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Hydrodynamic Characteristics of Ocean Engineering Numerical Pool Benchmark Model Relying on Numerical Simulation

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Abstract: The development of water resources and energy is increasing day by day, including the exploration and development of marine resources and natural gas. Over the past 30 years of reform and opening up, my country's economic development has made remarkable achievements, high-tech enterprises and power plants have also developed rapidly, and the demand for electricity and resources is also increasing. The purpose of this paper is to study the hydrodynamic characteristics of the numerical pool benchmark model for marine engineering relying on numerical simulation. This paper develops a numerical model for a design reference test case of a semi-submersible platform and predicts the hydrodynamic properties under three typical operating conditions, namely survival and pumping, space acceleration operation, etc. Comparing the dynamic response calculation results with the existing sixth-generation response numerical simulation results, the trend is consistent, which proves that the model is as reasonable and advanced as the reference model. In this paper, the comparative results of numerical simulations are analyzed. The motion performance of the platform and its motion system under different conditions, such as changing the height of the center of gravity, changing the composition of the mooring line, changing the initial pre-tightening angle of the line mooring, and breaking the line under its influence are studied. The results of the difference law of displacement and motion between the platform and the mooring system provide a specific reference for the optimal design of the platform. Experiments show that the maximum relative errors of mooring line tension, heave motion and pitch motion are 13.9%, 7.69% and 11.6%, respectively. From the above calculation results, it can be seen that there is a certain error between the experimental value and the numerical calculation value .

1. Introduction

Improve the pump load simulation and motion response accuracy required for the design of my country's ship and marine engineering equipment, improve the test ability of the standard model physical pool, and meet the optimization design problem. Equipped with ship technology, China has developed a " numerical pool ". Whether it is a reference model test or a numerical simulation of hydrodynamic performance, a specific reference model is required as the research object. Through extensive research on marine machinery and equipment, a reference model was selected for the reference test and numerical simulation needs of the numerical tank project, and the Type 1 semi-submersible platform was finally determined as the reference model. The design of this model is the sixth-generation semi-submersible platform, which conforms to the characteristics of current marine technology development and is advanced [1-2].

In the research on the hydrodynamic characteristics of the numerical pool benchmark model for marine engineering based on numerical simulation , many scholars have studied it and achieved good results. For example , Guo M designed a sinkable cage lifting system, which is Floating pipes are installed on the periphery of the cage, and the gravity and buoyancy of the cage can be adjusted by filling and inflating the floating pipes in the cage to achieve stable sinking and floating. Based on this model, a physical model experiment is carried out in the wave tank. The lift dynamic response of the box. The numerical model of the cage was established, and the dynamic response of the cage system was studied based on Morrison equation [3] . Kim JS studied the tension of the mooring line and the movement of the cage after the failure of the mooring system. The results show that as the maximum tension of the mooring rope increases, the peak spectrum value corresponding to the dominant wave frequency is larger, and the frequency corresponding to the mooring force decreases [4] .

This paper introduces the frequency domain and time domain analysis theories of hydrodynamics respectively; the frequency domain analysis theory deduces the Morrison equation and the three-dimensional potential flow theory, and solves the frequency domain governing equations of the semi-submersible platform; The theory of wind loads and ocean currents is briefly introduced, and the time domain governing equations of the semi-submersible platform are solved. Ansys software creates a solid 3D model of the platform. Based on the 3D power flow theory, the platform model parameters are input into the AQWA-LINE module. The center of gravity and moment radius inertia are set to accept the additional mass and additional dimensions of the platform at various frequencies. Fluid dynamics information , such as damping and amplitude response factor (RAO).

2. Research on the Hydrodynamic Characteristics of The Benchmark Model of Ocean Engineering Numerical Pool Based on Numerical Simulation

2.1. Model Modeling Method

The numerical model tools used for the study are AQWA and FAST, which are mainly used for the analysis of hydrodynamic and wind loads of the integrated platform structure. The integrated platform facility consists of two structures, one is a small component structure and the other is a large panel structure. For small rod structures, the wave load is simplified to the resistance and inertial forces acting on the structure based on the Morison equation. In addition, the boundary element method based on the potential flow theory applies the diffraction theory to large-scale flat structures. Combining these two different scale structures (small-scale member structure and large-scale panel structure) can simulate and analyze the hydrodynamic response of the semi - submersible platform. This method avoids a large number of computations with only uniform surfels, and the result is inaccurate with only Morison elements. Figure 3.2 shows the numerical model, including surface elements and Morrison elements. Select the rod element to model the cage bracing and the net clothing system, and select the surface element to model the main body of the cage and the fan. In order to make the numerical model of the fan closer to the original model, the lumped mass method is proposed to define the mass of the upper fan structure, and the discrete idea is used to segment objects such as slender rods or cables. Analysis, the mass points in this model are loaded in MechanicalModel [5-6] .

2.2. Comparison of RAOs with Different Wave Incident Angles

In the engineering design of ships and offshore platforms, the main task to be solved is to determine the motion, force and deformation of these structures under the action of external forces such as waves and wind. We can think of these structures as a dynamic system, the action of waves is called the input of the system, and the movement of the structure, the force, etc., are called the output of the system. The RAOs are an important index to initially judge the hydrodynamic performance of the semi-submersible platform, and it is also the output response of the structure. The hydrodynamic response of the platform is a linear system whose response to the input is equal to the sum of the responses of each input component acting independently. When calculating the dynamic system of the platform, the frequency response method is often used, and the frequency response function or transfer function of the platform can be obtained. Its modulus is called the amplitude response operator RAOs, which is equal to the amplitude ratio of the output and input. The frequency response function of the platform gives the steady-state response of a system. By determining the frequency response function at all frequencies, the dynamic characteristics of a system can be completely determined [7-8].

2.3. Motion Response of the Overall Structure of the Integrated Platform under Normal Sea Conditions

In order to ensure the stable production of the offshore floating wind power structure in the marine environment, it is necessary to study its various motion parameters under normal working conditions to ensure that it meets the API design specifications. The specification requires that the platform sway or surge drift distance is less than 10% of the water depth of the sea area under the living sea conditions, the drift distance is less than 5%-6% of the water depth under the working sea conditions, and the heave displacement is less than 5% of the water depth. For the offshore floating wind power structure, the heave motion is too large, which will cause the lower structure and the upper fan blades to move violently, which will affect the installation firmness of the equipment and accelerate the aging of the equipment. If the swaying motion response of the floating wind power structure is relatively large, the angle of attack between the blades and the wind speed will change drastically, which will cause the structure to fail to generate wind power normally, and will also accelerate the damage of the fan system. Generally, when the dynamic swing value is less than 5°, the floating wind power structure can ensure normal power generation. In order to verify whether the integrated platform constructed in this paper can exist stably in the ocean, the time domain analysis of the platform is carried out from the motion and mooring cable tension. The dynamic simulation time is 2000s, and extreme wind conditions are selected for analysis. Whether the lower motion response value can meet the requirements of the specification, and whether it is in a stable state most of the time [9-10].

This paper analyzes the mooring system of the platform in the previous chapter. After optimizing the mooring system of the platform, a preliminary design of the mooring system of the platform is carried out. The time domain analysis is carried out on the platform under the set sea state. The time domain module studies the motion response of the integrated platform under the set sea state, and obtains a long-term motion duration response curve. The calculated results are compared with the

API engineering specifications. Research whether this comprehensive platform can work safely and stably.

2.4. Algorithm Selection

RF computing has a long history of development. If the frequency response of the platform power and motion in the positive wave is obtained through scientific analysis (such as pool tests, etc.) in the important frequency range of interest, it can be obtained under sea conditions with the help of spectrum analysis technology (that is, it can be determined that the platform is in the form of wave energy. Several computational features of the shock or motion [11-12] .

The equation of motion in the frequency domain is:

$$\left[-w^2\left(M_s+M_a(w)\right)-iwB+K\right]X(w)=F(w) \tag{1}$$

$$\mathrm{RAO}=\frac{\mathrm{X}(w)}{A} \tag{2}$$

In the formula, w is the angular frequency of the incident wave; A is the amplitude; M. is the structural quality matrix; M. is the additional mass matrix; B is the damping coefficient; K is the hydrostatic stiffness; X(w) is the platform motion matrix; F(w) is the wave surge force matrix.

3. Research and Design Experiment of Hydrodynamic Characteristics of Numerical Pool Benchmark Model of Marine Engineering Relying on Numerical Simulation

3.1. Mooring System

According to the physical model test, the physical model test uses spring simulation. After simplifying the mooring line, tension mooring, multi-point (four-point) mooring method, plus anchoring, spring stiffness 160N/m, initial pre The tension is 1.6N. The mooring line length is set to 3m, and the included angle to the horizontal plane is 25 °[13-14] . Based on a discrete approach, the numerical model was divided into multiple Morison elements and surface elements to calculate the hydrodynamic response of a semi-submersible aquaculture facility. The numerical simulation results of the hydrodynamic responses such as mooring line tension, heave motion and pitch motion are compared with the experimental values in terms of force, displacement and rotation angle. In order to ensure the accuracy of verification, the same as the physical model test method, the data sequence that is stable within 10s in the operation result is selected, and the average value of all peaks in the 10s sequence is selected for calculation [15-16] .

3.2. Experimental Design

In view of the research and verification of the mooring system in this paper, this paper mainly studies the numerical simulation of the hydrodynamic response of the mooring line tension, heave motion, pitch motion, etc., followed by the simulation analysis of six different damping effects.

4. Experiment Analysis of Hydrodynamic Characteristics of Marine Engineering Numerical Pool Benchmark Model Relying on Numerical Simulation

4.1. Mooring System Research

In order to ensure the accuracy of the verification, the same as the physical model test method, the data sequence that is stable within 10s in the operation result is selected, and the average value of all peaks in the 10s sequence is selected for calculation.

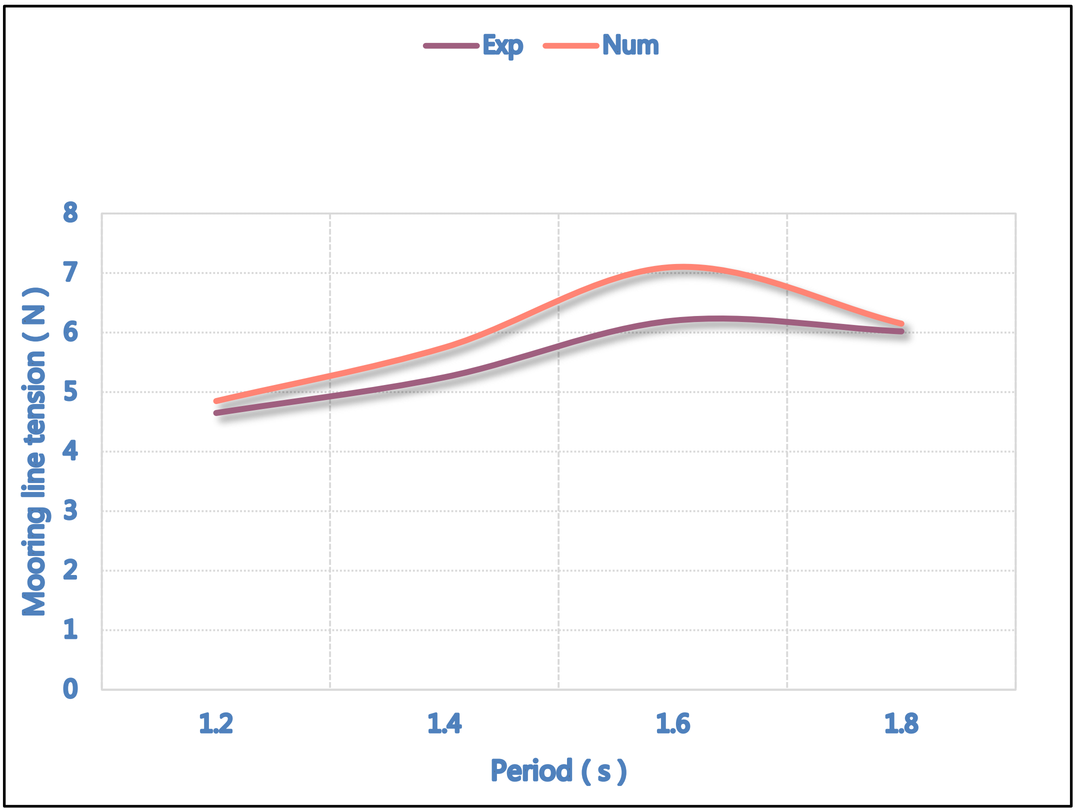

Figure 1. Cable tension

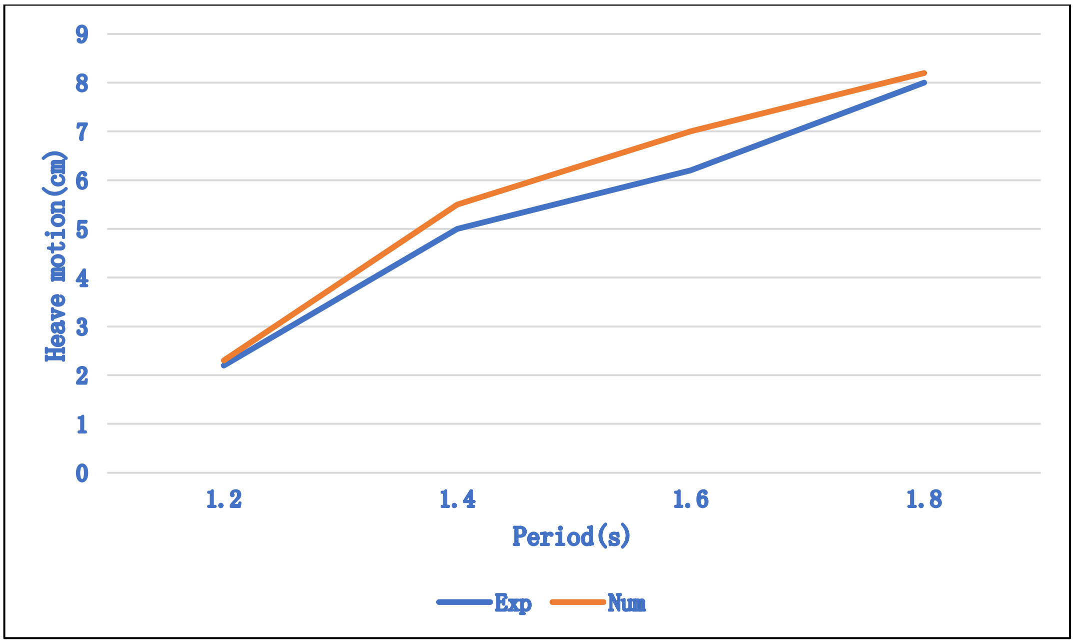

Figure 2. Looping

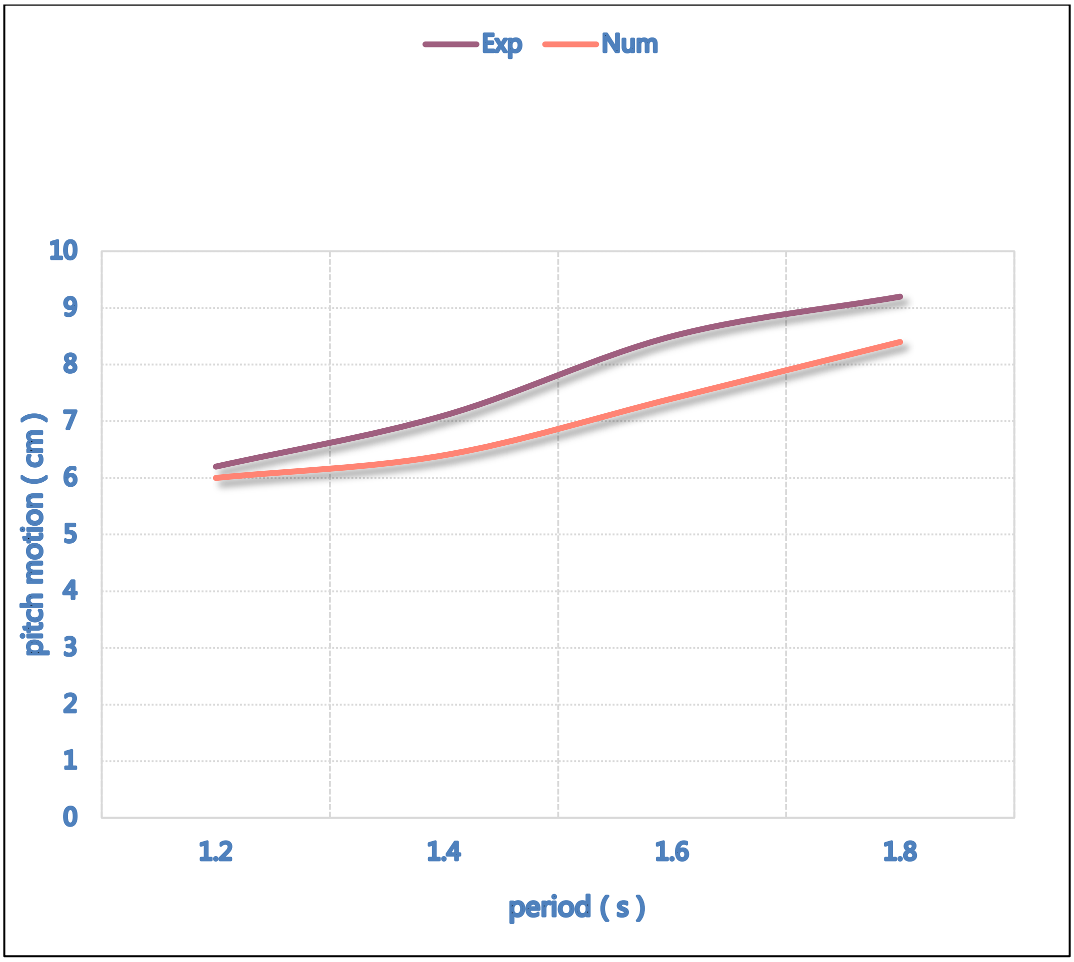

Figure 3. Vertical shake

From Figures 1, 2, and 3 that the numerical simulation results of the hydrodynamic responses such as mooring line tension, heave motion, and pitch motion are compared with the experimental values. The maximum relative errors of 13.9%, 7.69% and 11.6%, respectively. From the above calculation results, it can be seen that there is a certain error between the experimental value and the numerical calculation value. Because the rod element based on the Morison equation was used for the simulation, the influence on the wave field could not be considered, so that the simulated value and the experimental value were in error. The numerical simulation conditions are difficult to be completely consistent with the actual situation, and the difference between the physical model and the numerical model is also small. In addition, considering that the heave motion response is not very large, the error is not large, while the pitch motion response is more obvious, so the error is slightly larger, and the combination of polyethylene rope and spring in the test may be the reason for the error in the cable tension [17] -18] .

4.2. Additional Damping

In this paper, the results of the comprehensive additional damping are studied, and the comparison of 6 different additional dampings is mainly studied. The experimental results are shown in Table 1.

Table 1. Additional damping comparison

	0.0	0.1	0.2	0.3	0.4
GX-GX	0	0.1	0.1	0	0
GY-GY	0	0.1	0.1	0.2	0.1
GZ-GZ	0	0.1	0.1	0.2	0.1
GRX-GRX	0	0.1	0.1	0.4	0.2
GAMES	0	0.1	0.1	0.4	0.2
GRZ-GRZ	0	0.1	0.1	0.8	4.3

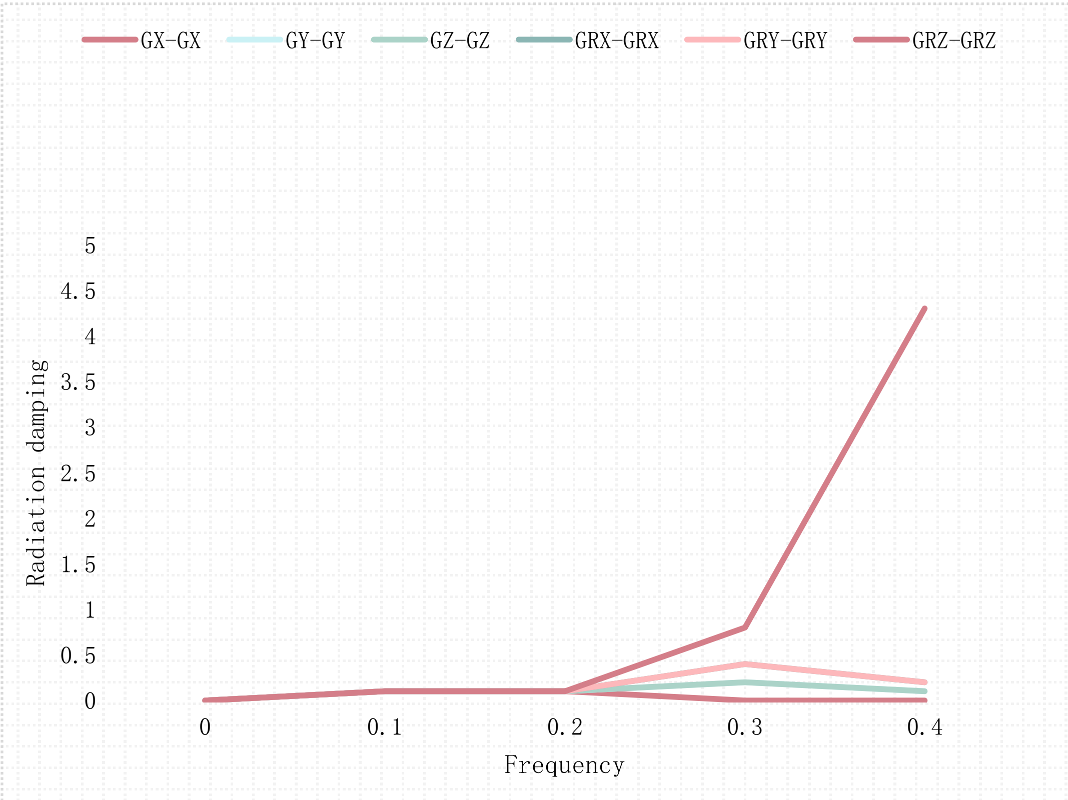

Figure 4. Six additional damped contrasts

It can be seen from Fig. 2 that, different from the additional mass force of the platform, the additional damping trend of the sway and surge of the platform is inconsistent, and the platform

11 > 22 . This is because the wave incident direction is 0° , and the damping force on the platform is greater in the direction of the headwind. And the additional damping of the surge is very little in the low frequency part, and changes obviously in the high frequency part. The additional damping of platform heave is mainly concentrated in the low frequency part. The overall change trend of the additional damping of the platform is not synchronized with the change trend of the additional mass force of the platform. However, like the additional mass force, the additional damping produced by the semi-submersible platform during rolling, pitching, and yaw motions is much greater than the additional damping produced by the platform doing sway, surge and heave motions.

5. Conclusion

In this paper, the numerical model of the integrated platform is established in AQWAWORKBENCH. Based on the three-dimensional potential flow theory and Morrison equation, the surface element model and the Morrison element model are established respectively, which can more accurately reflect the actual situation of the integrated platform system for wind power and fishery. In terms of establishing the mesh unit, fully consider the force characteristics of the mesh, and simulate the mesh by establishing a beam element. Changing the mooring line parameters can significantly improve the positioning performance of the platform. Different arrangements of mooring lines of the platform will affect the motion response of the platform. For the platform swaying motion, its motion response increases first and then decreases with the increase of the arrangement angle; at the same time, the mooring increases to a certain extent. The cable pretension can significantly reduce the displacement of the platform; for this platform, when the pretension is less than 3200kN, with the increase of the pretension, the swaying motion response of the platform decreases significantly, indicating that the pretension can be Limit the swaying motion displacement of the platform; changing the tension angle of the cable to a certain extent will affect the motion response of the platform and the magnitude of the cable tension. The motion response of the platform under the combined conditions of extreme wind and waves is studied with the help of the FAST program. The results show that the heave and pitch motions of the platform respond significantly to the changes in the draft of the platform. When the frequency is small, the heave motion response is correspondingly large. , the overall decrease as the frequency increases. For pitch motion, when the frequency is greater than 0.06Hz, the larger the draft of the platform, the smaller the amplitude, and the platform is near the natural frequency, and the reduction of draft is more conducive to the vertical motion of the platform. By comparing the motion responses of the platform in four directions and the cable tension under different wind speeds, it can be concluded that within a certain wind speed range, with the increase of the external wind speed, the platform motion response is larger, which is in line with the general law; for the wave period In other words, with the increase of the wave period, the three motion responses of sway, heave and pitch also have an increasing trend, and the wave period is near the natural frequency of the platform, and the response is more obvious.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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