Use of Optical Tracking System for Measurement of Dynamic Signal in a Wave Tank

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Abstract: **Physical modeling serves as an important tool in the development of the full scale devices especially in the oil and gas industry. Dynamic responses of the scaled model subjected to the environmental forces are obtained by testing the models in the wave tank. Conventionally accelerometers have been used to determine the dynamic motion responses of the model in the six degrees of freedom. However, the accelerometer has limitation that it can measure the translation motions only and rotation motions have to be interpreted from them. Recently developed optical tracking system has proven to be very efficient in measuring all the dynamic responses. Hence, many Laboratories use both the accelerometers and optical tracking system for mutual validation and accuracy of the measurements. In this paper, a new optical tracking system acquired by the Offshore Laboratory of Universiti Teknologi PETRONAS (UTP), is discussed. The details of the system and the tracking procedures are presented and the paper concludes by presenting very reliable results based on these measurements.**

I. INTRODUCTION:

Scaled physical model tests are regularly being carried out in the multidirectional wave tank of the Offshore Laboratory in UTP. The model tests are conducted for offshore structures such as Spars, Semi-submersibles, TLPs, and transportation barges. The dynamic motion responses of the structures are the important results to be determined. Accelerometers have been serving as important sensors for recording the motion responses. However, the accelerometer has limitation that it can measure the translation motions only and rotation motions have to be interpreted from them. To overcome this limitation, optical tracking system and the accelerometers can be combined.

Optical tracking is defined as a method to obtain the position of an object by determining the active and passive position through the marker reflection attached on the object by a camera capturing system. The high spatial accuracy and update rates encourage the system to be widely used [1]. Zaitsev et al [2] implemented the motion tracking system to study the prospective correction of arbitrary rigid body motion in magnetic resonance imaging of freely moving objects. In this study, the performance of the system and the connection to the magnetic resonance imager were analyzed. Rhinefrank et al [3] performed a high resolution wave tank testing on a scaled wave energy converter (WEC) structure. The study incorporated the optical tracking system and data acquired to facilitate the optimization of the WEC structure to efficiently convert the ocean wave motion to the electrical energy. Due to the wide application of the system, the accuracy of the system has well been investigated and improved. Bauer et al [4] studied the accuracy of the system by focusing on the error that might occur in the optical tracking system, e.g. the image plane error, fiducial location error, marker target error and target registration error. Also, they have proposed an error prediction model by propagating the error through different steps in the tracking process. Maletsky et al [5] studied the accuracy of the active-marker optical system on tracking the motion of rigid bodies. Two setup variables were considered in the study; the distance between the camera and the rigid bodies and the motion of the bodies relative to the cameras. It was found that the precision decreased as the distance increased, and the translations and rotations should be within the camera viewing plane. Pentenrieder et al [6] studied the accuracy of the marker based tracking system and identified the parameters that affecting the accuracy of the system based on a simulation of ground truth data.

In this paper, the details of the system implemented in the Offshore Laboratory of UTP and tracking procedures are presented.

II. WAVE TANK SPECIFICATION:

The model tests were performed in the wave tank 22m long, 10m wide and having 1m water depth. The wave generator consists of sixteen individual paddles that could generate waves propagated to different directions. Other components that are integrated in the wave tank tests are the wave probes, load cells, accelerometer, and vectrino. In this paper, an example of the wave tank test, where the truss spar model was subjected to multidirectional wave with 0.5Hz wave frequency and 0.08m wave height, are presented. Figure 1 shows the wave tank facilities of UTP.

Figure 1 Wave tank facilities - Wave generator

III. MODEL SPECIFICATION

A truss spar model has been considered for this paper. As the water depth of the wave tank was only 1m, the model dimensions were chosen to simulate the behavior of the floaters fairly well. Table 1 and Figure 2 show the dimensions and typical truss spar model used. Figure 3 shows the setup arrangement of the truss spar model.

TABLE I

DIMENSION OF TRUSS SPAR MODEL

Description	Value, mm
Truss Spar	
Diameter	300
Hull Length	420
Hull Draft	190
Heave plate	300 x 300 x 50

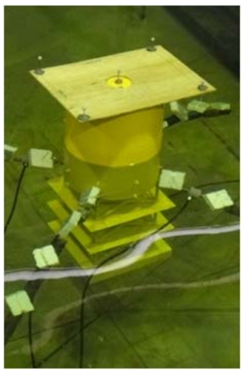

Figure 2 Truss Spar model

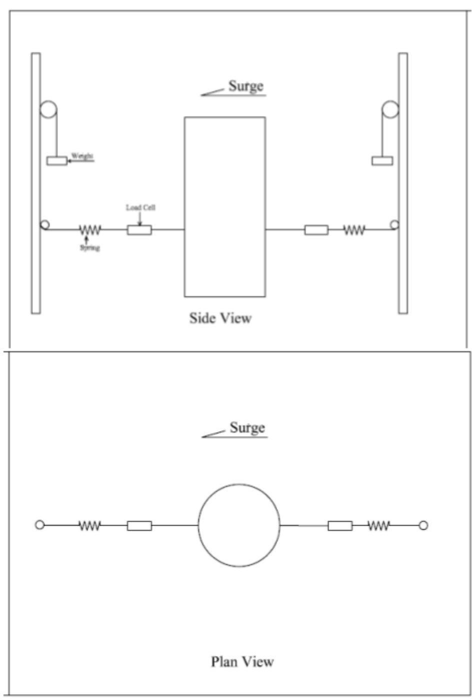

Figure 3 Setup arrangement for wave tank test

IV. OPTICAL TRACKING SYSTEM:

Table II and Figure 4 show the details of the optical tracking system, which included the cameras, markers, and calibration tools.

TABLE II

DETAILS OF THE OPTICAL TRACKING SYSTEM

Camera	
Resolution	640x480
Frame Rate	100 FPS
Lense FOV	38°, 46°, 58°
No. of LED	26
Latency	10 ms
Marker	
Type	Reflective hard spherical marker
Diameter	3/4"
Threaded hole	6-32
Calibration Tool	
Three-marker calibration wand	
Calibration Square	

Figure 4 Optical tracking system components

V. IMPLEMENTATION:

To overcome the limitation of accelerometer that determined only the translation motions, the optical tracking system implemented offered motion capture in six degrees of freedom. The procedure used is as follows [7]

A. Setup

The cameras and markers are to be positioned firstly. Cameras need to be located at the ideal place, where it should able to capture the overall motion of the structure. A three-sensor axes that cover a minimum of three orthogonal planes for the position of a marker is necessary for the determination of six degrees of freedom [7]. Figure 5 shows the setup of the tracking system.

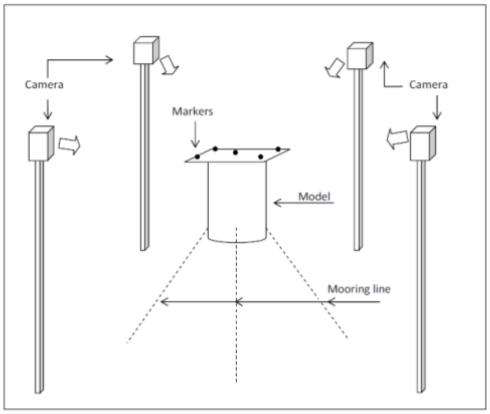

Figure 5 Optical tracking system setup

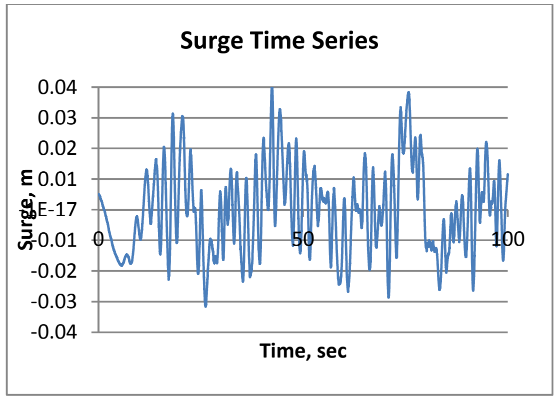

Figure 6 Surge time series

B. *Calibration*

In the calibration, the positions and the orientations of the cameras relative to each other are figured out. Also, the focal points of each camera are determined [1]. To calibrate the cameras, calibration wand is used for three-marker camera calibration process. This is necessary to improve the accuracy of the tracking system.

C. *Tracking*

As the wave generates, the translation and the rotational motions of the structure due to wave actions are captured by the system in real time. The motion data are returned back to the host computer.

D. *Diagnostic*

As the motion data are returned to the host computer, diagnostics of the data are performed, to check for any possible failure or loss of data.

VI. EXAMPLE

The six degrees of freedom time series responses of the truss spar model subjected to short crested multi-directional wave for frequency 0.5Hz, and 0.08m high are shown in Figures 6 to 11.

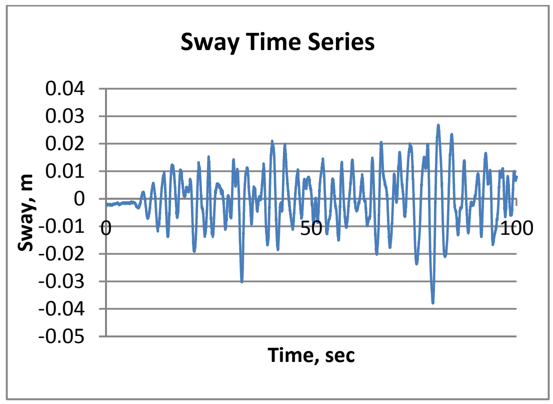

Figure 7 Sway time series

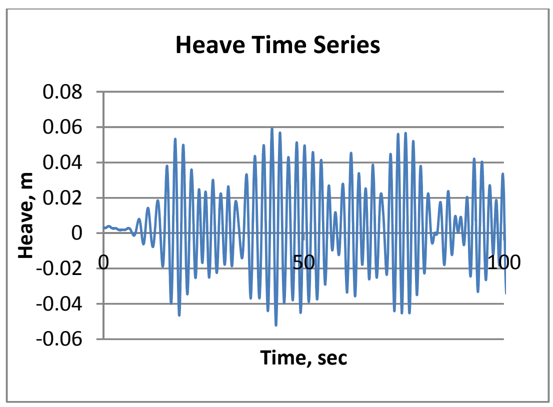

Figure 8 Heave time series

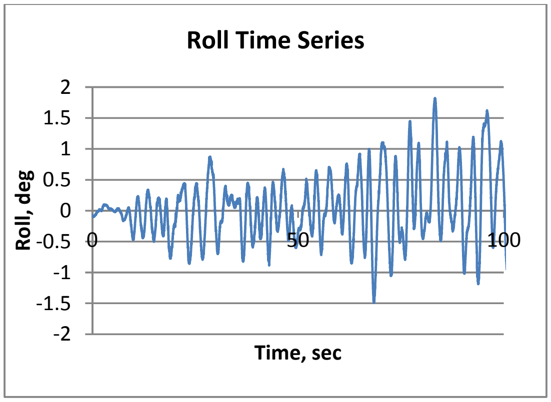

Figure 9 Roll time series

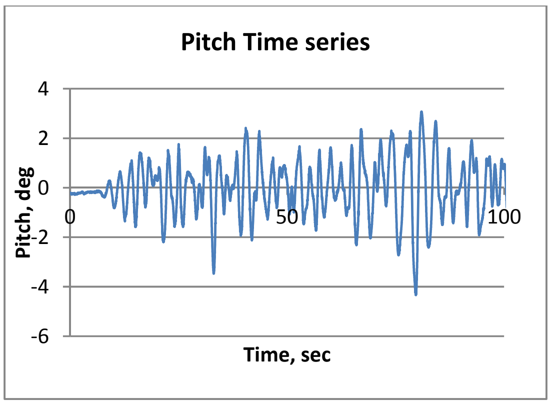

Figure 10 Pitch time series

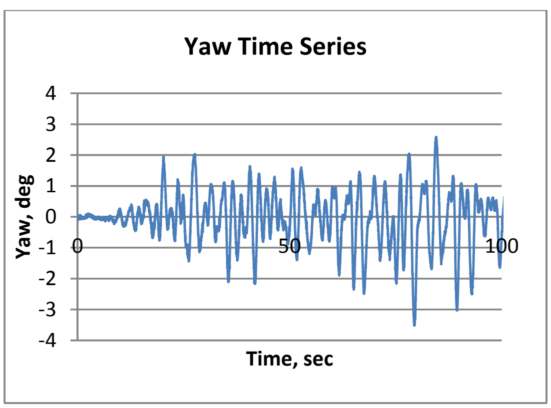

Figure 11 Yaw time series

VII. Conclusion

1) In this paper, the details of the new measurement method, the optical tracking system, which was acquired for the Wave Tank at the Offshore Laboratory of Universiti Teknologi PETRONAS, are discussed.
2) The dynamic responses of the truss spar model in all the six degrees of freedom subjected to multidirectional wave were determined by the optical tracking system. The system captured the reflection of the markers located on the model, and returned the data to the host computer. These results have proven to be consistent and agreeing with standard results.
3) The Optical Tracking System has been found to be very reliable, simple in operation and accurate for measurement of all the six-dof responses of the model for wave tank tests.

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