Study on strength of filter system of modular mechanical water treatment plant

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Abstract. Now the modular mechanical water treatment technology is a new kind of technology in water treatment. The new technology has changed the work way of conventional water plants and got very wide use in practice. In this paper, the strength and deformation of filter systems which includes filter frames and filter plates are analyzed with ANSYS. The stresses and deformations of upper filter system and lower filter system are compared and discussed. The upper and lower filter plates have enough safe margins which can prevent the permanent deformation of the filter plates. The lower filter frame can make the best of the property of steel tubes and saved the materials under safety condition. Finally, according to the analysis results, the paper combined analytical results with practice and optimized the design plan of filter systems.

Keywords: FEM; water treatment; filter; strength.

1 Introduction

China has a vast territory, a large population and rich water resources. But the average water resource of every person is very low. Further more, the most water of our country is surface water and the components of the water are very complicated. This will threaten the safety of the water for life especially for rural water for life. So it is a very important to protect and apply the surface water scientifically. On the other hand, most parts of our country are mountains and desert. The available land resource is not abundant. With the increase of the population, the development of the economy and the quickening of urbanization process, the land resources will get more and more precious. So how to save in water treatment project has become an important subject.

Now the conventional water plants of our country use steel concrete structures as the main constructions which need large land and large building project which will cost long time and much money. On the other hand, the conventional water plants are not flexible in work. So the modular mechanical water treatment plants are getting wider and wider use because they need low invest, short time limit, small land and have the advantages of flexibility, high automation and easy operation.

According to the characteristics of modular mechanical water treatment equipment, this paper has analyzed the strength and stiffness of the filter system, discussed the stress and the deformation of the filter frame and plate, presented the cloud pictures of stress and deformation. At last, combining theory with practice, the paper has improved and optimized the design of filter system.

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2 Filter system structure

In this paper, the water treatment plant uses two-layer homogeneous filter material filter chamber which includes frames, filter plates, filter material etc. Filter frames and filter plates bear the gravity of filter materials mainly. The filter material is quartz sand whose density is about 2.6 g/cm^3 and stacking density is 1.6 g/cm^3 . The filter plates are rigid plastic PVC plates whose thickness is 20mm. The filter frames are composed of Q235B steel tubes whose sizes are $160 \times 80 \times 5 \text{ mm}$, $120 \times 80 \times 5 \text{ mm}$, $80 \times 80 \times 5 \text{ mm}$.

The upper filter frame uses 1*9 layout plan, i.e. one $160 \times 80 \times 5 \text{ mm}$ longitudinal beam and nine $120 \times 80 \times 5 \text{ mm}$ transverse beams. Under the longitudinal beam, there are four uniformly distributed $80 \times 80 \times 5 \text{ mm}$ upright columns, as shown in Fig. 1.

The lower filter frame uses 3*9 layout plan, i.e. three $80 \times 80 \times 5 \text{ mm}$ longitudinal beam and nine $80 \times 80 \times 5 \text{ mm}$ transverse beams. The supports columns are twelve (3×4) uniformly distributed $80 \times 80 \times 5 \text{ mm}$ upright steel tubes, as shown in Fig. 5.

3 Strength analysis on upper filter system

For the rectangular sheets with usual constraints, we can use theoretical formulae to compute[1]. But for the complicated combination of beams and sheets, the theoretical formulae can not be used to analyze the strength[2,3]. In this case, numerical calculation must be used. In this paper, the FEM software ANSYS is used to calculate the stress and deformation of complicated structures.

In the upper filter system, the filter plate uses 20mm PVC plate in which a number of filters are mounted. The filter frame uses 1*9 layout plan, i.e. one $160 \times 80 \times 5 \text{ mm}$ longitudinal beam and nine $120 \times 80 \times 5 \text{ mm}$ transverse steel tubes. There are four uniformly distributed $80 \times 80 \times 5 \text{ mm}$ upright square tubes that support the longitudinal beam, as shown in Fig. 1. In transverse direction, the frame uses nine $120 \times 80 \times 5 \text{ mm}$ rectangular steel tubes which all are welded to the longitudinal beam. The load of quartz sand is about 0.02785 MPa . The upper filter plates are fixed on 4 sides. Fig. 2 - Fig.4 are the analytical results of upper filter system.

Figure 1. Model of upper filter system

Figure 2. Stress of upper filter system

Figure 3. Stress of upper frame

Figure 4. Stress of upper filter plate

From the FEM analytical results we find that the largest deformation of the upper filter plate is about 7.1mm and the largest equivalent stress of the filter plate is about 11.4 MPa. The largest deformation of the upper filter frame is about 1.8mm, and the largest equivalent stress of the frame is about 123.6 MPa. They all are in safety.

4 Strength analysis on lower filter system

In the lower filter system, the filter plate uses 20mm PVC plate in which a number of filters are mounted. The filter frame uses 3*9 layout plan, i.e. three 80*80*5mm longitudinal steel tubes and nine 80*80*5mm transverse steel tubes. There are twelve(3*4) uniformly distributed 80*80*5mm upright square tubes that support the three longitudinal tubes, as shown in figure 5. In transverse direction, the frame uses nine 80x80x5mm square steel tubes which all are welded to the longitudinal tubes. The load of active carbon is about 0.02785 MPa. Fig. 6 - Fig.8 are the analytical results of lower filter system.

Figure 5. Model of lower filter system

Figure 6 . Stress of lower filter system

Figure 7. Stress of lower frame

Figure 8. Stress of lower filter plate

From the FEM analytical results we find that the largest deformation of the lower filter plate is about 6.1mm and the largest equivalent stress of it is about 11.5 MPa. The largest deformation of the lower filter frame is about 1.4mm, and the largest equivalent stress of the filter frame is about 123.6 MPa. They all are in safety too.

5 Analysis of results

The deformations and stresses of the upper and lower filter systems under the normal work loads are shown in Table 1.

Table 1. Deformations and stresses of the upper and lower filter systems

	Equivalent stress (MPa)	Deformation (mm)
Upper filter plate	11.4	7.1
Upper filter frame	123.6	1.8
Lower filter plate	11.5	6.1
Lower filter frame	151.2	1.4

From Table 1 we find that under the normal loads the stress of the upper filter plate and the stress of the lower filter plate are close to equal, but the deformation of the upper filter plate is larger than the deformation of the lower filter plate. The reason is that upper filter frame is sparser than lower filter frame. Further more, the upper frame only has 4 supporting tubes. In general, the sparse structure is good for operation. The stress of lower filter frame is larger than the stress of upper frame, but the deformation of lower frame is smaller than the deformation of upper filter frame. The main reason is that the lower filter frame used the thinner 80*80*5mm tubes and more (12) supporting tubes. Because there is no need in process requirements for the operation of lower frame, so it can have more supporting tubes.

6 Summary

The paper analyzed the strength and stiffness of the filter systems of modular mechanical water treatment equipment by use of FEM. The analysis results show that the designs of filter systems are reasonable which can satisfy the requirements of strength and stiffness. The upper and lower filter plates have enough safe margins which can prevent the permanent deformation of the filter plates. The lower filter frame can make the best of the property of steel tubes and saved the materials under safety condition. The upper filter frame used sparser structure which is convenient to operation and can improve processes. At the same time, the upper frame also has some safe margin which can bear the changes of load. So, the analysis is very meaningful to modular mechanical water treatment.

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