Effect of Turning Angles on the Inflow Characteristics in a Waterjet Propulsion Pump

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Abstract: To study the influence of turning maneuvering navigation angle on the inflow characteristics of water jet propulsion pumps, numerical simulations were conducted on mixed flow water jet propulsion pumps under straight and left and right 15 °/30 ° turning navigation states. By comparing the hydraulic performance differences of water jet propulsion pumps under five navigation states, the intrinsic relationship between turning angle and pump inflow morphology was elucidated, and the evolution mechanism of pump inflow morphology under straight navigation and turning conditions was emphasized, and conduct quantitative analysis on the inflow quality. The research results of this article provide a theoretical basis for selecting appropriate operating angles for ships under turning maneuvers.

Keywords: Waterjet propulsion pump, Turning angles, Inflow characteristics, CFD.

1. INTRODUCTION

Water jet propulsion device is a new type of special power device applied to ships [1-4]. During operation, it freely flows through the bottom of the ship into the inlet channel, enters the impeller through the inlet surface of the water jet propulsion pump, flows out from the nozzle through the guide vanes, and obtains thrust through the reaction force of the water jet from the water jet propulsion pump. Compared to traditional propulsion devices, water jet propulsion pumps have advantages such as high propulsion efficiency, good cavitation resistance, low noise, and simple structure [5, 6]. Therefore, they have been widely used in high-speed ships, concealed submarines, and large and medium-sized transport ships [7, 8]. When the ship is turning and maneuvering, due to the deviation of the velocity and pressure distribution on the inlet flow surface of the inlet channel at different turning and angles, the liquid flow pattern on the pump inlet surface exhibits strong non-uniformity, leading to changes in the internal flow characteristics of the water jet propulsion pump, affecting the propulsion efficiency and operational stability of the water jet propulsion pump [9-11]. Therefore, it is of great significance to study the flow patterns of water jet propulsion pumps under different turning conditions and explore the impact mechanism of the internal flow characteristics of the pumps.

2. MODELS AND METHODS

To reflect the actual navigation situation, a flow field control body was added below the inlet channel of the water jet propulsion pump to simulate the water around the bottom of the ship. Figure **1** shows a three-dimensional model of the water jet propulsion pump and its water area, mainly composed of five parts: the control body, inlet channel, impeller, guide vane, and nozzle. The geometric dimensions of the length, width, and height of the water body to be set to 30 times, 10 times, and 8 times the outer diameter of the impeller, respectively. Based on the characteristics of each turbulence model, this article adopts RNG k-ε the model solves the calculation [12-16]. The motion attribute of the impeller is defined as the rotational domain, with an impeller speed of 4500r/min. The inlet is defined as the speed inlet, and its speed is the sailing speed of ship. Considering the different normal depths of the bottom and the influence of boundary layer, the Wieghardt formula is introduced to define the inlet speed vin, the control body outlet is defined as free outflow, and the nozzle is defined as the static pressure outlet.

3. PERFORMANCE ANALYSIS OF WATER JET PROPULSION PUMP UNDER DIFFERENT TURNING CONDITIONS

During the right turn of the water jet propulsion pump, the flow rate will decrease, and as the turning angle increases, the flow rate will decrease more significantly. When the turning angle reaches 30°, the change amplitude reaches 50m^3/h. During the left turn of the water jet propulsion pump, the flow rate increases due to the difference between the turning angle and the impeller rotation angle. When the left turn angle reaches -30°, the change amplitude reaches 20m^3/h.

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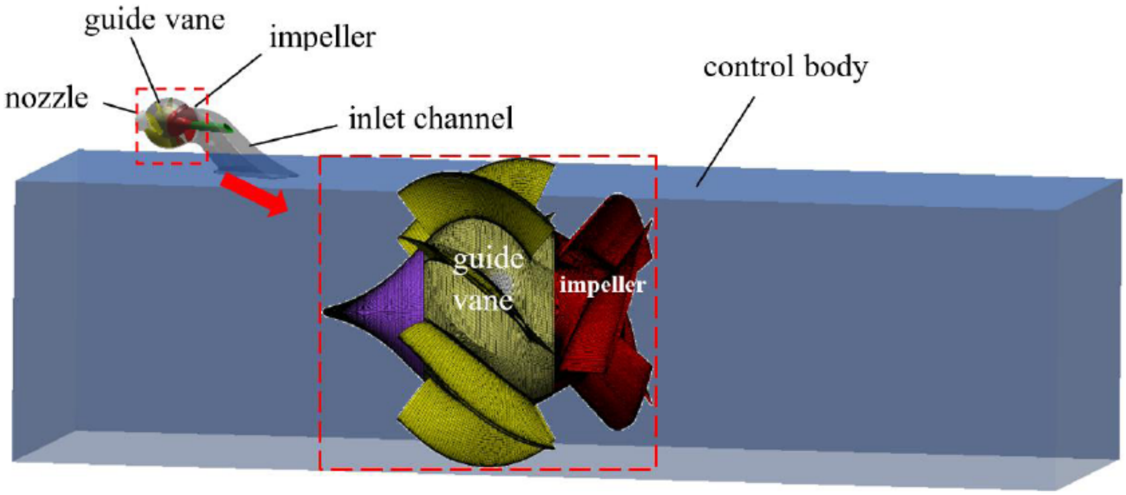
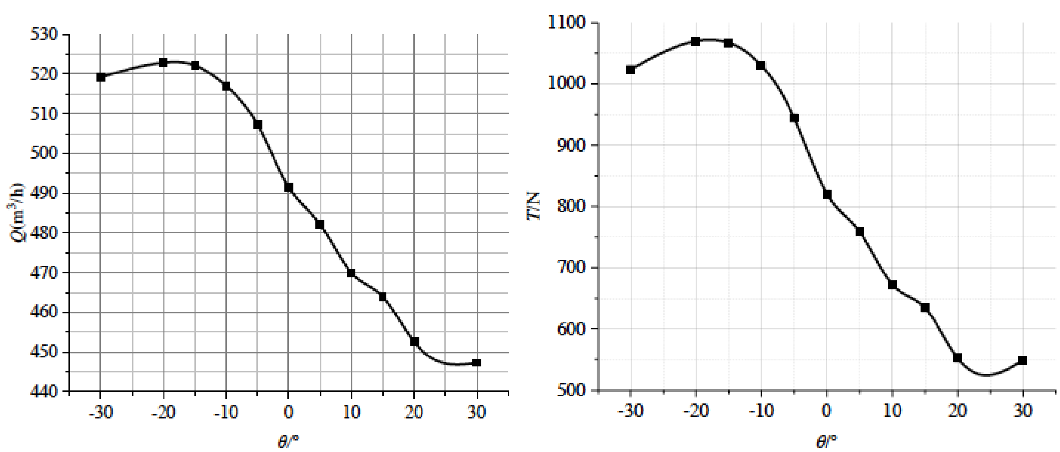


Figure 1: Calculation model and structural diagram.



(**a**) Flow characteristics (**b**) Thrust characteristics

Figure 2: Flow and thrust characteristics of waterjet propulsion at different angles.

4. RESULTS AND DISCUSSION

Under straight running conditions, affected by the thickness of the boundary layer at the bottom of the ship, the disturbance of the drive shaft and the structure of the inlet passage, the radial velocity and pressure gradient on the pump inlet surface are unevenly distributed, while the velocity and pressure are symmetrically distributed from left to right, so a separated vortex structure is formed above the drive shaft. Under turning conditions, the distribution of speed and pressure is no longer symmetrical, and the high-speed and low-pressure areas are deflected, and the position is opposite under right and left turning conditions. As the turning angle increases, the vortex flow in the inlet surface becomes stronger.

A comparative study was conducted on the changes in inlet surface energy of water jet propulsion pumps under different turning angles. The integrated indicators are used to evaluate the inflow performance in straight and turning, and the pump inflow characteristics are qualitatively discussed. Under turning conditions, the inflow unevenness decreases, but the overall energy decreases, the plane kinetic energy increases, and stronger secondary flow is induced, resulting in greater in-plane speed, and the trend of fluid rotation around the drive shaft increases.

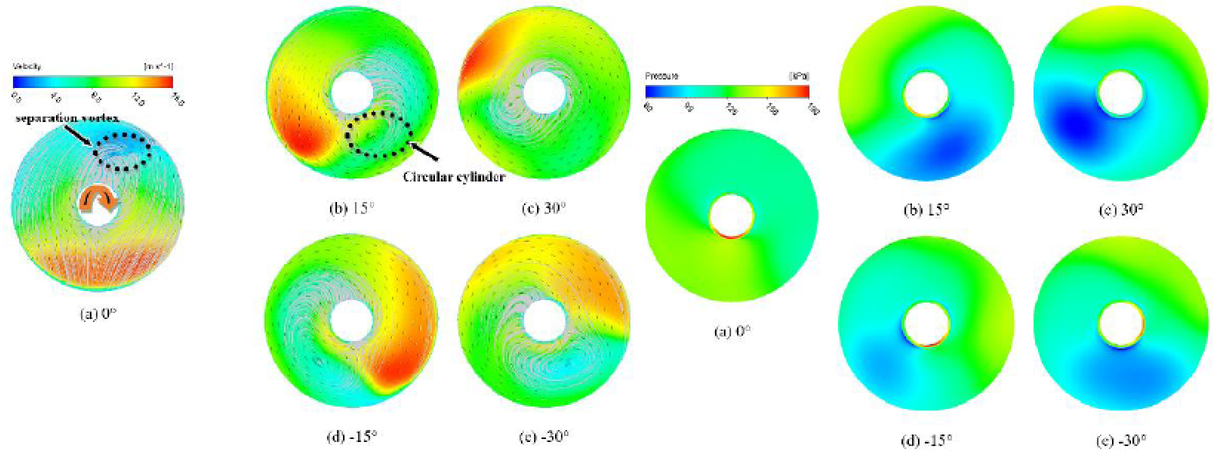


Figure 3: Flow pattern and pressure distribution on the pump inlet surface at different turning angles.

Table 1: Pressure Coefficient of Pump Inlet Surface at Different Angles

Integration metrics	-30°	-15°	0°	15°	30°
Average total pressure of mass C_{ptot}	0.289	0.32	0.331	0.285	0.27
Average total pressure of mass (axial) $C_{ptot\ ,\ x}$	0.221	0.25	0.309	0.207	0.175
Energy ratio $(C_{ptot}\text{-}C_{ptot\ ,\ x})\ /C_{ptot}$	0.234	0.22	0.07	0.274	0.35

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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