VERTICAL SUPPORT DESIGN AND STRENGTH ANALYSIS OF LARGE DIAMETER HIGH PRESSURE VESSEL

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ABSTRACT

As onshore oil and oil and gas in shallow water gradually depletion, deep water oil and gas development has become necessary. Designed a deep-water high voltage compartment which can simulation high pressure in 3000m water depth, high voltage compartment bottom head features multiple pipes, require the support must ensure the stability of the high pressure simulation chamber, as well as to facilitate the installation and maintenance of high voltage compartment and use, due to the high voltage to simulate the volume and weight of a large ,traditional vertical support cannot meet the requirements of pressure vessels. An improved support was designed based on Skirt support, the support structure is simple, easy to build, effective solution to the bottom of the head pipes space and high voltage module support questions.

**Key Words**: high pressure, large diameter, vertical vessel, simulation chamber, support

Introduction

As onshore oil and oil and gas in shallow water gradually depletion, deep-water oil and gas development has become necessary. As of 2013 global deepwater oil and gas production has exceeded 500 million tons of oil equivalent, accounted for more than 20% of the global offshore oil and gas production, and that percentage will rise[1]。 Currently, deep-water oil and gas development capacity has reached 3000m in the developed world, China also supports deep-water oil and gas resources as a strategic choice for national economy sustainable development, designed a deep-sea pressure Simulator that models 3000m depth, the deep-water high voltage compartment install vertically. Due to high pressure simulation class volume and weight huge, traditional vessel support, such as lug support, leg support, bracket supports, and skirt support [2-5] cannot meet using requirements, An improved support was designed based on Skirt support, the support structure is simple, easy to build, effective solution to the bottom of the head pipes space and high voltage module support questions.

Main structure parameters of high-pressure Simulator

Deep-sea high-voltage using vertical cylindrical structure, maximum working pressure: 40MPa, effective diameter 2500mm, effective Height 3000mm. Mainly composed of end cap locking components, end cap, cylinder ends, bottom of the cylinder, head, bottom support parts,

as shown in Figure 1.The top is the quick-opening structure, central to cylindrical shell, bottom is comprise by spherical head and vessel support, besides few gas vent in end cap, the rest of the holes are arranged on the bottom head, vessel support at the bottom anchor bolts for fixing.
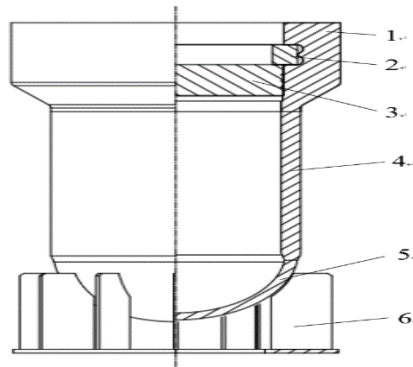

1-cylinder ends 2- split ring 3-end cap4- bottom of the cylinder5-head 6-vessel support

Figure 1High voltage module consisting

Supports Design

Vessel supports only support the weight of high pressure Simulator and its attachments, parts and accessories to be tested and the weight of the liquid in the tank, reach to 2.4x105kN, supports consists of several floors of the same composition and base ring, as shown in Figure 2. Vessel supports structure has similarities with skirt support, the structure size calculation, materials-reference when choosing a skirt bearing designs related to the calculation of calculation methods. structure size calculation, materials-reference are based on the calculation of skirt support[6]
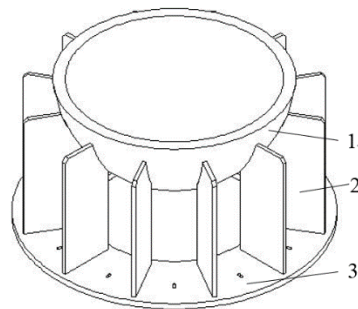
1-head 2- rib plate 3-base ring

Figure 2support structure diagram

Base Ring

The weight of deep-water high voltage compartment through vessel supports passed to concrete based Shang, support surface of based ring must makes load average distribution to concrete based Shang, and cannot break the concrete based Shang, while based ring must has must of thickness, when bear wind contains or earthquake load based ring was not folding

bent,[7]design and calculation of based ring main including inner diameter, and outer diameter, and thickness.

Outer diameter D_o and inner diameter D_i of based ring[8]

Skirt supports is through skirt shell welding the head and supports together, strengthened ribbed panels on the skirt shell, and this support will welding ribs and head together directly, rib plate is required to extend block skirt-support, so ribs will be larger than the width of the skirt-support rib width. Outer diameter of the based ring diameter larger than skirt-support, inner diameter of the based ring is small than skirt-support, according to the actual situation to increase the value of the base ring.

$$\begin{cases} D_o = D + (320 \sim 800)\,mm \\ D_i = D - (320 \sim 800)\,mm \end{cases} \quad （1）$$

the value of D in the calculation of the skirt support typically take the inner diameter of skirt shell, skirt shell inside diameter and outside diameter of the tower is close, so the design and calculation of the vessel support as a reference, The value of D in the formula near to outer diameter(2960mm) of the cylinder, take D=2950mm.

The base ring will eventually be fixed on the concrete basis, so must ensure that the cement base will not be crushed, so the pressure transfer to concrete basis by base ring must be less than the allowable pressure of concrete basis

$$\frac{4F}{\pi\left(D_o{}^2 - D_i{}^2\right)} \leq [\sigma] \quad （2）$$

Thickness of base ring δ

The thickness calculation of base ring reference ribbed skirt-supports base ring thickness calculation methods[9], base ring thickness is calculated as:

$$\delta = \sqrt{\frac{6M_s}{[\sigma]_b}} \quad （3）$$

Deep-sea pressure Simulator will eventually placed in prior prepared pit, in whole life cycle will not bear wind load, so base design calculation only consider earthquake load, for $H/D \leq 5$ vertical container cannot consider vertical earthquake force effect in calculation earthquake load, while deep-sea pressure Simulator is basic symmetric structure, can ignored eccentric quality caused of bent moment, so high pressure simulation class bearing based ring by of maximum bent stress $\sigma_{b\max}$ as:

$$\sigma_{b\max} = \frac{M_{\max}^{0-0}}{Z_b} + \frac{m_0 g}{A_b} \quad （4）$$

$$M_s = \max\left\{\left|M_x = C_x \sigma_{b\max} b^2\right|, \left|M_y = C_y \sigma_{b\max} l^2\right|\right\} \quad （5）$$

Bolt hole circle diameter of base ring

Bearing ring by the base of the anchor bolt supports will be fixed in concrete based on the base ring bolt number n must be a multiple of 4, calculation of bolt hole circle diameter as shown

in (5)[10]。

$$\phi = \frac{4(R^3 - r^3)\sin\alpha}{3(R^2 - r^2)\alpha} \quad (6)$$

R——outer diameter of base ring， mm

r——inner diameter of base ring， mm

α——adjacent angle between bolt hole centers， rad

The above calculated values, base ring parameters is shown in Table 1

Table 1base ring parameters

Inner diameter D_i f based ring	2150mm
Outer diameter D_o of based ring	3750mm
Thickness of base ring δ	80mm
Bolt hole circle diameter of base ring	3000mm

Rib plate

n ribs of the supports are uniform distribution on the base ring, and in the calculation of the thickness of the rib plate, it is considered that each rib is subjected to force as F, and the rib plate are mainly subjected to the compressive stress by F1 and the resulting bent stress by F2 , and $F_1 = mg/n$ a single rib stress analysis as shown in Figure 3. According to the size of the base ring to determine the width of the rib plate is 690mm, rib plate on both sides from the base ring diameter and diameter of the same distance, the thickness of the rib plate as δ , According to the size of the pipes at the same time to ensure that the bottom of the head space. The outer height of the rib plate is 1650 mm.
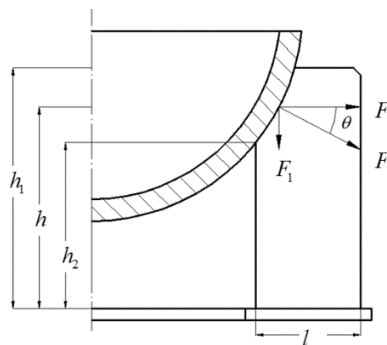

Figure3force analysis of rid plate

The bent stress of the rib plate：：

$$\sigma_b = \frac{M}{W} = \frac{6M}{\delta l^2} = \frac{6F_2 h}{\delta l^2} = \frac{6F_1 h \cot\theta}{\delta l^2} \quad (7)$$

The compressive stress of the rib plate：

$$\sigma_n = \frac{F_1}{\delta l} \quad (8)$$

The stress of the rib plate belongs to the combination of bending and compressive, and the

maximum stress of the ribs should be satisfied as：

$$\sigma = \sigma_n + \sigma_b \le 0.9[\sigma]^t \quad （9）$$

Then

$$\delta \ge \frac{F_1}{0.9l[\sigma]^t}(\frac{h\cot\theta}{l}+1) = \frac{mg}{0.9nl[\sigma]^t}(\frac{h\cot\theta}{l}+1) \quad （10）$$

Strength analysis of supports

FEA model of supports

The support is an axisymmetric model. In the analysis and calculation, a one-sixth model is used to calculate the constraint, add a fixed constraint to the bottom of the base ring of support and put a ring constraint to direction of the support Y direction ,the support load of the support is equivalent to the head to withstand the pressure in the Z direction, as shown in Figure 4. The head material is 13MnNiMo, the yield strength is 380MPa, the tensile ultimate strength is 570MPa and the Poisson's ratio is 0.3; the base ring and the rib material are Q345, the yield strength is 345MPa, the tensile ultimate strength is 470MPa and the Poisson's ratio is 0.3.
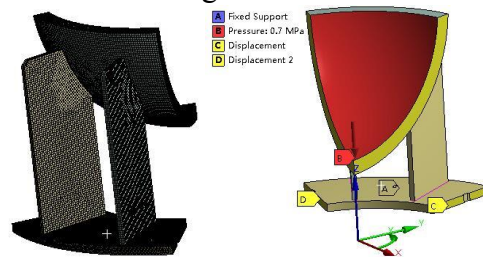

aFinite element gridb Load and constraint

Figure 4FEA model of supports

Supports analysis results

The finite element calculation results of the support are shown in Figure 5, and the maximum stress of the support is 100.62MPa, and the maximum stress of the support is within the allowable range of Q345. The maximum stress of the support is at the contact area between the support rib plate and the head, the maximum stress is 100.62MPa for the local stress concentration of the ribs , the requirements of the ribs plate meet the requirements; the maximum stress of the foundation ring is 23.55MPa , Located at the junction of the base ring and the rib plate, the maximum stress of the foundation ring is much smaller than the allowable strength of the Q345, and the base ring satisfies the requirement.
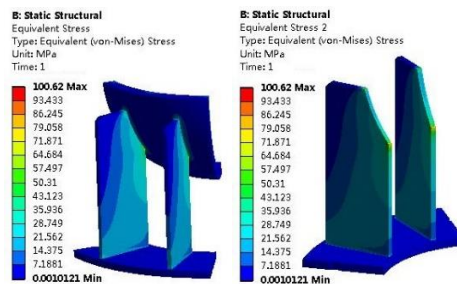
a the overall results Rib plate and base ring
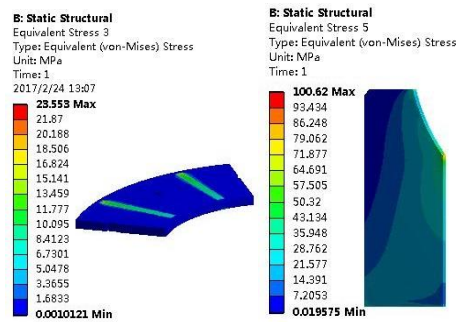
cbase ring drib plate

Figure5Support finite element results

Conclusion

An improved support was designed based on Skirt support has a simple structure, safe and stable characteristics, to achieve a high voltage module support must ensure the stability of the equipment, but also to facilitate the installation of high voltage module, maintenance and use requirements, Which effectively solves the problem of insufficient opening of the Skirt support and the lack of the bottom of the head pipes space , which provides a reference for the design of the non - standard vertical pressure vessel support.

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