYS Workbench, the crack and nearby rubber parts extracted in geometry were built as sub-model, as shown in Figure 1.

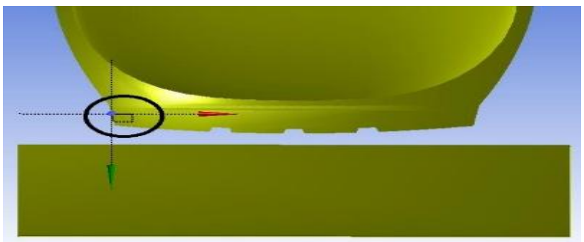

Fig. 1. Tire shoulder sub-model with crack.

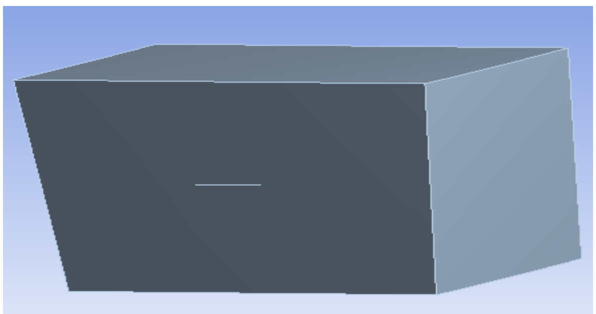

Fig. 2. Tire shoulder sub model with crack.

Analysis Result of the FEA

Stress Analysis

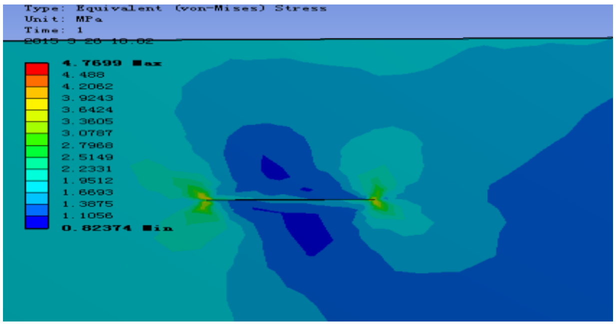

Fig. 3. Von-Mises stress under 100% load

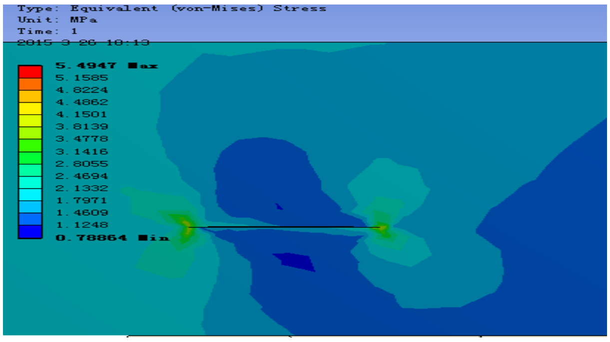

Fig. 4. Von-Mises stress under 110% load

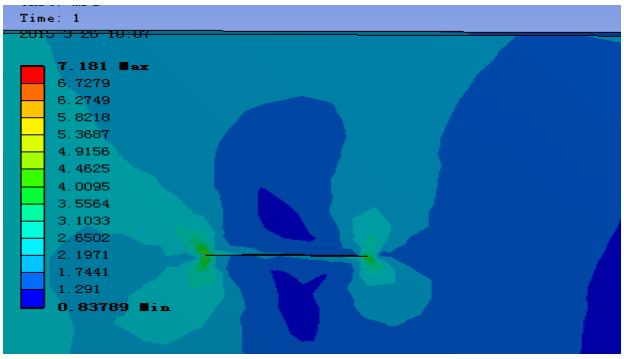

Fig. 5. Von-Mises stress under 120% load

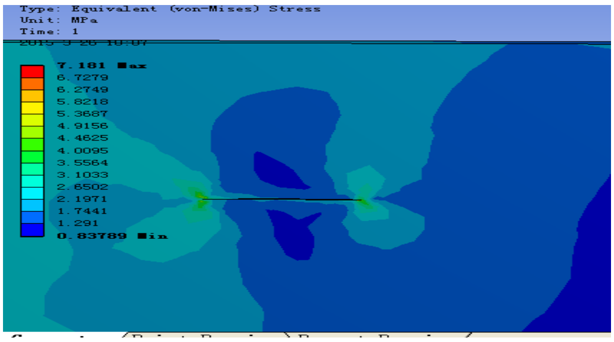

Fig. 6. Von-Mises stress under 120% load

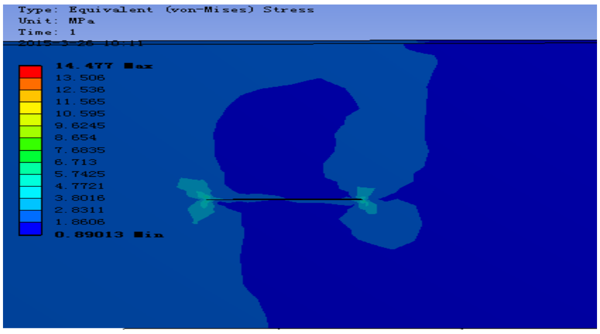

Fig. 7. Von-Mises stress under 130% load

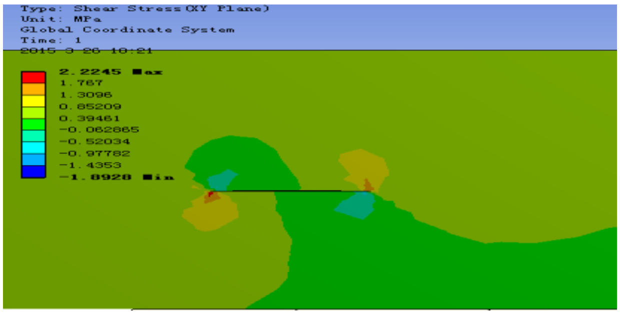

Fig. 8. Shear stress under 100% load

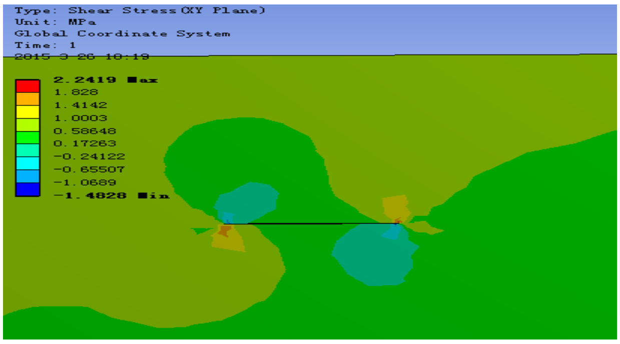

Fig. 9. Shear stress under 110% load

Fig. 10. Shear stress under 120% load

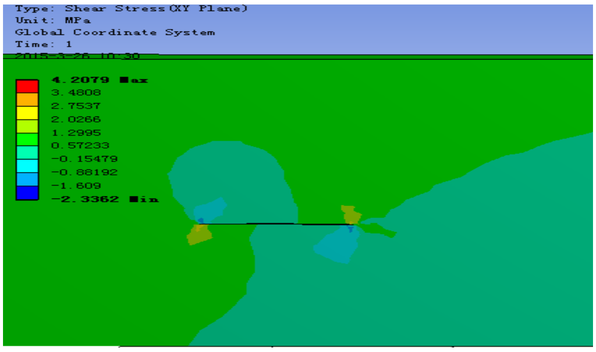

Fig. 11. Shear stress under 130% load

It can be seen that when the load increases, the shear stress change is very small, with the increase of the load, the shear stress growth rate also exceeds the load growth rate, and the growth rate is more and more big. As shown in Figure 6-12. With the increase of load exceeds the rated load value, equivalent stress at the shoulder fatigue cracks, etc., and the rapid increase in shear stress, from the perspective of stress, overload increases the risk of fatigue cracks at the shoulder.

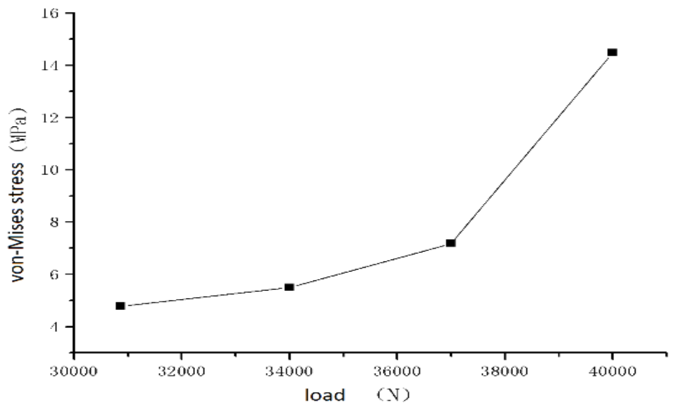

Fig. 12. Relationship between von-Mises stress and load

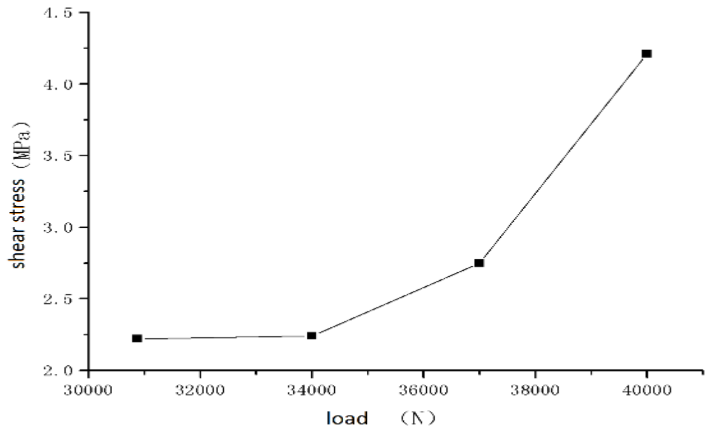

Fig. 13. Relationship between shear stress and load

Deformation Analysis

The deformation around the crack is also of great significance to the crack propagation. The following figure is the analysis of the deformation of the crack

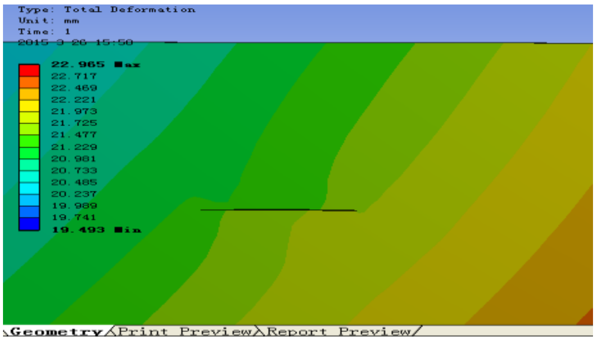

Fig. 14. Shear stress under 130% load

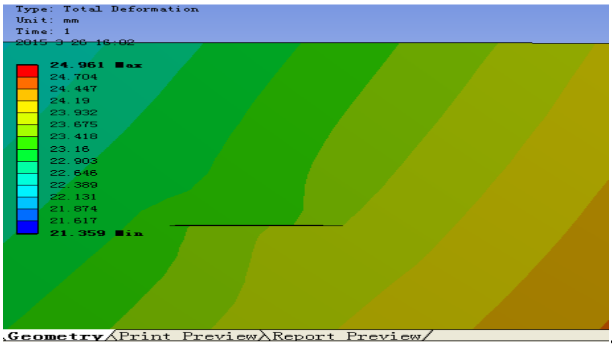

Fig. 15. Shear stress under 130% load

The Crack Propagation

The crack was simulated under 100%, 120%, 110% and 130% loads. In this paper, only the 100% and 110% loads of crack tearing energy Gmin [5] are listed:

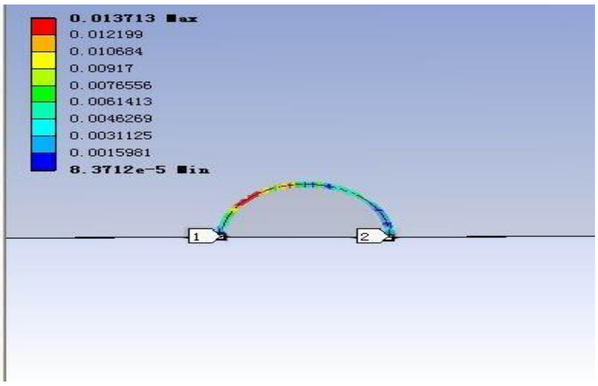

Fig. 16. Gmin under 100% load

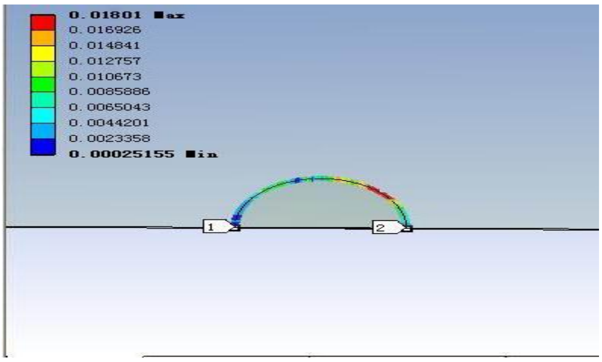

Fig. 17. Gmin under 180% load

Table 1. Gmax and Gmin under different load

Load(N)	Gmax(mJ/mm2)	Gmin(mJ/mm2)	ΔG(mJ/mm2)
30870	0.32	0.0137	0.306
34000	0.408	0.018	0.39
37000	0.547	0.0181	0.529
40000	0.716	0.0185	0.698

Taking the tire of the rated load under the standard inflation pressure as an example, the service life of crack in tire shoulder was simulated and calculated. For the purposes of comparison, nuumber of cycles was calculated crack extension to the 8mm required, can get each Gmax、Gmin andΔG. MATEC Web of Conferences 2 (2012) 01001, 2 corresponding to the volume and 01001 to the number of the article (replacing thus the page number).

Table 2. Gmax and Gmin under different load

Step	Gmax(mJ/mm2)	Gmin(mJ/mm2)	ΔG(mJ/mm2)
1	0.32	0.0137	0.306
2	0.394	0.0141	0.38
3	0.487	0.015	0.472
4	0.599	0.0164	0.583
5	0.717	0.0173	0.699
6	0.901	0.0179	0.883

By comparing the two crack growth life under standard inflation pressure and rated load conditions，Because the value of the tire shoulder cracks Gmin is very small and little change, resulting in tire shoulder crack of ΔG is relatively large, making here crack propagation increases rapidly. Under the standard inflation pressure and the rated load, the crack propagation in the tire shoulder is expanded to 8mm which mileage is only 68% in the tire bead. When the tyre is overloaded, the mileage is lower.

So in the tire shoulder rubber selected should be noted: ΔG value at the tire shoulder is relatively large, the rubber material here should be more emphasis on fatigue resistance of the material. Overloading the vehicle led to a sharp increase in ΔG value, seriously affecting the life of the tire shoulder, so the rated load is a necessary condition for loading cars safe driving.

Conclusion

In this paper the cracks at the shoulder were studied. First, literature and pointed out that the actual situation the shoulder of the tire at risk of fatigue cracks, and its causes are simple exposition. Establish sub-models in the tire shoulder and scraped crack submodel. The equivalent stress and shear stress of the crack are analyzed. Calculation tire Gmax, Gmin and ΔG at different loads, then get here crack propagation life. Through the analysis, we can get the following conclusions:

Overload can cause crack stress of the rapid increase in the 110, 120, 130% load, the crack von Mises stress is rated load of 115%, 151% and 30.4%, the shear stress is rated load of 101% and 127% and 190%, which makes the danger of crack increased rapidly.

Through the displacement of cracks at the shoulder which is set on the analysis, the crack belongs to type II crack, which compared with the open crack under tension stress, its instability risk is relatively low.

Gmax increases with the increase of the value of overload, and increases the risk of crack failure.

In the selection of rubber materials, rubber at the shoulder should pay more attention to the anti-fatigue properties

Acknowledgments

This work was supported by the Project of science and technology project of Shandong Province (2014GGX103004).

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