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Structural Mechanics Analysis of Multi-row Cable Drum of Port Machinery Based on ANSYS Workbench

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Abstract: Single row cable reels are often used in the study of cable reels by heavy port machinery equipment, but there are problems of less cable capacity and larger circumferential space. In the design of the traditional heavy machinery cable drum design concept principle as the basis, on the basis of the drum structure optimization and strength check. According to the design of cable parameters, it is concluded that the winding of drum occupies less space, the cable is arranged in a regular order and can accommodate a large amount of cable. In this paper, Ansys Workbench is used for structural mechanical analysis of the drum body, and the final results show that the maximum stress of the drum under the working load is far less than the allowable stress value. By analyzing the mechanical state under the working condition, the effect of cable capacity increase is obvious, and the relative mass is reduced, and the stability of the drum structure meets the requirements.

Keywords: Port machinery, Cable reels, Structure statics, Finite element analysis.

1. Introduction

In the application environment of port industry, cable drum is a key component as a power source and cable retractable device to complete the long distance operation amplifier or lifting task of port machine. The effect of cable retracting and retracting is not only affected by its structure and size design, but also affects the overall structure size and use function of cable retracting and retracting device. With the continuous development of shipping industry, the load capacity of port ships increases, and the long-distance transportation of port machinery is a trend of future development[1-3]. As an important bearing part of the port machine, the reliability of its structural design affects the safe operation of the port machine. Due to the lack of accurate calculation of the cable drum, the theoretical cable distance of the drum is not accurate. If the carrying capacity is greater than the actual load, it is easy to cause the failure of the drum itself, affecting the working efficiency and causing potential safety problems[4].

2. Structural Size Analysis and Selection of Drum Device

In order to ensure that the structure size of the drum meets the requirements, the design condition should be considered according to the maximum allowance. According to the engineering requirements, the cable outer diameter is set to 60mm, the cable retracting and discharging capacity is set to 450m, based on the principle that the minimum winding radius of the cable is not less than 10 times of the cable outer diameter. The inner diameter of the drum is set as 800mm, and the design is carried out according to the length of the cable 500m. The port unit should adjust the opening of the cable drum regularly, and keep the opening of the drum always larger than the outer diameter of the cable a certain distance, so as to prolong the service life of the cable. The outer diameter allowance of the drum is set as 200mm, and the axial allowance is set as 50mm. The relationship between cable row number, layer number, maximum outer diameter of drum and axial size of drum is shown in Table 1 below:

Table 1. Cable reel parameters setting control table.

Row number b	1	3	5	6	8	10
layer number n	43	21	15	12	10	8
Drum diameter (mm)	3400	226	1900	1720	1600	1480
Drum shaft long (mm)	110	230	350	410	530	650

According to the actual horizontal working conditions, considering the spatial analysis, the parameter combination of row number 6, layer number 12, inner diameter 800mm, outer diameter 1720mm and shaft length 410mm is selected. The material of the drum is DH36, a Marine high strength structural steel, with yield limit [σ]=355MPa, Poisson's ratio =0.30, and elastic modulus 210GPa. The external size of the side plate is large, and the reversing load is relatively small in the reversing process. Some spare space can be reduced to minimize the materials used to save some cost and weight. Material properties are shown in the following table 2:

Table 2. Material properties of DH36.

Material type	Modulus of elasticity E/GPa	density (kg/m3)	Poisson's ratio ц	Yield limit σ_s/Mpa	Ultimate strength σ_s/Mpa
DH36	210	7700	0.30	355	460

3. 3D Modeling of Cable Drum

Cable drum structure is mainly used to complete cable retracting and releasing functions under the control of relevant systems, including brush, slip ring, shaft, drum side plate and other parts. Figure 1 is the cable drum 3D model diagram, in which the optimized design of the drum side plate ensures that the overall structure can save materials and meet the normal cable retraction function while reducing the mass, which reflects the superiority of the overall structure design. Its 3D modeling is completed in SOLIDWORKS as follows:

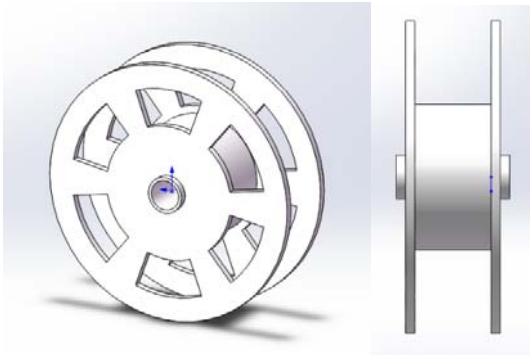

Figure 1. Three dimensional model of cable reel

4. Mechanical Simulation Analysis of Cable Drum Structure

4.1. Statics analysis of cable reel

Cable drum structure is mainly affected by the dead weight and cable load, local stress and strain is easy to occur in the process of cable retraction, so it is necessary to carry out structural statics finite element analysis of cable drum device to ensure reasonable design safety and reliability. The maximum horizontal tension of the cable shall not exceed 16% of the calculated breaking force of the cable, so that the cable is staggered in the space on the drum to avoid the phenomenon of breaking disorder.

4.2. Model establishment and simulation analysis

According to the structural optimization parameters of cable drum, a cable drum model is established in ANSYS Workbench. The drum mainly consists of two sides and the middle drum structure. The design requires that the deformation of the two sides should be less than 4mm, the deformation of the middle barrel should be less than 3mm, and the stress value should be less than the yield strength of the material.

4.2.1. Meshing

Based on the particularity of cable drum structure, the side plate and drum body are meshes. Lateral plate shape size is big, small work under partial load, thus adopting tetrahedron division, using the Mesh functions for automatic classification, drum tube structure is in the process of the cable and main bearing structure, for more accurate to explore the loading and deformation of cylinder, the cylinder structure is set to the hexahedron Mesh differentiate, in the chamfering by fine processing, and other critical areas and bend A more reasonable free mesh is generated with proper ratio of thickness and fineness, which not only saves calculation space but also makes the result close to reality. Element Size is set to 20mm, and the overall model is divided into 101626 nodes and 40,780 units. As shown in Figure 2:

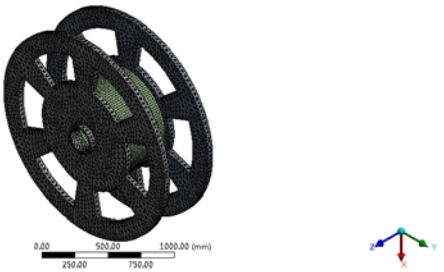

Figure 2. grid division of cable drum

4.2.2. Finite element boundary condition processing

According to the actual conditions of port machinery, because can circuition cable drum, drum end can regard as fixed constraint (limit of five degrees of freedom), drum input and shaft coupling, power to pass this end, constraints, the input on the surface of the inner hole three direction translational degree of freedom and the rotational degree of freedom to simulate coupling connection properties, on the other end in accordance with the simply supported model constraints, Small movement along the axial direction (limited to 4 degrees of freedom) can constrain two translational degrees of freedom and two rotational degrees of freedom on the cylinder surface of the support end, which can be axially translational and circumferential.

4.2.3. Applied stress load

The stress of the drum adds constraints and imposes loads on the structure. The load of cable drum mainly includes the compressive stress produced by cable dead weight, cable tension, drum dead weight and so on. During the working process of the drum, the cable is gradually reversed and wound to the end-side plate. Because the end-side plate is generated axial thrust, the stress state generated at the transition between the drum wall and the end-side plate is more complicated, and the end-side plate is bent, and the force is treated as uniform load. The axial compressive stress produced by the side plate is small when the cable is reversed. The cable on the drum of the radial pressure decreases in line with the euler diminishing, according to the model of the simply supported beam, the cable in the middle of the drum, release stress exerted on it when the drum is the largest, also because of the different cable charge volume changes lead to drum load bearing, when the applied load according to the maximum load simulation, guarantee the reliability of the whole structure of drum.

4.2.4. Results analysis

The final Solution calculation result of cable drum is obtained by solving calculation, and the equivalent stress cloud diagram and total deformation cloud diagram of cable drum are output. The results are analyzed and studied, as shown in FIG. 3, the maximum stress of cable drum is concentrated in the center of the drum, and the maximum stress value is 153.47mpa, which is less than the allowable load of cable drum.

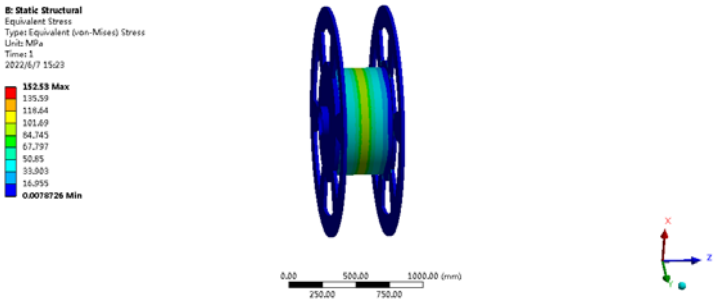

Figure 3. Cloud chart of drum stress under load

According to the cloud image, as shown in FIG. 4, the maximum shape variable is 0.261mm, which is less than the 4% requirement of the overall deformation. It can be seen from the above that the overall structure meets the design requirements. In addition, in order to ensure that the drum meets the long-term load and service life, the intermediate strength of the drum and the stiffness of the outer edge of the side plate should be improved.

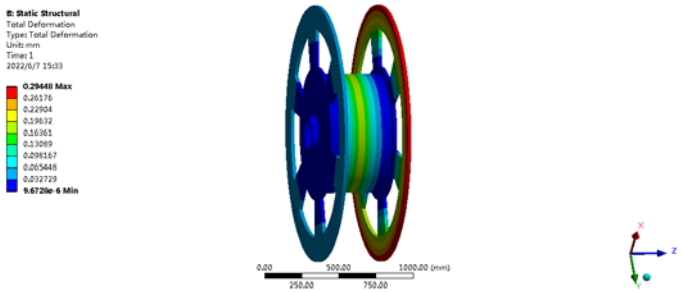

Figure 4. Cloud chart of drum deformation

According to the pressure curve of the outer wall of the drum, it can be known that the pressure is within the allowable range of the material, and a safer working environment can be obtained. The maximum pressure is in the center of the drum, which is a more reasonable scheme to ensure that the pressure is not too large. Pressure curve of drum outer wall is shown in Figure 5:

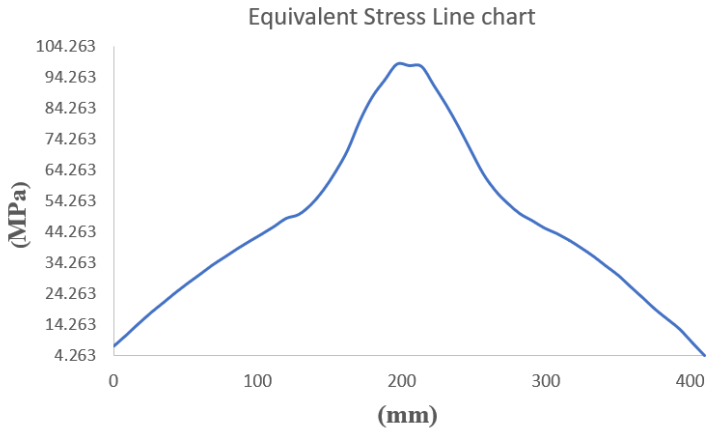

Figure 5. Pressure curve of drum outer wall

4.2.5. Strength check

Wall strength of cable drum is checked and the wall thickness of cable drum is 50mm. As the ratio of drum diameter to wall thickness D/ D > 10, it is a thin-walled structure, so the wall thickness OF drum D should meet the following requirements:

$$\delta = \frac{2AF}{b*[\sigma]} \quad (1)$$

Where δ -- wall thickness of drum mm D -- inner diameter of drum mm [σ] is the allowable compressive stress of the cable drum material, [σ]*n=σ_b $\sigma_b$is the tensile strength of the drum material, because the cable drum is DH36 structural steel for high strength hull, σ_b = 355MPa, n is the safety factor of the drum, generally 3. According to the formula, δ > 25mm, so it is theoretically verified that the wall thickness of cable reel meets the strength design requirements.

5. Conclusion

According to the strength theory and conventional cable drum design principles, the cable capacity of multi-row cable drum can reach nearly 500m in length. According to the cable parameters and cable capacity combined with the actual application space requirements, the parameters under different specifications are calculated, which improves the cable capacity length to better adapt to the long-distance transportation operations and activities of port cranes. Ansys Workbench software is used to analyze the drum structure. According to the generated results, the stability and reliability of the structure are verified accurately, which provides an effective reference for the safety basis.

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