Verification of numerical simulation codes for underwater catenary chain

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Abstract

Virtual simulation is a ecconomical and effective method in mechanical system design. This paper aims at verifing the accuracy of the numerical simulation for underwater catenary chain modeling. The numerical modeling of the chain is developed based on a new kind of local frame which is formulated by the vectors of the element orientation and relative velocity of fluid. Formulations of both the rotational transformation matrix and hydrodynamic drag forces are expressed effectively with the new local frame. The numerical simulation code is established considering the stiffness and damping of the chain, apparent weight, hydrodynamic drag forces and the effect of added mass. The simulation results by the numerical simulation code were compared with those by commierical simulation code, ProteusDS. The motion of chain and tension within chain by the numerical code matched well with those by the ProteusDS.

One end of the chain is fixed with the tank and the other end is connected with a X-Z traversing device which moves with a constant speed, as shown in Figure 1. The motion of the chain node is recalled by a camera and the tension within chain is measued by tension sensor. After that, the video is proceed by TEMA software. Finally, the simulation results by the numerical simulation code are compared with experiments. The devices for the real experiment are shown in Figure 2.

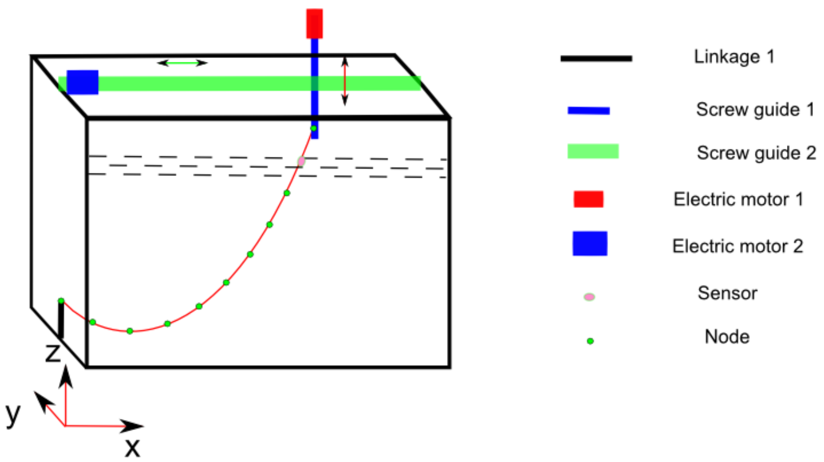


Figure 1: Procedure for the real experiment of chain modeling.

(a) X-Z traversing device on the water tank

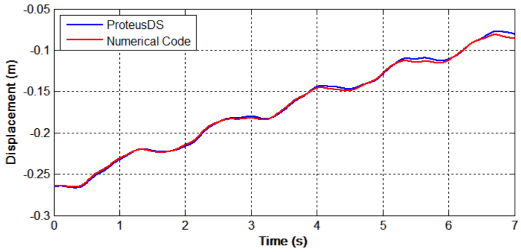
(b) Tension sensor

Figure 2: Devices for the real experiment.

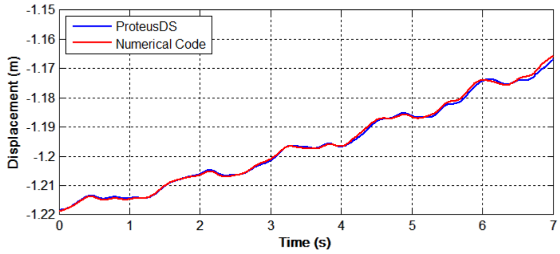
The chain is divided into 10 elements by 11 nodes, and the forces acting on each chain element are shared equally by the element-terminal nodes. The governing equation for the $\mathbf{i}^{\mathbf{th}}$ node is defined by the forces acting on the $(\mathbf{i}-1)^{\mathbf{th}}$ and $\mathbf{i}^{\mathbf{th}}$ elements, as shown in Equation (1).

$$\mathbf{M}^{\mathbf{i}}\ddot{\mathbf{N}}_{\mathbf{g}}^{\mathbf{i}} = \underline{\underline{\mathbf{A}}}^{\mathbf{i}}(\mathbf{T}_{\mathbf{b}}^{\mathbf{i}} + \mathbf{D}_{\mathbf{b}}^{\mathbf{i}} + \frac{1}{2}\mathbf{F}_{\mathbf{D}}^{\mathbf{i}}) - \underline{\underline{\mathbf{A}}}^{\mathbf{i}-1}(\mathbf{T}_{\mathbf{b}}^{\mathbf{i}-1} + \mathbf{D}_{\mathbf{b}}^{\mathbf{i}-1} - \frac{1}{2}\mathbf{F}_{\mathbf{D}}^{\mathbf{i}-1}) + \frac{1}{2}(\mathbf{F}_{\mathbf{W}}^{\mathbf{i}} + \mathbf{F}_{\mathbf{W}}^{\mathbf{i}-1}) \quad (1)$$

$\mathbf{M}^{\mathbf{i}}$ and $\ddot{\mathbf{N}}_{\mathbf{g}}^{\mathbf{i}}$ are the mass and acceleration of the $\mathbf{i}^{\mathbf{th}}$ node, respectively. $\mathbf{T}_{\mathbf{b}}^{\mathbf{i}}$, $\mathbf{D}_{\mathbf{b}}^{\mathbf{i}}$, $\mathbf{F}_{\mathbf{D}}^{\mathbf{i}}$ and $\mathbf{F}_{\mathbf{W}}^{\mathbf{i}}$ are the tension, damping force, drag froce and weigh force in water of the $\mathbf{i}^{\mathbf{th}}$ element, respectively. Matrix $\underline{\underline{\mathbf{A}}}^{\mathbf{i}}$ indicates the transformation matrix of the $\mathbf{i}^{\mathbf{th}}$ element with respect to the inertial frame.
The verification with the virtual simulation code was finished with ProteusDS. For the uniformity at the beginning of simulation, the initial position of the chain in the numerical code is obtained from the ProteusDS. The simulation results by ProteusDS were compared with those by the numerical code, as shown in Figure 3.



(a) Displacement in X direction.



(b) Displacement in Z direction.

Figure 3: Motions the 6th node of chain compared by ProteusDS and numerical code.

The verification with the real experiment is in process. The 1st node is connected with the traversing device, and the 11th node is fixed with the water tank. The traversing device provides a constant speed by which the chain moving in water as shown by Figure 2. The traversing device moves 7 seconds with the speed 0.05 m/s during the simulation.

References

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