Static Analysis on the New Piston Retaining Frame of One-Stage Gasholder

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***Abstract*—The piston retaining frame is an important supporting structure in the sealing system of the one-stage gasholder. A new type retaining frame is designed with simple form and high bearing capacity. In the paper, the integral deformation of the structure, the deformation and stress of the vertical rigid frame, and the stress of the members of the circumferential bracing system are respectively obtained through the FEM static analysis. The results show that both single member and integral structure can meet the design and application requirements. It can be used in one-stage gasholder design.**

***Index Terms*—one-stage gasholder, retaining frame, vertical rigid frame, circumferential bracing system, static analysis**

I. Introduction

Gasholders are widely used for gas storage and utilization in the iron and steel metallurgical industry. The gasholder is connected with pipe network, so it also has the function of balance the pipe pressure. Gasholder is composed of outer cylinder and internal piston which can move up and down. The piston must ensure the minimum of gas leak by setting perimeter sealing device. One-stage rubber-film-sealed gasholder (Figure 1), with large-capacity and high-pressure, has the advantages of pressure equilibrium and convenient usage. It is suitable for iron and steel companies to meet the development requirements of low-energy and high-competitiveness at this stage [1].

Piston sealing system is a key part of the gasholder. It includes retaining frame, rubber membrane and piston shell. The rubber membrane is connected to cylinder at bottom end, and to the retaining frame at top end. When gas fills in the cylinder, piston system floats, and the rubber membrane supported by retaining frame suffers gas pressure and rolls up. Main function of the retaining frame is to ensure lifting smoothness and the stability of the reservoir pressure. The piston jam will cause the gasholder to fail to operate normally, and may lead to major safety hazards of gas leakage [2]. The piston retaining frame is an important support structure in the sealing system of one-stage gasholder (Figure 2). It is mainly in the form of triangular brackets [3], but the improvement of its structural form has always been concerned by the field of design and research. The form of retaining frame must be carefully designed for the large volume and high pressure gasholder [4]. Through a great deal of calculation and comparison, cylindrical structure form is a better choice [5].

Figure 1. One-stage gasholder.

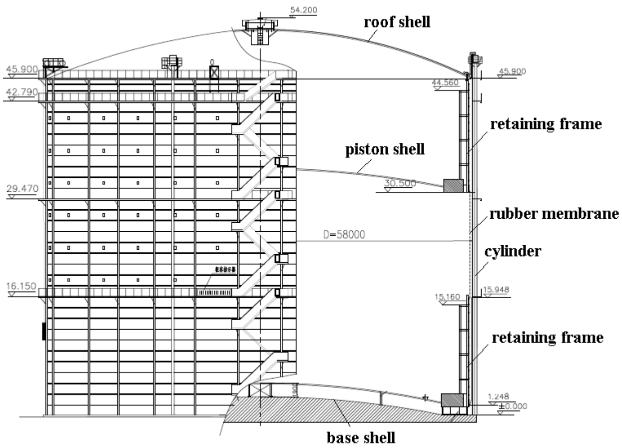

Figure 2. Structural sketch of one-stage gasholder.

A new structural form of the piston retaining frame is composed with the portal frame and horizontal bracing (Figure 3). It has the advantages of simple form and high bearing capacity. In this paper, the static analysis is carried out, and the working performance of the overall structure, the vertical rigid frame, and the circumferential bracing system are investigated. The analysis results provide the reference for the engineering design.

Manuscript received March 15, 2018; revised April 15, 2019
Project number, Anhui Provincial Natural Science Foundation Project (1708085ME126) ;

doi: 10.18178/ijmerr.8.3.472-476

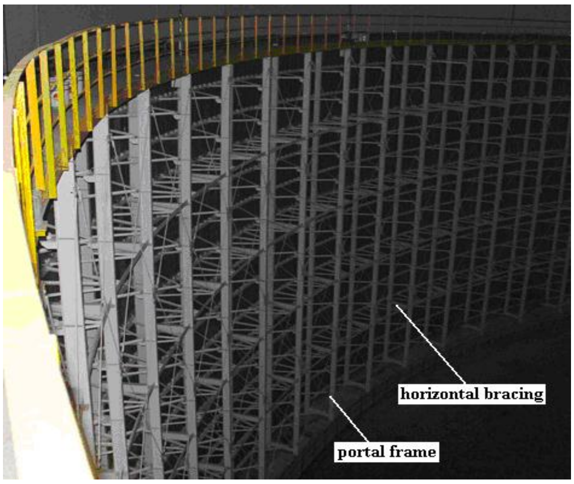

Figure 3. A new structural form of the piston retaining frame.

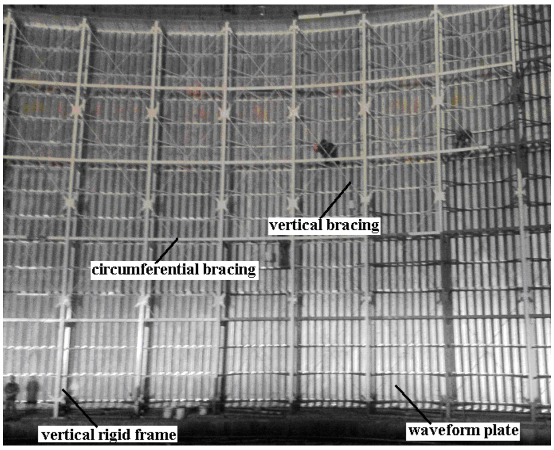

Figure 4. Partial of piston retaining frame.

II. Simulations

A. A New Retaining Frame

The main structure of a new type of piston retaining frame is composed of vertical rigid frames, circumferential bracing system, vertical bracing system, and waveform plates (Figure 4). The circumferential bracing system includes horizontal trusses, horizontal knee bracings, and top and bottom girts.

The vertical bracing system is arranged as X shape bracing with steel rods (Figure 4). The waveform plates, which are paved on the outside of outer chord in circumferential bracing system, carry the gas pressure directly.

The structure parameters are as follows: 64 vertical rigid frames arranged in a ring, with 16550 mm high, inner diameter 57780 mm, outer diameter 60380 mm, and 1050 mm for beam spacing; The horizontal trusses is arranged on the beam plane with 3150 mm spacing; Horizontal knee bracings are arranged at other beam positions without trusses; The top beam is set as the top walkway handrail. The member sizes are listed in Table I. The transverse section of column and beam in vertical rigid frame is narrow flange H-shape steel, and the transverse section of the other members is angle steel.

TABLE I. Member Sizes For Piston Retaining Frame

Member		Size
vertical rigid frame	column	HN250x125
	beam	HN250x125
horizontal truss	outer/inner chord	L125x12
	web member	L50x6
horizontal knee bracing	outer chord	L125x12
	knee bracing	L50x6
top & bottom girt		L125x12

B. Finite Element Model

The analysis model is established by finite element software ABAQUS. Considering that there is a certain safety reserve for the structure, the vertical bracing system and waveform plates are ignored when modeling (Fig. 5).

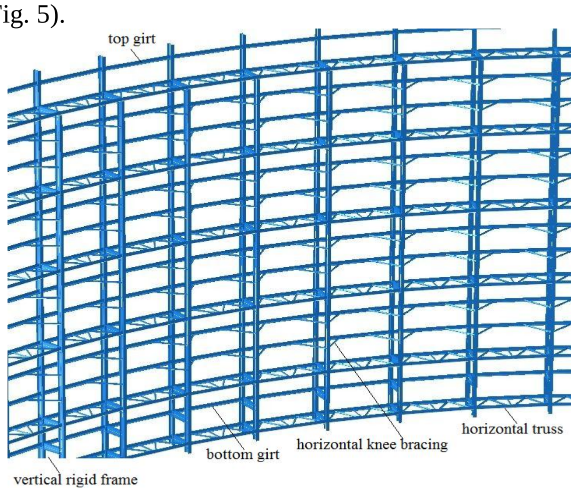

Figure 5. Partial model of piston retaining frame.

The components of the entire model are modeled with beam element and the element type is B33. Each member is tied at the connecting node. The material is steel with a yield stress of 235 Mpa, an elastic modulus of 206 GPa, and a Poisson ratio of 0.3. The gas pressure applied to the waveform plate is converted into a uniformly distributed line load with the value of 12.6 kN/m acting on the outer chord. The boundary conditions at the base of colomns are set to two kinds: fixed support and hinged support. The overall FEM model of the retaining frame with load and boundary constraint is shown in Figure 6.

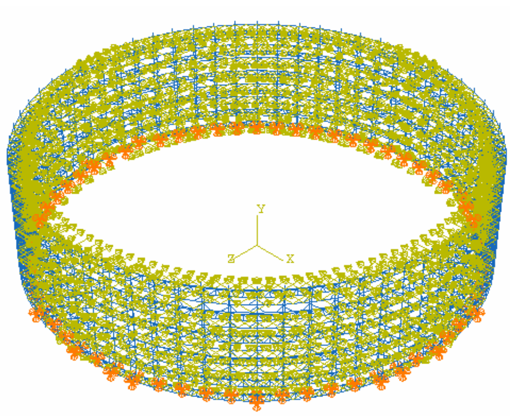

Figure 6. Retaining frame model with load and boundary constraint.

III. Result Analysis

A. Analysis Results of the Overall Structure

Through the static analysis of the retaining frame, the trend of deformation and stress changes are respectively obtained under two kinds of constraint conditions at column base. It is found that the constraint conditions have little effect on the displacement and stress distribution of the whole structure. The maximum displacement and stress diagrams of overall retaining frame are shown respectively in Fig. 7 and Fig. 8.

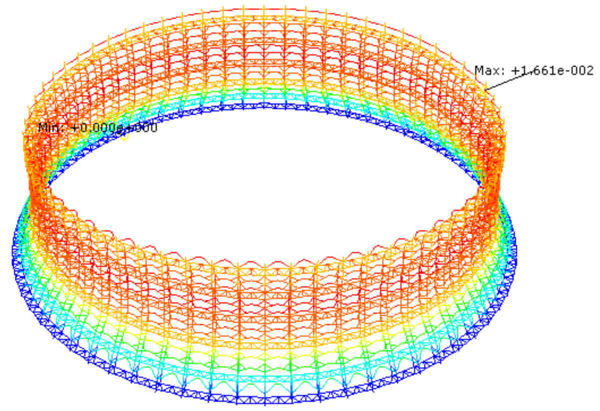

Figure 7. Deformation diagram of retaining frame.

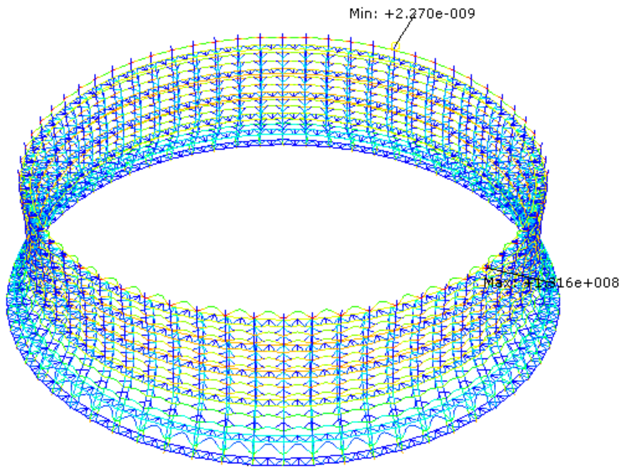

Figure 8. Mises stress diagram of retaining frame.

The maximum displacement of the whole retaining frame occurs in the middle of the span of the top beam (Figure 7). The displacement value is 16.61 mm, which is about 1/1000 of the height of the retaining frame.

The maximum stress occurs at the end of top beam (Figure 8). The stress value is 131.6 Mpa, and less than the yield stress of steel. The results show that the overall stiffness and bearing capacity of overall structure can meet the requirements of normal operation.

B. Mechanical Behavior of a Vertical Rigid Frame

Since the overall structure and load are symmetrical, the internal force and deformation are also symmetrical; just a vertical rigid frame, a horizontal truss and a horizontal knee bracing are taken out from the output data for analysis.

The trend of deformation and stress changes of vertical rigid frame are respectively obtained under two kinds of constraint conditions at column base. The displacement and stress curve with the height of vertical rigid frame are shown in Fig. 9 and Fig. 10.

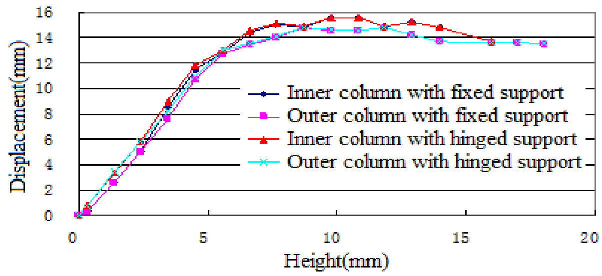

Figure 9. Displacement curves with height of a vertical rigid frame

From Fig. 9, it can be seen: (1) Under the constraint conditions of fixed and hinged supports, the deformation of the vertical rigid frame is basically the same. (2) The displacement of the rigid frame increases with the increase of height. When exceed 1/ 2 of the height, the change of the displacement value is relatively small. (3) The maximum displacement 15.8 mm occurs at the top of the outer column, which is about 1 / 1000 of the height of the vertical retaining frame.

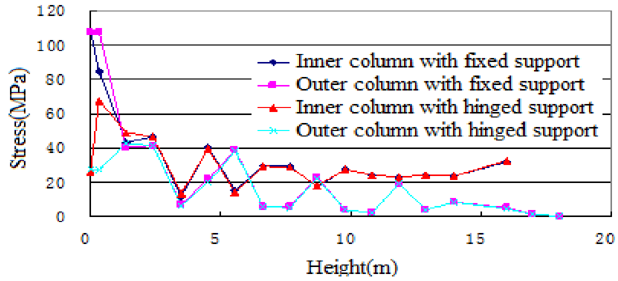

Figure 10. Stress curves with height of a vertical rigid frame

Fig. 10 shows the variation of Mises stress along the height. It can be seen: 1) The Mises stress in the vertical rigid frame decreases with the increase of height. Over one third of the height, the stress values of the inner and outer columns are all less than 60 Mpa. 2) In the fixed support frame, the maximum stress 158.15 MPa appears at the bottom end of the outer column; in the hinged support frame, the maximum stress 140.85 MPa occurs at the intersection of the bottom column and the first horizontal knee bracing. Both of them are less than the yield stress of steel, and satisfy the static load bearing requirements.

C. Mechanical Behavior of Circumferential Bracing System

The horizontal truss and knee bracing not only provides lateral support for the vertical rigid frame, but also undertake the gas pressure from the waveform plate paved on them. Each member of the truss and knee bracing is tied at the joint to simulate the welding connection (Fig. 11).

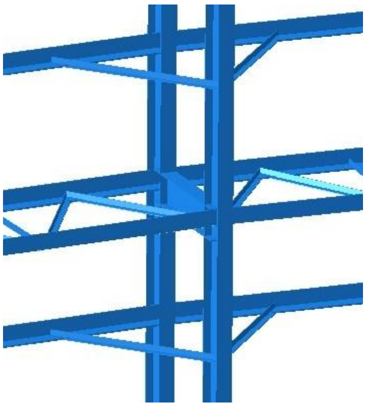

Figure 11. Tied joint of members in circumferential bracing system

Fig. 12 and Fig. 13 show the number of the members of the horizontal truss and the horizontal knee bracing. The Mises stress of each member is listed in Table II

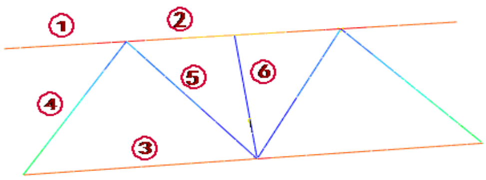

Figure 12. Member number of horizontal truss

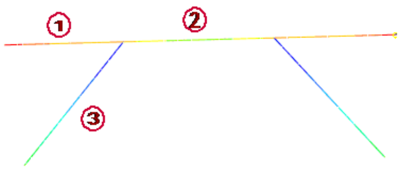

Figure 13. Member number of horizontal knee bracing

As can be seen from Table II, the Mises stress of web members and knee bracing are smaller than the outer chords. The maximum stress, which appears on the No. 1 and No. 2 that directly bear the gas pressure, is less than the yield stress of steel.

TABLE II. MISES STRESS FOR THE MEMBERS OF HORIZONTAL TRUSS AND KNEE BRACING

Member number			Mises Stress(Mpa)
Horizontal truss	Outer chord	1	110.8
		2	110.8
	Web chord	3	107.0
		4	44.96
		5	19.81
		6	7.95
Horizontal knee bracing	Outer chord	1	119.2
		2	100.8
	Knee bracing	3	51.9

The top and bottom girts can be regarded as a bending member fixed to the outside of the vertical rigid frame at both ends. The maximum stress at the end is 131.6 Mpa.

IV. Conclusion

(1) The new type of piston retaining frame has the performance of a cylindrical structure. The overall stiffness is large, and the deformation satisfies the requirements of normal operation.

(2) The support forms of column base have less influence on the overall deformation and stress distribution of the retaining frame. The hinged support is simple and can be used for engineering design.

(3) The stiffness of the vertical rigid frame is relatively large. When the support is fixed, the maximum Mises stress appears at the bottom end of the outer column, which satisfies the design requirements.

(4) In the circumferential bracing system, the Mises stresses of the outer chords are larger than those of web members. All members are safety for bearing static load.

(5) The vertical bracing system and the waveform plates should be considered in analysis of piston retaining frame in future discussion.

Acknowledgment

The authors wish to thank JIANG Dejin and YANG Jun. This work was supported in part by a grant from Anhui Provincial Natural Science Foundation Project (1708085ME126).

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