

Research on the Planetary Gear Deceleration Machine Design of a Novel Rapidly-Opening/Closing Actuator of Manual Valve

Bin Shi, Feng Wang*, Huaqing Wang, Yajun Chen, Cunyin Chen

Engineering Research Center of Chemical Technology Safety of the Ministry of Education, Beijing
University of Chemical Technology, Beijing 100029, China
wangfeng991@163.com

Keywords: manual valve, rapidly-opening/closing, actuator, deceleration machine

Abstract. Failing to promptly close the valve whose circuits have been burnt out is one of the important causes leading to an amount of oil leakage after the Dalian oil pipeline explosion. Moreover, the opening/closing torque of the manual valves will be bigger due to no actions for a long time, corrosion, rust, etc. And the operators will stay in a dangerous environment for a long time and thus they will have life problems when there are abnormal conditions or accident conditions.

This paper proposes a design idea of a novel rapidly-opening/closing actuator of a manual valve, in order to resolve the problem that how to open/close a manual valve rapidly. The research on the rapidly-opening/closing actuator of a manual valve should include the calculation of the opening/closing torque of the manual valve and the designs of the deceleration machine and the chuck. The output shaft of the deceleration machine connects with a chuck, while the chuck connects with the wheel of the valve. The work principle of the actuator is that a motor drives the rotation movement of the deceleration machine so as to realize the rapid opening/ closing of the valve. This paper mainly focuses on the design of the deceleration machine, wherein the structure of planetary gear is designed through the theoretical calculation and the computer-aided design method. The research of the method provides the design method and the technical support for the design of the rapidly-opening/closing actuator of the manual valve.

The actuator could be employed to the safety prevention departments of the chemical industries after the successful design of the device. The device can be utilized to cope with the problem that how to open/close a manual valve with more rotating laps or in emergency conditions rapidly. Moreover, the accident rescue ability of the chemical industries will be further improved, and the loss of the accidents will be reduced.

1. Introduction

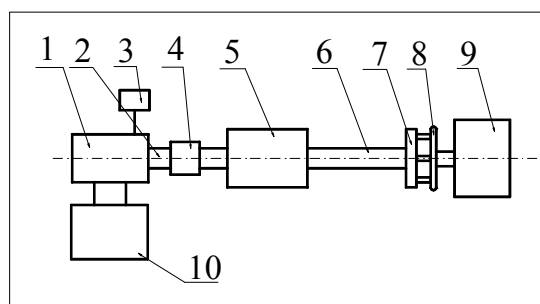
In chemical industrial enterprise, the valve is a very important control unit in a fluid delivery system. Failing to promptly close the valve whose circuits have been burnt out is one of the important causes leading to an amount of oil leakage after the Dalian oil pipeline explosion. Such as on July 16, 2010 in Dalian Xin'gang oil pipeline explosion and oil leakage accident, one of the important reasons was that oil burning damaged the power system and the power-driven valves had been disabled, then the operation personnel rushed into the third tank, spent more than one hour to rotate the valve over 8,000 circles by hands to close the valve completely. Finally, the oil leaking out of the tank stopped. The delay of the closing of the valve had induced a large amount of oil leakage and oil burning, which caused a huge loss in the accident and serious environment pollution. In

addition, the operation personnel stayed in the dangerous environment for a long time to deal with the emergency, which also increased the possibility of casualties. Moreover, the opening/closing torque of the manual valves will be bigger due to no actions for a long time, corrosion, rust, etc.

In order to cope with the problem that how to open/close a manual valve rapidly, this paper mainly focuses on the structure design of the planetary gear deceleration machine through the theoretical calculation and the computer-aided design method. The research of the method provides the design method and the technical support for the design of the rapidly-opening/closing actuator of the manual valve.

2. Structure and function principles of the actuator

2.1 Figure of the actuator structure



- 1—electromotor 2—electromotor shaft 3—frequency conversion 4—torque limiter
5—planetary gear deceleration machine 6—output shaft 7—chuck 8—wheel of the valve
10—body of the valve 11—accumulator

Fig. 1. Figure of the actuator structure

2.2 Function principles

As shown in figure 1, the function principles of the rapidly-opening/closing actuator of a manual valve are that an accumulator (10) will supply the power for an electromotor(1), the power output from the electromotor transfer to a chuck(7) through a planetary gear deceleration machine deceleration. The chuck will drive the wheel of a manual valve (8) rotating to realize the rapid opening/ closing of the valve.

3. The planetary gear deceleration machine design

3.1 Summary of the planetary gear

The actuator selects the two grade-NGW-type planetary gear with higher efficiency, and the framework diagram is shown in Fig. 2, where a is the sun wheel, b is the ring gear, and c is the planetary wheel [1].

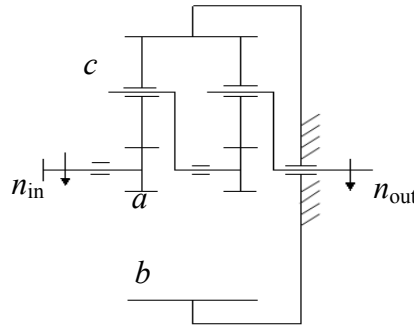


Fig. 2. Framework diagram of the two-grade-NGW-type planetary gear

3.2 Planetary gear deceleration machine design method

3.2.1 Design process

As shown in Fig.3, the design process includes four steps.

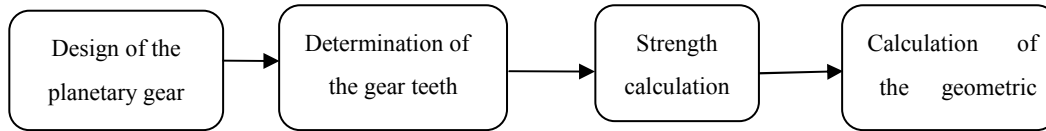


Fig. 3. Planetary gear design steps

3.2.2 Planetary gear deceleration machine design

The planetary gear structure has two grades, wherein the sizes and the structures of the high grade and the low grade are the same. Thus we should merely design the low grade.

(1) Determine the gear teeth

According to the condition of the gear teeth, the gear ratio i_{aH}^b , the number of the sun wheel teeth Z_a and the number of the planetary wheel n_w have the following relations:

$$\frac{i_{aH}^b Z_a}{n_w} = C \quad (1)$$

Adjust the gear ratio i_{aH}^b properly to convert C to be an integer, and to work out Z_a . Then use the equations (2) and (3) to work out the number of the ring gear teeth Z_b and the number of planetary wheel teeth Z_c .

$$Z_b = C n_w - Z_a \quad (2)$$

$$Z_c = \frac{1}{2}(Z_b - Z_a) \quad (3)$$

According to the different C values, we can obtain many groups of the number of the teeth, and we select an appropriate number of the teeth based on the size and other conditions.

(2) Strength calculation

Calculate the centre distance according to the teeth contact strength:

$$a \geq J_a (u+1)^3 \sqrt{\frac{K T_1}{\phi_a u \sigma_{HP}^2}} \quad (4)$$

where J_a is a calculation factor, which can be looked up according to Table 2-55[2]; K is a load factor, and $K = 1.2 \sim 2.2$; T_1 is a sun wheel transmission torque, which can be calculated according

to the formula $T_1 = 9550 \frac{P}{n_\lambda \cdot n_w} K_c$ (where K_c is a load uneven factor, which can be looked up

according to Table 7-18[2]); ϕ_a is a teeth width coefficient, and usually $\phi_a = 0.5$; σ_{HP} is an allowable contact stress, and $\sigma_{HP} = 0.9\sigma_{H\lim}$; $\sigma_{H\lim}$ is a gear contact fatigue limit, which can be looked up according to Table 2-80[2].

The initial value of the gear modulus is:

$$m = \frac{2a}{Z_a + Z_c} \quad (5)$$

If the modulus is not a standard value, then the value is taken as the standard value (1, 1.25, 1.5, 2, 2.5, 3, 4, 5).

Then the actual gear center distance is:

$$a_{ac} = \frac{1}{2}m(Z_a + Z_c) \quad (6)$$

(3) Geometry size calculations

The pitch circle diameter: $d = Zm$;

The top circle diameter: $d_a = d + 2m$ (for the sun wheel and the planetary wheel),

$$d_a = d - 2m \text{ (for the ring gear);}$$

The root circle diameter; $d_f = d_a - 2.5m$ (for the sun wheel and the planetary wheel)

$$d_f = d_a + 2.5m \text{ (for the ring gear).}$$

Conclusion

The application of the planetary gear deceleration machine in the rapidly-opening/closing actuator of manual valve has the advantages of compact structure, light weight, high efficiency, a wide range of transmission ratio, etc. Because the output shaft and the input shaft of the rising stem gate valves are on the same straight line, and the valve stem would be moved up and down during the valve opening/closing, while the chuck connects with the wheel of the valve, enough space is needed for the shaft at the top of chuck. Therefore a hollow shaft that longer than the stem between the output shaft and the chuck need to be added, and due to the astaticism of the shaft, the actuator instability will be increased. Further research to eliminate the defects will be needed.

References

- [1]. Xiaolu Zhu. The manual gear machine design. Beijing: chemical industry press, (2005)76668-727
- [2]. Xiaochun Huang. Design and application of Planetary gear transmission. Mechanical engineering, (1997)48-52
- [3]. p. Zak, V. Dynybyl. Testing of the Gears-would come With Standard Profile. Seattle, USA, (2007) 11-15