Static characteristic analysis of a transmission line detection robot

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Abstract The functions of the transmission line inspection robot mainly depend on the metal structure. Whether the strength of the metal structure meets the requirements is directly related to the reliability of the robot. Taking a flying-wheel transmission line inspection robot as the research object, the static characteristics of its metal structure under common load conditions are analyzed by finite element software, and whether the strength of the structure meets the application requirements is investigated. Through analysis, it is found that the maximum working stress of the metal structure of the robot under working load appears near the left wheel pressure, and its value is less than the allowable stress of the material. With the increase of wind pressure, the maximum working stress of the mechanical structure of the robot increases.

1. Introduction
Overhead transmission line plays an important role in the power transmission system. It covers a wide range, and its environment is generally poor. The traditional manual inspection method can not meet the needs of modern power development [1-2]. The development of robot technology provides a reliable solution for the smooth development of modern power inspection. Since the world's first line inspection robot was developed by Tokyo Electric Power Company of Japan [3], the related research of robot line inspection technology has attracted great attention of researchers at home and abroad [4-9]. So far, a lot of useful results have been achieved. As the main load-bearing part of the robot, whether the static characteristic indexes such as the strength meet the requirements directly affects the possibility of the robot to complete the line detection work. Compared with other robots working on the ground, the line detection robot is more complex in the load and the strength requirements of the mechanical structure are higher. However, the research on the static characteristics of the mechanical structure of the line detection robot has not attracted enough attention. In this paper, a wheel flying transmission line inspection robot was taken as the research object, and the strength performance of its mechanical structure in high altitude wind load environment was analyzed by using the finite element software.

2. Mechanical structure sketch and finite element model of robot
In this paper, the transmission line detection robot mainly relies on the contact between the top two wheels and the transmission line to achieve the movement along the line direction. The structure of the whole machine is made of aluminum alloy, and the performance parameters of the material are given
in Table 1. Before the analysis, the finite element model of the structure was established in the finite element software. Because the model is irregular structure, solid187 element was used to simulate, and the free grid was used to divide it. The finite element model was divided into 294128 elements and 417654 nodes. The finite element model of the mechanical structure of the transmission line inspection robot was shown in Figure 1.

| Performance Parameters | Density/kg/mm³ | Modulus of elasticity/MPa | Poisson's ratio | Yield strength (0.2%)/MPa |
|------------------------|----------------|---------------------------|----------------|--------------------------|
| Values                 | 2.7e-6         | 0.69e5                    | 0.34           | 455                      |

Fig. 1 Finite element model of robot mechanical structure

3. Static characteristic analysis of robot mechanical structure

The main working environment of the transmission line inspection robot is in the high altitude, and the wind load is its main working load. Wind load is a kind of random load, its direction and magnitude will change with time. In contrast, when the direction of wind load is perpendicular to the direction of robot motion, the mechanical structure bears a larger working stress. Therefore, The static characteristics of the structure under the wind load perpendicular to the direction of robot motion was studied, and the influence of wind pressure on the static characteristics of the structure was also investigated in this paper.

Referring to the definition of wind pressure in the Crane Design Code GB 3811-2008, the typical working conditions when the wind power level is respectively 4-12 was considered in this paper. From the table, the corresponding relationship between wind power level and wind pressure under each typical working condition is shown in Table 2. The wind pressure in Table 2 was applied to the mechanical structure surface of the robot in the form of uniform load. After static analysis, the stress distribution of the structure was extracted. The mechanical structure finite element model of the robot after applying the wind load was shown in Figure 2.

| Wind power level | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|------------------|---|---|---|---|---|---|----|----|----|
| Wind pressure/Pa | 50| 150| 250| 350| 500| 600| 800| 1200| 1500|
Fig. 2 mechanical structure finite element model of loaded robot

After analysis, the stress of the structure was extracted. The stress nephogram of the mechanical structure of the robot under different wind pressures was shown in Figure 3.

(a) wind power level is 4 (wind pressure 50 Pa)
(b) wind power level is 5 (wind pressure 150 Pa)
(c) wind power level is 6 (wind pressure 250 Pa)
(d) wind power level is 7 (wind pressure 350 Pa)
(e) wind power level is 8 (wind pressure 500 Pa)

(f) wind power level is 9 (wind pressure 600 Pa)

(g) wind power level is 10 (wind pressure 800 Pa)

(h) wind power level is 11 (wind pressure 1200 Pa)

(i) wind power level is 12 (wind pressure 1500 Pa)

Fig. 3 working stress nephogram of robot mechanical structure
It can be seen from Figure 3 that under the action of wind load with different wind pressure, the maximum working stress of the robot mechanical structure occurs near the left wheel. The enlarged drawing of maximum working stress position of robot mechanical structure when the wind power level is 12. From Fig. 3 (a) to Fig. 3 (i), it can be seen that with the increase of wind pressure, the maximum working stress of the mechanical structure of the robot increases gradually. When the wind power level is 12, i.e. the wind pressure is 1500 Pa, the working stress of the mechanical structure reaches the maximum, with a value of 209.854 MPa, which is less than the allowable stress of the material. Therefore, it can be concluded that the strength of the mechanical structure of the robot meets the design requirements.

4. Conclusion
In this paper, the finite element software ANSYS was used to analyze the static characteristics of the mechanical structure of a transmission line inspection robot, and to investigate whether the static strength of the structure under the air wind load meets the design requirements. The main conclusions are as follows.

(1) Under the action of wind load with different wind pressure, the maximum working stress of the robot is located near the left wheel.

(2) With the increase of wind power level, that is, the wind pressure, the maximum working stress value of the mechanical structure of the robot is also increasing. When the wind power level reaches 12, that is, the wind pressure increases to 1500 Pa, the maximum working stress value of the structure also reaches the peak value, which is 209.854 MPa, less than the allowable stress of the material, and the static strength of the material meets the use requirements.

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