Simulation Analysis of Collective Escape Capsule in Deep-sea by FEM

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Key Words: The collective escape compartment；Pressure structure；Hydrostatic pressure；Displacement；stress

Abstract: The mechanical property of collective escape capsule of pressure hull in deep-sea environment is studied In the engineering examples of new type of variable thickness escape capsule，the different thickness of the displacement, stress distribution and its regularity of distribution of mechanical stress maximum position of the hull is obtained by finite element analysis. The results show that vertical deformation of capsule turns out to be the major deformation under hydrostatic pressure，and the overall deformation is relatively small，the stiffness of pressure hull satisfies the requirement. The stress of capsule are dominated by vertical and shear stress Vertical stress is given priority to tensile stress and its value at a higher level，while shear stress is mainly compressive stress. By analyzing the stress distribution rule，all the stress meet the safety requirements. In this paper, The calculation method and simulation results in this paper could provide the reference for both optimization design and structure reliability assessment of collective escape capsule.

Introduction

Collective escape pod is an independent, self-contained new escape device,which is used in underwater structure such as deep space station and submarine, and can effectively improve the self-help ability of wrecked underwater staff, ensure the safety of personnel in the process of escape. is better than any escape system [1].

Collective escape pod started later in domestic research,there was a kind of escape capsule the end of last century ,which can be released through a compartment docking with the submarine;Huang Haocai etc[2] studied the form of the overall structure about the escape pod , analyzed the nonlinear buckling of thin wall spherical shell.Feng Liang etc[3] analyzed the ultimat strengh of the pressure cylinder shell in deep-sea dive by applying analytic method of strength stability comprehensive theory; Liu Mingjing etc[4] researched the overall performance of the collective escape compartment. Li Xiangyang etc[5] study the deep-sea manned submersible pressure spherical shells,analyzed the contact problems of manned deep-sea pressure spherical shells through contacting finite element analysis method;Yu Yingxia etc[6]analyzed the influence factors of the strength in finite element calculation for ribbed cylindrical shell structure and calculated the reliability of ring rib cylindrical shell structure.The collective escape compartment is thin-wall spherical shell structure, the main bearing structure is opening pressure spherical shells. The existence of the hole can produce stress concentration, but also weaken the ultimate bearing capacity of pressure spherical shell[7], which need strength and stability analysis when it’s designing to guarantee the security of spherical shell with holes.

In this paper,pressure hull structure researched is the thin-wall pressure spherical shells,the deformation of spherical shell is large strain, large deformation, which has been calculated by the application of geometric nonlinearity. This article researchs the strengh of the collective escape compartment under the action of static pressure underwater by using the finite element analysis with ANSYS software, calculates its displacement,stress distribution of normal stress and other, verifies its static pressure under water whether can meet the safety requirements.

The finite element model of pressure hull structure

The weight of collective escape pod, must be strictly controlled.It is show that the titanium alloy spherical shell is more sensitive to defects than high strength steel, although the titanium alloy bulk density is small,through the comparison and analysis results.From the perspective of safety, high strength steel has been selected as the material of escape pod.High strength steel: density ρ= 7.85 kg/m^3 , elastic modulus E= 2.1×10^5 MPa, poisson's ratio μ= 0.3.

The finite element model of collective escape compartment includes the main body of escape capsule and connection module.The overall coordinate system was established in the finite element software ANSYS, the X axis is the radial,Y is tangential,Z axis is vertical.Unit type adopts SHELL 93 unit, the unit need to define the shell thickness. To check the grid convergence,The grid size of thin shell is 50 mm×50 mm, other locations are 30 mm×30 mm. Finite element model of the collective escape compartment is shown in figure 1.

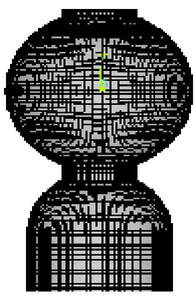

Figure 1 The finite element model of collective escape compartment

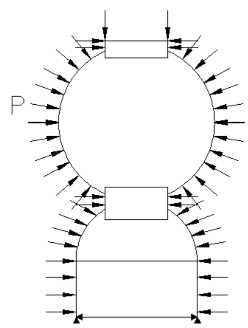

Figure 2 The load diagram of collective escape compartment

In this paper,the design depth of the collective escape compartment is 1000m. Hydrostatic pressure is:

$$P' = r\,\mathrm{gh}=1.0\mathrm{kg/m^3}\times 10\mathrm{N/kg}\times 1000\mathrm{m}=10\mathrm{MPa} \quad (1)$$

According to the submersible specification,the computational load is 1.5 times the maximum working pressure. As a result, the uniform hydrostatic pressure that applied to pressure hull is:

$$P = P'\times 1.5=10\times 1.5=15\mathrm{MPa} \quad (2)$$

The load diagram of the collective escape compartment is shown in figure2. The bottom is completely constraint.

The calculation principle of pressure hull with strength

As a typical solid and revolution structure, the collective escape compartment is composed of pressure spherical shell and cylindrical shells, hydrostatic pressure is the main load when its working.Considering the symmetry of the load and structure of the pressure hull, the calculation results of strength can be obtained by analytical element method. Cylindrical shells and spherical shells which is rotary shell under the action of boundary load and the positive pressure on the surface, the expression form about relationship of the boundary displacement and internal force is consistent with the results that derived from elastic foundation beam. In other words,The opening problem of spherical shell that reinforced by cylindrical wall can use the corresponding elastic foundation beam method, it is adaptive to more complex structure and complex stress state, Still displacement, the benging with warp and weft on the hole side of spherical shell, the longitudinal and circumferentialb ending stress on the hole side of the casing can be obtained. Then units within two parallel section that the angle is dq on the plane will be analyzed, balance equation of rotors is obtained, that is:

$$\begin{cases} \frac{d(T_1 r_2 \sin q)}{dq} - T_2 r_1 \cos q + N_1 r_2 \sin q = -p_1 r_1 r_2 \sin q \\ \frac{d(N_1 r_2 \sin q)}{dq} - (T_1 r_2 + T_2 r_1)\sin q = p_n r_1 r_2 \sin q \\ \frac{d(M_1 r_2 \sin q)}{dq} - M_2 r_1 \cos q = N_1 r_1 r_2 \sin q \end{cases} \quad (3)$$

Among them, *T*, *N*, *M* are respective for the pull force, shear force and bending moment on the selected element,ρ is the spherical shell curvature, *p* is positive pressure.

4 The calculation results and analysis of the pressure hull

In this paper, the finite element calculation about the strength of the collective escape compartment under the action of static pressure has been carried out ,which mainly analyses the change rule of different thickness from the aspects of displacement and normal stress, as well as summarizes and discusses the weak positions of the escape capsule under hydrostatic pressure.

4.1 The calculation results and analysis about displacement of the pressure hull

The displacement change rule of radial and vertical directions along the height of the collective escape compartment under hydrostatic pressure are shown in figure 2

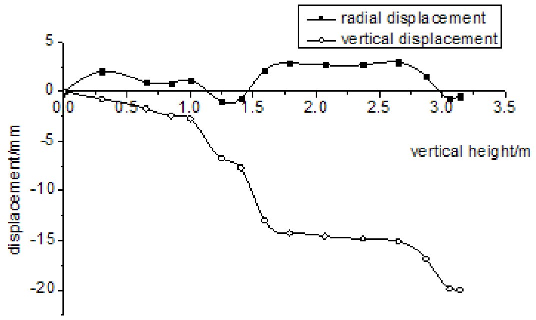

Fig 3 The displacement curve of pressure hull

As can be seen from the figure 3, the tangential displacement values of the pressure hull along the height are all small. The radial displacement values along the height are almost positive, there is negative on the height of 1.2 m to 1.4 m and the top, the two are the casing. The maximum of the radial displacement is 2.10, which the ratio is 1.3% with the corresponding location radius of pressure hull, the negative peak is 1.02 mm, which the ratio is 0.3% with the corresponding location radius of pressure hull , the relative value are small. The vertical displacement along the height increases, the displacement in the height of 0~1.0 m, 1.5~2.8 m changes slowly, This is due to the thickness of the tank shell here is thick, the displacement on the top of the tank shell is the maximum, which is 20 mm and 0.6% times of the height of tank shell, the vertical displacement is relatively small, the design about stiffness of the hull is reasonable.

4.2 The calculation results and analysis about stress of the pressure hull

The stress change rule of radial, tangential and vertical directions along the height of the collective escape compartment under hydrostatic pressure are shown in figure 4.

The figure 4 shows that the stress value mutate in vertical height of 1.2 m to 1.6 m and 1.6 m to 3.06 m of the spherical shell, which are the junction of the wall, the thin thick spherical shell and thick spherical shell, the casing and confining shell, up and down confining shell and other special locations. The phenomenon of concentration stress appears in these positions because of the junction or the change of shell thickness. The maximum of compressive stress for the structure is 847.2 MPa, the maximum of tensile stress is 737.43 MPa. The desigin value about tensile strength of high strength steel is 785 MPa.While the maximum of compressive stress is larger than the design value compressive strength, but when the stress coefficient is introduced to verify, that is, Stress coefficient = maximum of compressive stress/ design value of compressive strength = 1.08

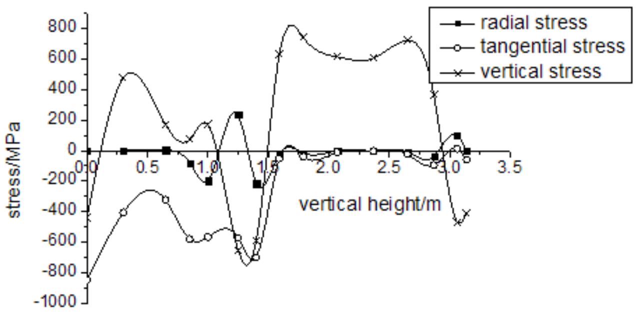

Fig 4 The stress curve of pressure hull

Conclusion

(1) The radial and toroidal displacement of pressure hull are smaller. It gives priority to vertical displacement. Vertical displacement increases along the spacecraft and reach to the maximum on the top of the pressure hull. The vertical displacement is relatively small and the design about rigidity of the pressure hull is reasonable.

(2) Although the vertically and radially positive pressure appears the local stress concentration in the thickness change parts, it can be ignored while considering the model simplification. The vertical and the radial stress are all less than the tensile and compressive strength of high strength steel as well as stress coefficient that Specifications tipulate. Although tangential stress at the bottom of the tank shell

stress is slightly larger than the compressive strength of high strength steel, but it's less than the stress coefficient 1.2. The strength of pressure hull meets the requirements.

(3) The displacement and stress are larger in the connection parts which is a weak part of the hull.

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