

Nonlinear analysis of the GFRP material wheel hub

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Abstract. In this paper, the current bicycle wheel was replaced by the ones which composed by the wheel hub with Glassfiber Reinforced Plastic (alkali free thin-walled cylinder material, hereinafter referred to as GFRP) material and the protective components made up of rubber outer pneumatic pad. With the help of the basic theory of elastic-plastic mechanics, the finite element "Nonlinear buckling" analysis of the wheel was carried out. The results show that the maximum elastic deformation of the wheel hub and the critical value of buckling failure load were restricted by the elasticity under the condition of external loads. Considering with the tensile strength and elastic modulus of the GFRP value of the material, it is demonstrated that the material is feasible to be used for wheel hub.

1 Introduction

Bicycle wheel is mainly composed of two parts: the wheel hub and the tires. Wheel hub and bearing are connected by spokes, and tires are made up of rubber, which should be inflated in the first time and plays the role of buffering and energy dissipation. But the following drawbacks of traditional rubber tires mainly exists in daily use: firstly, it must be inflated in the first time, which greatly hampered the flexibility of bicycles; secondly, the rubber tires are easy to age after long-term cyclic loading and temperature effects and the worse is difficult for awareness; finally, rubber tires are very prone to sudden burst problems, especially on the condition of bad road or the high outside temperature. It would be a direct threat to the personal safety when the ride speed is fast.

The GFRP thin wall cylinder was used as the hub material. When added the load function, we need to judge whether there would be a buckling deformation. In normal operation, GFRP is elastic-plastic materials, and the nonlinear buckling analysis method should be used to describe the stress-strain. At the same time, we could grasp the judgment that the large-scale path of shaping material damage would not occur. The convergence of the solutions was obtained by using the iterative method. that happened in the elastic range of loss of load critical point failure, to ensure that the instability structure problem would not appear in the bearing [1, 2].

2 The basic theory of nonlinear elastic mechanics

2.1 Nonlinear analysis method

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The elasticity of the material mainly depends on the yield point definite by the material and the internal force under the yield stress. The material after being unloaded could be fully reinstated without any residual strain. In the view of micro perspective, elastic material is mainly based on the force between the small molecules or atoms, to return to the original natural molecular or atomic sequence after being unloaded.

But in the practical working condition, the material force often exceeds the yield point of the material and the plastic deformation. The mechanism is that the material force goes beyond its elastic range and destroys the molecular or atomic force between the molecules or atoms which formed between the new pattern matching. In most cases, between molecules or atoms re matching is caused by the material under shear stress plastic deformation and material. The dislocation between the molecular or atomic caused the change of the material strain energy and the overall energy dissipation. In other words, the plastic deformation of materials is a non-conservative process [3]. While the material is in the state of machining process, stress strain theory is only suitable for the stage of small deformation. The stress-strain curve is used to characterize the true elastic-plastic body, so it could be the greatest simulation by the relation between force and deformation [4].

The steps of the simulation are as follows:

To achieve the yield strain two times before:

$$\sigma = \sigma_{eng}, \varepsilon = \varepsilon_{eng} \quad (1)$$

Necked before:

$$\sigma = \sigma_{eng} (1 + \varepsilon_{eng}), \varepsilon = \ln(1 + \varepsilon_{eng}) \quad (2)$$

In the necking stage, the instantaneous relation of the stress-strain should be measured on cross section:

$$\sigma = \frac{P}{A_i}, \varepsilon = \ln\left(\frac{A_0}{A_i}\right) \quad (3)$$

2.2 Nonlinear yield criterion

Yield criterion is a point, which is linked by the multi axial stress state and the single axis nodes. The uniaxial tensile test data was provided by the existing residue. We can draw the one-dimensional stress-strain curve, but the actual structure is general multi-axial stress state which provided the material yield criterion of the stress state. is set to the value. The "von Mises" Yield criterion is most commonly used and its equivalent stress is as follow:

$$\sigma_e = \left[\frac{3}{2} \{S\}^T \cdot [M] \cdot \{S\} \right]^{\frac{1}{2}} \quad (4)$$

A method for solving nonlinear equation is to decomposed it into a series of incremental load. when the solution of each increment step is completed, the stiffness matrix would be adjusted to adapt to the nonlinear condition. The corresponding balance equation is as follow:

$$\sigma_e = \left[\frac{3}{2} \{S\}^T \cdot [M] \cdot \{S\} \right]^{\frac{1}{2}} \quad (5)$$

3 The basic theory of nonlinear elastic mechanics

Considering that the GFRP thin-wall cylinder material stress-strain relation is similar to the prestressed steel strand, the 0.75 times CFRP thin-wall cylinder material tensile strength was regarded as the protocol of yield strength. Before reached the internal force yield strength, the cylinder material was regarded in elastic stage. The analysis model and the strain diagram are shown in Fig.1 and Fig.2.

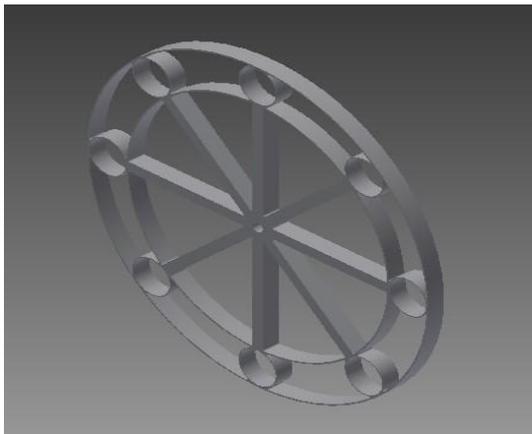


Figure 1. The analysis model

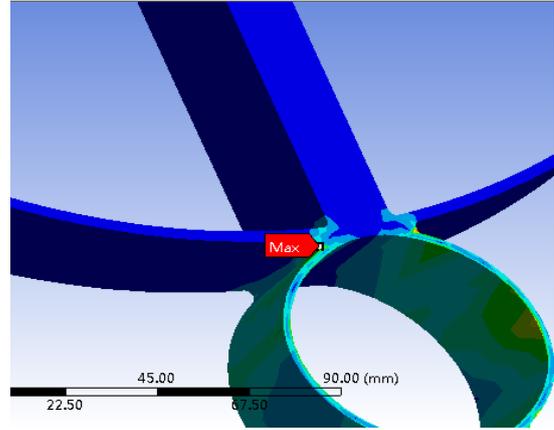


Figure 2. The analysis of images

According to the analysis diagram shown in Fig.2, the nonlinear structure can be determined. The maximum effective stress value location under the condition of the applied load is shown in Fig.2. As the nonlinear equivalent stress and strain energy curve shown in Fig.3 and Fig.4, the "max" identification was obtained by using the nonlinear buckling analysis.

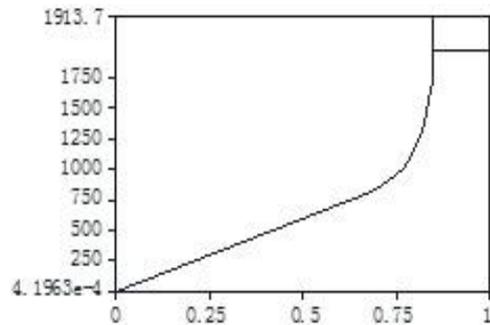


Figure 3. The curve of equivalent stress (von-Mises)

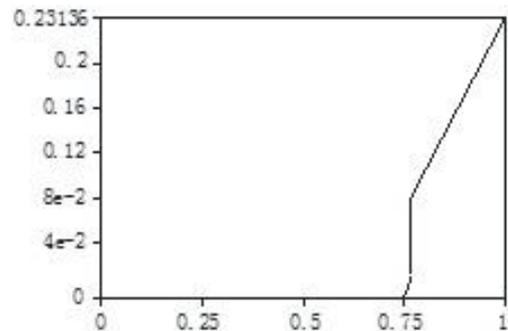


Figure 4. The curve of nonlinear strain energy

The analysis results from Fig.3 and Fig.4 is apparent that when $t=0.75s$, the structure load occurred mutation as the advance of the loading time. The corresponding stress value $\sigma = 1000MPa$, which fully meets the maximum internal force caused by the external load. The value of the bicycle may affect the stress value. At the same time, under the same time step condition of $t=0.75s$, the strain energy of the wheel occurred mutation and the yield point was reached. While the external load did not reach the critical value, so the wheel was still stability.

According to the deformation of the wheel, with the help of static analysis, the X direction deformation of the wheel hub is 0.25271mm when the bearing load 500N of Y direction was added. And the results show that the requirements of the bicycle wheel can be completely satisfied in the rotation process.

4 Conclusions

We can get the following conclusions according to the nonlinear buckling analysis in this paper:

(1)When the axial load $F=3.63\text{KN}$ in Y direction is applied on the wheel, the strain step and equivalent stress mutation will occur in the position that the small cylinder contacts with the ground.

(2)Through the conversion, the carrying capacity of at least 300kg on the wheel can be guaranteed, which can fully meet the demand of riding users.

References

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