EXPERIMENTAL STUDY ON WATER COOLING SYSTEM FOR INFLUENCE FACTORS OF LOW NOISE CONFIGURATION

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Water cooling system is an important part of ship's auxiliary system, which configuration is more complex. Different system configurations have great influence on the system's vibration noise, and directly affect the stealth of ship. Through the experimental study on vibration noise of simulated ship's water cooling system, obtained the vibration noise characteristics for the different configurations of water cooling system, given the important influence factors on the vibration noise of water cooling system in the configuration, which can provide a basis to carry out the low noise configuration for water cooling system of ship.
Keywords: water cooling system, low noise configuration, vibration noise

1. Introduction

Water cooling system is an important component of ship's auxiliary system, which is a necessary system to ship and mainly provides the water such as cooling and filling weight for ship. As the configuration of water cooling system is very complicated, it involves a large number of equipments, pipelines and valves. The vibration generated by equipments, pipelines and valves of the system usually passes to the hull structure through the hull base and pipelines, and forms the underwater radiation noise. It’s the main source of underwater radiation noise for ship in the low speed, and affects the stealth of ship.

In order to study the vibration noise characteristics of water cooling system, a large number of research have been carried out by experts and scholars at home and abroad. In 1995, Morgenroth established a centrifugal pump flow noise test system and studied the relationship between the shape of the volute tongue and the flow noise of the pump [1]; In 2000, Rzentkowski et al. proposed a prediction model for the transfer matrix of centrifugal pump[2]; Bardeleben used a two-port model to measure the flow noise characteristics of the centrifugal pump[3]; In 2002, Liang Xiangdong et al. carried out the experimental research on the vibration damping effect of non metal damping and flexible connector in the pipeline[4]; By using the statistical energy analysis method, Lou Hongwei et al. established a simple SEA theoretical model for the sound propagation of the pipeline system and the sound radiation of the nozzle [5]; In 2005, Cheng Guangfu et al. used the boundary element method to calculate the radiation noise characteristics of the inlet and outlet pipe[6]; Wu Shi et al. carried out the numerical and experimental research on the flow noise of
valve in the fluid filled pipe system, and gave the main influence factors on the flow noise of the valve[7].

In this paper, through simulating the test bench of the ship cooling system, emphasizing on the changes of system configuration parameters caused by equipment frequency conversion, different equipments combination mode, valve regulation and so on, and studying the influence of the configuration parameters of water cooling system on the vibration noise of the system, and to find out which are the important impact factors of water cooling system configuration to vibration noise.

2. Test equipment and test system

The test bench for water cooling system is mainly composed of three frequency conversion pumps (The rated flow of No.1 and No.2 pump is 25t/h, and the rated flow of No.3 pump is 50t/h) , auxiliary pipelines, pipeline fittings, water tank and configuration parameters measuring devices. The measuring points mainly include the vibration measurement points of equipments and pipelines and the measuring points of pulsation pressure. The test bench schematic diagram is shown in Fig.1, the site diagram of bench test is shown in Fig.2.

![Test bench schematic diagram.](image1)

![Site diagram of bench test.](image2)

3. Analysis of test results

3.1 Influence of pump power on change regulation of equipment vibration

When studying the influence of pump power, using the average value of vibration acceleration level of the pump foot to analysis. Fig. 3 shows how the average value of vibration acceleration
level of No.1 pump change with the pump power. The pump power is increased by adjusting the working frequency, with the increase of power, the vibration of pump is on the rise, and the change law of vibration is approximately linear with $10\log (W)$ ($W$ is the pump power).

![Figure 3: Relationship between pump power and vibration characteristics of equipment.](image)

### 3.2 Influence of different working modes of equipment on vibration noise of water cooling system

During No.1 pump is working in frequency conversion and fixed frequency, keeping the flow rate of header pipe basically the same, and researching the influence of different working modes of the equipment on the vibration noise of the water cooling system. Table 1 shows the configuration parameters of water cooling system in different working condition. Fig. 4 (a) shows the variation curve of the vibration acceleration levels of the pump foot and the header pipe change with the flow rate of header pipe when the pump is working in frequency conversion; Fig. 4 (b) shows the variation curve of the vibration acceleration levels of the pump foot and the header pipe change with the flow rate of header pipe when the pump is working in fixed frequency, and at the same time the ball valve is adjusted; At this time, the flow rate in the header pipe is basically the same, and the vibration acceleration of the pump foot and the header pipe in (b) is higher than that shown in (a). Vibration of the pump has little to do with the flow velocity of the header pipe, mainly due to the pressure of the pipeline after the adjustment of the ball valve, so that the pump outlet pressure increase, which can lead to pump vibration increase.

### Table 1: The configuration parameters of system in different working condition

<table>
<thead>
<tr>
<th>working condition</th>
<th>working in fixed frequency</th>
<th>working in frequency conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pump outlet pressure (MPa)</td>
<td>flow rate in header pipe (t/h)</td>
</tr>
<tr>
<td>1</td>
<td>0.10</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>0.20</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>0.26</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>0.30</td>
<td>0.7</td>
</tr>
<tr>
<td>5</td>
<td>0.32</td>
<td>0.6</td>
</tr>
<tr>
<td>6</td>
<td>0.35</td>
<td>0.4</td>
</tr>
<tr>
<td>7</td>
<td>0.38</td>
<td>0.3</td>
</tr>
</tbody>
</table>
3.3 Influence of different combination of equipment on vibration noise of water cooling system

No.1 pump and No.2 pump are working in parallel and synchronous frequency conversion. No.3 pump is working independently and keeps the working frequency of each pump consistent. The influence of equipment combination on vibration noise of water cooling system is studied. Table 1 shows the power of each pump and the flow rate of header pipe under different working frequency. Fig. 5 shows the vibration curve of the vibration acceleration levels of the pump foot and the header pipe change with the working frequency of the pump. It can be seen that under different frequencies, No.1 pump and No.2 pump foot vibration acceleration level was lower than No.3 pump, and the vibration acceleration level of header pipe are basically equal. At the same frequency, the flow rate of two pumps is smaller than the two pumps working alone, and larger than No.3 pump. But Compared to the power of No.3 pump, the other two pumps was significantly increased.

Table 2: Pump power and flow rate of header pipe under different working conditions

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>pump power (kW)</th>
<th>The flow rate of header pipe (t/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.1 pump</td>
<td>No.2 pump</td>
</tr>
<tr>
<td>15</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>20</td>
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<tr>
<td>30</td>
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<tr>
<td>40</td>
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<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>60</td>
<td>4.11</td>
<td>4.11</td>
</tr>
</tbody>
</table>

(a) the vibration of the pump foot

(b) the vibration of the header pipe

Figure 4: The vibration acceleration levels of the pump foot and the header pipe.

Figure 5: The vibration of the pump foot and the header pipe.
3.4 Influence of valve on vibration noise of water cooling system

Opening No.3 pump separately, by adjusting the opening of the ball valve in the pipeline to change the pressure and flow rate of the system, and carrying out experimental research on the effect of different valve opening degree on the vibration noise of the water cooling system, and using the average value of vibration acceleration level of the pump foot and the header pipe to analysis. Fig. 6 shows the vibration curve of the vibration acceleration levels of the pump foot and the header pipe change with the opening degree of the valve. With the increase of flow rate, the vibration of pump and header pipe does not show a linear upward trend, but tends to the minimum value near the rated flow of the pump. So, we can see that by adjusting the valve of the pipeline, the system function parameters (pressure, velocity, etc.) will be changed, and than the water cooling system can work in the better acoustic working points which can effectively reduce the vibration of pump and pipeline and match the system function with acoustic characteristics.

![Image](image.png)

Figure 6: The vibration of the pump foot and the header pipe.

4. Conclusion

The vibration tests under different working conditions are carried out by simulating the water cooling system of the ship, and the results are analyzed and some useful conclusions are drawn:

1. The vibration of pump is closely related to pump power, and the vibration change law is approximately linear with 10log(W) (W is the pump power).

2. With the same pump is working in frequency conversion and fixed frequency, by keeping the flow rate of header pipe basically the same, the water cooling system can get better acoustic performance when the pump is working in frequency conversion.

3. With two same pumps are working in frequency conversion, at the same frequency, the vibration of two pumps were lower and the power of two pumps were higher than a bigger pump, which the rated flow is the sum of two pumps. It is necessary to balance the decision in accordance with the general requirements.

4. With the pump is working in fixed frequency, by adjusting the valve of the pipeline, the system function parameters (pressure, flow velocity, etc.) will be changed, and than the water cooling system can work in the better acoustic working points which can effectively reduce the vibration of pump and pipeline and match the system function with acoustic characteristics.

REFERENCES