Analysis and research on ultimate stress of main bearing block of wind generator

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Abstract—As an indispensable part of wind turbine, bearing block is subjected to alternating load or impact load for a long time, so it is very important to analyze its dynamic performance and vibration. In order to improve the vibration resistance of the structure, this paper relies on the powerful modal analysis function of ANSYS software. In the analysis, the finite element optimization method was used to analyze the main stress and ultimate strength of the main bearing block of the wind generator. Furthermore, the results are used to guide the optimization of bearing structure.

1. INTRODUCTION

With the development of wind turbine to high power, megawatt wind turbine has become the main type in the market. As an important part of the wind turbine, the bearing block of the wind turbine bears the load of the wind wheel and various components on the frame. With the increase of fan power, the structure of main frame is becoming more and more complicated. As a key component, the strength and fatigue analysis of bearing seat are particularly important. Bearing seat is subjected to the external load from the fan's own parts and the transmission of the wind wheel. Due to the complicated stress situation, it is difficult to obtain reliable analysis results by using the traditional mechanical method. The use of ANSYS software can not only check the structure, but also guide the design and optimization of the structure[1]. Ease of Use

2. BEARING STRUCTURE

2.1. Bearing block design

Bearing block is used to support shaft parts, as the main supporting parts of the spindle, its performance and reliability are very critical. The structural form, shape, wall thickness, connection dimension and material selection of the bearing block should be determined through comprehensive analysis and calculation of load with spindle and wind wheel. Bearing housing design has the following characteristics and requirements.
2.1.1. Accuracy and positioning: Bearing block precision includes whole assembly, component size precision and geometric precision. Matching accuracy and positioning accuracy. For example, the blanking clearance value and its evenness of the punching die, the plastic injection die, the die positioning and guiding accuracy of the die-casting die, etc. all need to be ensured by the shape of the punch and the die, the position accuracy, the position of the guide installation and the matching accuracy. Therefore, it is necessary to stop the design and calculation of strict dimensional accuracy when designing the bearing block. At the same time, it is necessary to consider the manufacturing technology and precision of the parts to ensure the precise function and reliability of the bearing block.

2.1.2. Guide installation of bearing housing: The bearing block is limited in the direction of movement and is guaranteed by the installation. At the same time, guide installation on the bearing block clearance of the average, accurate movement also plays a role in positioning. Guide installation commonly used, guide column and guide sleeve composition of the guide installation (including sliding and rolling); Guide plate guide installation (including common guide plate pair and self-smooth guide plate pair), mainly used for large punch, slider and guide rail composed of oblique core guide; Die feed guide plate guide four kinds. Bearing block movement direction of the guide installation, as a fine guide and fine positioning role, so the requirements of high precision, good guide stiffness, etc., often used positioning guide.

![Figure 1. Example of a figure caption.](figure caption)

2.1.3. Process analysis of bearing block: Bearing block is used as a bearing bracket for mounting bearings. The main technical requirements of the parts are analyzed as follows: the part drawing shows that parts of the base bottom and inner hole, end face and the top surface of the bearing have roughness requirements, the rest of the surface accuracy is not high, that is to say the rest of the surface does not need to processing, just according to the accuracy of the casting. The bearing block is in static balance while working. The casting should not have sand hole, loose and other defects, to ensure the strength, hardness and fatigue of the parts, under the action of static force, not accident.

2.2. Guide installation of bearing housing: Material characteristics of main bearing blocks

The material shall be ball-ground cast iron, and the material specification shall be en-gjs-350-22u-lt. The performance test report of the cast block with the same casting state is shown in table 1.

|                  | Tensile strength | The yield strength | Elongation | Hardness (reference) |
|------------------|-----------------|--------------------|------------|----------------------|
| $\sigma_b \geq 320\text{N/mm}^2$ | $\sigma_{0.2} \geq 200\text{N/mm}^2$ | $\delta \% \geq 15$ | HBS 120-180 |

The impact energy test of the casting block v-notch sample with the same state as the casting is conducted and the report is provided: Test temperature: -40°C±2°C, the average value of the three samples shall be no less than 12J, and the individual value shall be no less than 9J.

The metallographic inspection of materials shall be carried out in accordance with ISO945, and the metallographic test specimen must be taken from the attached casting block, and the requirements are
as follows: the spheroidization rate shall reach above 80%; Graphite size 5-7 grades; Ferrite matrix (pearlite content not higher than 10%).

3. **CALCULATION AND ANALYSIS OF MAIN BEARING BLOCK**

3.1. **An overview of main bearing block**
Main bearing housing calculation and analysis report mainly check the bearing housing ultimate strength analysis and fatigue life analysis. Check whether the strength of the main bearing block meets the design requirements under the limit condition.

3.2. **Analysis process**

3.2.1. **Coordinate system**: In Guidelines for reference of coordinate system, the wheel hub is fixed to coordinate system, as shown in figure 2.

3.2.2. **Material performance parameters**: Material: en-gjs-400-18u-lt, density: 7000kg/m3, elastic modulus: 1.73×105MPa, poisson's ratio: 0.3, mechanical properties of materials: EN 1563. The specific data can be seen in table 2.

![Figure 2. Wheel hub fixed coordinate system](image)

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**TABLE 2. CASTING -- DUCTILE IRON EN1563[3]**

| Brand            | Wall thickness | Tensile strength /MPa | Yield strength /MPa | Elongation/% | Hardness/HBS |
|------------------|----------------|-----------------------|---------------------|--------------|--------------|
| EN-GJS-400-18U-LT| 30<t<60        | 390                   | 240                 | 15           | 130~180      |
|                  | 60<t<200       | 370                   | 220                 | 12           |              |

**TABLE 3. DATA SHEET SEW550 FOR LARGE FORGING ALLOY STEEL MATERIALS**

| Brand        | Tensile strength /N/mm² | The yield strength /N/mm² | V - notch test bar impact work /(-20±2°C) | Elongation /% | Hardness/ HB |
|--------------|-------------------------|----------------------------|--------------------------------------------|---------------|--------------|
| 42CrMo4      | 690~840                 | 460                        | 27J                                        | ---           | 207~255      |
| 34CrNiMo6    | 740~890                 | 540                        | 31J                                        | ---           | 228~269      |

Spindle material: 42CrMo4, density: 7850 kg/m3, elastic modulus: 2.1×105 MPa, poisson's ratio: 0.28, material mechanical performance index: steel material data sheet SEW550, see table 3[2].

3.3. **Calculation and analysis process**

3.3.1. **Model processing**: Solidworks 2007 was used to model the main bearing housing, the main frame and the mounting seat of the growth box. According to FEA analysis theory, some features of the
models that did not affect the calculation results were simplified accordingly. The processing results are shown in the figure below. The rest of the parts are modeled directly in Ansys11.0. The element type Settings of the finite element model are shown in table 4[4].

| Calculation model                      | Unit type | Number of nodes | Node degree of freedom | Unit number |
|----------------------------------------|-----------|-----------------|------------------------|-------------|
| Main frame, bearing block              | Solid186  | 20              | 3                      | 46247       |
| Main frame, bearing block              | Solid187  | 20              | 3                      | 8240        |
| The spindle                            | Beam188   | 2               | 6                      | 25          |
| Mounting seat for increasing box       | Solid45   | 8               | 3                      | 8922        |
| The contact unit                       | Conta174  | 8               | 3                      | 1410        |
| The contact unit                       | Targe170  | 8               | 3                      | 2175        |
| The bearing connection                 | Link10    | 2               | 3                      | 2686        |

3.3.2. Mesh division of each part: Material: The main frame, bearing block, mounting seat of growth box and main bearing were mesed to form the assembly modeling of the whole analysis model, as shown in the figure below.
TABLE 5. ULTIMATE LOAD: WHEEL HUB (STATIONARY COORDINATE SYSTEM)

| No. | Mx      | My      | Mz      | Myz    | Fx  | Fy  | Fz  | Fyz |
|-----|---------|---------|---------|--------|-----|-----|-----|-----|
| 1   | Max     | dlc1.1.12 | 2219.5   | -397.7 | 1405.8 | 169.5 | 14.7 | 382.5 | 382.8 |
| 2   | Min     | dlc2.24 | 2393.7   | -1105.8 | 68.0  | 1107.9 | 106.8 | -26.6 | -323.9 | 325.0 |
| 3   | Max     | dlc1.1.24 | 715.9    | 3784.1  | -794.7 | 3866.6 | 46.2  | -106.6 | -353.0 | 368.8 |
| 4   | Min     | dlc1.3.16 | 887.4    | -2632.3 | 93.7  | 2634.0 | 315.9 | 6.7   | -426.4 | 426.5 |

Figure 5. Assembly modeling of the whole analysis model

Figure 6. The loading point on the spindle axis at the hub center

Figure 7. The calculation results of von stress cloud diagram of the main bearing housing under working condition 1
Figure 8. The calculation results of von stress cloud diagram of the main bearing housing under working condition 2
Figure 9. The calculation results of von stress cloud diagram of the main bearing housing under working condition 3
Figure 10. The calculation results of von stress cloud diagram of the main bearing housing under working condition 4
3.3.3. Boundary conditions and loads: The contact surface between the main frame and the tower cylinder flange is 6 degrees of freedom. The loading point is located on the spindle axis of the hub. Considering that Mx acts on the mounting seat of the gear box, the link 10 on the main bearing cannot transmit Mx torque, equivalent to the free end, so Mx has no effect on the analysis result of the main bearing block, so only five components of My, Mx, Fx, Fy and Fz are loaded.

3.4. Static strength analysis of bolts under limit conditions

3.4.1. Limit load conditions: Load case of the wheel hub under stationary coordinate system is show in table 5.

3.4.2. Calculation results of ultimate static load of main bearing block: The ultimate load of 1-16 working conditions was loaded on the main bearing block, and the calculated results of the von stress cloud diagram were as follows (only 1-4 working conditions were shown in limited space).

3.4.3. Bar chart of bolt stress results under various limit conditions: The ultimate stress of main bearing block under different working conditions is analyzed and the statistical results are as follows.

3.4.4. Calculation results of ultimate strength

| No. | $\sigma_{max}$/MPa | $\sigma_y$/MPa | $[\sigma]$ | Safety factor $\lambda$ | Whether to meet |
|-----|--------------------|---------------|------------|------------------------|----------------|
| 1   | 193.06             | 240           | 218        | 1.129183               | Y              |
| 2   | 94.891             | 240           | 218        | 2.297373               | Y              |
| 3   | 84.65              | 240           | 218        | 2.57531                | Y              |
| 4   | 183.146            | 240           | 218        | 1.190307               | Y              |

$\sigma_{max}$: The maximum tensile stress of the X-axis of the bolt

$\sigma_y$: The yield limit of the bolt

$[\sigma]$: the allowable stress of the bolt

$[\sigma] = \frac{\sigma_y}{1.1}$, $\lambda = \frac{\sigma}{\sigma_{max}}$

Figure 11. the Bar chart of ultimate stress of main bearing block

4. CONCLUSION

As an indispensable part of wind turbine, bearing block is subjected to alternating load or impact load for a long time, so it is very important to analyze its dynamic performance and vibration. In this paper,
by means of the powerful modal analysis function of ANSYS software and based on the thought of finite element, the modal analysis of the bearing block is carried out, and the ultimate strength analysis and fatigue life analysis of the bearing block are checked whether the strength of the main bearing block under the ultimate working condition meets the design requirements, so as to guide the optimal design of the structure.

- in the process of preprocessing the bearing block with ANSYS, the density of the model must be specified, otherwise the desired result cannot be obtained.
- the model is solved under the assumption of no damping and free vibration.
- constraints consistent with the actual situation must be applied to the model, and non-zero displacement constraints are not allowed.
- Finite element dynamic modal analysis of the bearing housing was conducted by ANSYS software, and the fatigue strength of the main bearing housing met the requirements of GL specification. The results can provide theoretical basis for dynamic response calculation and structural optimization design of bearing housing. It can shorten the r&d cycle and improve the design quality.

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