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Introduction

1.1 What Is a Mixed-flow Pump?

A mixed-flow pump is a centrifugal pump with a mixed-flow impeller [1]. The specific speed (n_s) lies between 35 and 80 rpm for low-speed mixed-flow pumps and between 80 and 160 rpm for higher-speed mixed-flow pumps (in special cases, even higher). It has characteristics of both radial flow and axial flow pumps. As liquid flows through the impeller of a mixed-flow pump, the impeller blades push the liquid out away from the pump shaft and to the pump suction at an angle greater than 90°. The impeller of a typical mixed-flow pump and the flow through a mixed-flow pump are shown in Fig. 1.1.

1.2 Types of Mixed-flow Pumps

Based on the type of suction chamber, mixed-flow pumps can be divided into two types: volute mixed-flow pumps and guide vane mixed-flow pumps, as shown in Fig. 1.2. The former is close to the design of a centrifugal pump, and the latter is close to the design of an axial flow pump.

At present, majority of mixed-flow pumps are volute mixed-flow pumps which are similar to a single-suction centrifugal pump but are different in the type of impeller: the impeller of a mixed-flow pump of high specific speed is similar to that of an axial flow pump which is open type with adjustable blades; the impeller of a mixed-flow pump of low specific speed, on the other hand, is closed type which is similar to that of a single-suction centrifugal pump, but its flow channel is wider and the blade outlet is inclined.

Compared to the axial flow pump, the guide vane mixed-flow pump has slightly higher efficiency and a relatively flat efficiency characteristic curve. In other words, it can ensure higher efficiency when the water level changes; hence, it is very suitable for farmland drainage and irrigation and saves power, but compared to the volute mixed-flow pump, its diameter is smaller. For the vertical guide vane mixed-flow pump, the impeller is submerged in water during operation, so there is no need for water diversion equipment, and therefore the needed floor area is small. Therefore, in places where the axial flow pump is used (except for the axial flow pump with large adjustable blades), it is advantageous to replace it with an appropriate model of guide vane mixed-flow pump.

Other classifications of mixed-flow pumps are:

1. According to the inspection and disassembly form, they can be divided into the extractable mixed-flow pump and the non-extractable mixed-flow pump.
2. According to the blade regulation type, they can be divided into the fixed mixed-flow pump, the semi-regulated submersible axial flow pump, and the fully regulated mixed-flow pump.

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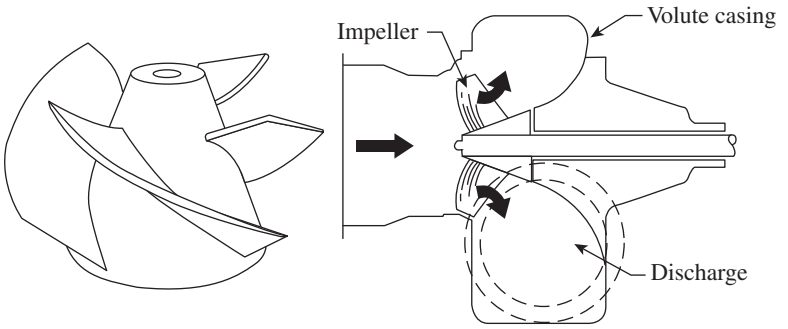

Figure 1.1 Mixed-flow pump impeller and mixed-flow pump model.

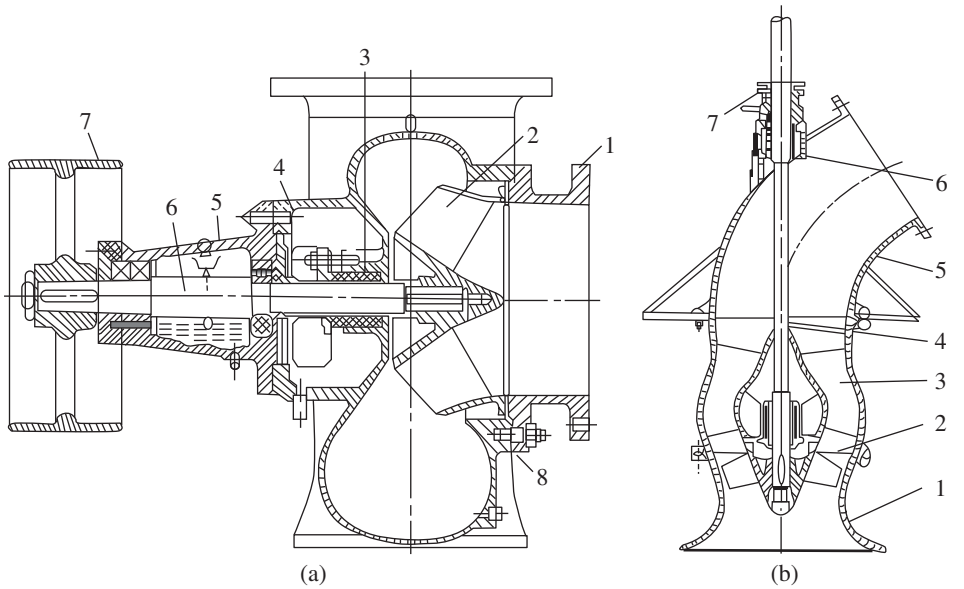

Figure 1.2 Classification of mixed-flow pumps. (a) Structural diagram of volute mixed-flow pump 1. Pump cover, 2. Impeller, 3. Packing, 4. Pump body, 5. Bearing body, 6. Pump shaft, 7. Pulley, 8. Bolt. (b) Structural diagram of guide vane mixed-flow pump. 1. Suction horn, 2. Impeller, 3. Guide vane, 4. Outlet elbow, 5. Pump shaft, 6. Rubber bearing, 7. Stuffing box.

1.3 Agricultural and Industrial Applications of Pumps

Due to the characteristics of moderate head and large flow rate, the mixed-flow pump is widely used in farmland irrigation, flood prevention and drainage, sewage treatment, power station cooling systems, and other applications.

In agricultural production, the main function of the mixed-flow pump is irrigation and drainage. There are vast rural areas in the world, thus a large number of pumps are needed every year. Generally, agricultural pumps account for more than half of the total output of the pumps.

In the mining and metallurgical industries, mixed-flow pumps are also widely used. The mixed-flow pump is used for drainage and water supply in the process of beneficiation, smelting, and rolling in mines.

In the power sector, power stations need a large number of boiler feed pumps, condensate pumps, circulating pumps, and ash pumps, among which mixed-flow pumps account for the majority.

In the shipbuilding industry, many advanced water jet propulsion pumps are of mixed-flow pump types.

The following are examples of large-scale mixed-flow pump station projects in which Chinese companies have been engaged inside China as well as in neighboring countries for development of shipping, flood discharge, and other functions. The three representative projects are briefly described below:

1. Pumping station of Zaohe River in Suqian, Jiangsu province, China [2].
   The first-stage renovation project of the Zaohe River pumping station in the eastern route of the south-to-north water diversion project is located in Zaohe town, Suyu district, Suqian City, Jiangsu Province, China. Its primary task is to pump the diverted water from the Liulaodian pumping station into Luoma Lake, achieving a target water delivery of 175 m^3/s to Luoma Lake and addressing the drainage needs in the regions of Pihong River and Huangdun Lake.

   The Zaohe pumping station, shown in Fig. 1.3 is currently equipped with two sets of 5700HLQ100-4.78 vertical fully adjustable guide vane mixed-flow pumps. The pumps are designed with a net head of 4.78 meters, a design flow rate of 100 m^3/s, an impeller diameter of 5.70 meters, a rated speed of 75 r/min, and an adjustable blade angle in the range +2° to −18°. They are paired with TL7000-80/7400 vertical synchronous electric motors with a rated capacity of 7000 kW and a total installed capacity of 14 000 kW. The first unit was successfully started on April 8, 2011, at 15:40 in the afternoon.
2. Qushou pumping station of Qinglongshan irrigation area in Heilongjiang Sanjiang Plain, China [3].

Figure 1.3 Pumping station of Zaohe River in Suqian, Jiangsu province, China. Source: [2]. Jiangsu Aerospace Hydraulic Equipment Co., Ltd. https://www.pumpcj.com/case/95.html. Last accessed 17 January, 2024.

Figure 1.4 Qushou pumping station of Qinglongshan irrigation area in Heilongjiang Sanjiang Plain, China. Source: [3]. Jiangsu Aerospace Hydraulic Equipment Co., Ltd. https://www.pumpcj.com/case/97.html. Last accessed 17 January, 2024.

The installed flow rate capacity of the Qushou pumping station of Qinglongshan irrigation area is 381 m^3/s, and the total installed power capacity is 56 000 kW. It has six sets of 3300HLQ38.1-9.74 fully adjustable mixed-flow pumps to irrigate the largest irrigation area in Heilongjiang province. Furthermore, it is the second largest mixed-flow pump station in China, as shown in Fig. 1.4. This infrastructure plays a crucial role in realizing increased grain production and efficiency, optimizing the regional water resource allocation, and implementing the coordinated scheduling of surface water, groundwater, and rainwater resources for irrigation in the Sanjiang region – the largest granary in the country. It contributes significantly to promoting the coordinated and sustainable development of the economy, society, and ecology in the region.

3. The Belt and Road project of Chongqing Electromechanical Group – the Hyderabad flood control irrigation project in Telangana, India – has been successfully tested recently [4]. The 24 large, closed-volute mixed-flow pumps and 12 large synchronous motors used in the project have all been developed by Chongqing Hydro Turbine Co. Ltd. with independent intellectual property rights. Twenty-four large mixed-flow pumps are installed in this flood control and irrigation project. Each water pump has a flow of 41 m^3/s, a lift of 11 m, and a rotational speed of 136.6 r/min. It is the largest closed mixed-flow pump with single unit power of 6500 kW synchronous motor. The energy index and stability index of water pumps and synchronous motors have reached an international advanced level.

1.4 Summary

This chapter provides an overview of the main structural forms of the mixed-flow pump, its classifications, and industrial applications. In terms of the rotational speed, the specific speed (ns) ranges between 35 and 80 rpm for low-speed mixed-flow pumps and between 80 and 160 rpm for

higher-speed mixed-flow pumps. Considering the structure of the suction chamber, mixed-flow pumps can be categorized as volute mixed-flow pumps and guide vane mixed-flow pumps. Additionally, the broad applications of mixed-flow pumps in agricultural irrigation and other major industrial projects attest to their excellent operational range, performance, and stability.

References

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2 https://www.pumpcj.com/case/95.html.
3 https://www.pumpcj.com/case/97.html.
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