Holistic approach to PROJECT CWC with ALTAIR

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Abstract

A Circulating Water Channel (CWC) generates a controlled flow environment and is used for various hydrodynamic research activities including flow around ships, study of fishnets, etc. The current paper utilizes various modules of ALTAIR HYPERWORKS to provide a holistic solution in completing the project i.e, modelling using SOLIDTHINKING, flow analysis across the working section of the CWC using ACUSOLVE, and developing a mechanism to generate ship motions with MOTIONSOLVE. One of the many experiments that can be conducted with the CWC is an internal tank sloshing test. A free surface flow analysis is performed for a 2D tank using RADIOSS solver validating the same with existing experimental results.

Keywords: Circulating Water Channel, ACUSOLVE, CFD, MOTIONSOLVE, RADIOSS, ALE, SPH

1. Introduction

Indian Maritime University Visakhapatnam Campus (IMUV), erstwhile National Ship Design and Research Centre (NSDRC), was established in 2008 under the Act of Parliament for the purpose of conducting research activities in maritime industry, providing consultancy works in ship design, and imparting education &training through short term courses and programs. During the past five years, IMUV has been awarded 17 research projects sanctioned by the Ministry of Shipping, one such being ‘Study of Flow around Ships in a Hydrodynamic Test Facility.”

The first phase of the research project is to build a 1:4 scaled model test facility called the Circulating Water Channel (CWC). The CWC generates a controlled flow environment for the purpose of conducting various hydrodynamic research activities such as resistance test, manoeuvring test, studies for fish nets, sediment flow studies etc. While the experimental facilities such as towing tank facility, sea keeping and manoeuvring basin are expensive, a relative low cost CWC, recognized by the International Towing Tank Conference (ITTC) community, is designed to facilitate academic and research activities. Currently, the 1:4 scaled model of the CWC is fabricated, tested and commissioned within IMUV and the full scale facility would be established soon as a part of the second phase.

2. Utilizing various modules of Altair Hyper Works

2(A) Modeling using SOLIDTHINKING

Data from 26 existing channels was collected to estimate dimensions of test section, power consumed, experiments conducted, single/twin propeller type and instruments used. The dimensions of the CWC were finalized within the constraints of space and costs. A 9m x 2m x 2m working section was considered for the 11m x 24.35m overall plan area on par with the existing CWCs [1].

The CWC, consisting of 20 individual parts, are the subassemblies of various steel plates, steel strips, sections, angles, bars, flanges, guide vanes, etc consistent with Bureau of Indian Standards. Solid Thinking uses 2D drawings to model components at the lowest assembly level. These components together are then assembled to create individual parts in 3D, after which, they are imported to one single file and carefully assembled. The 1:4 scaled model CWC (7.3m x 3.7mplanwith working section 2m x

0.5m x 0.5m) is modelled and rendered as shown in Figure 1. The working section can accommodate ship models up to 250mm x 30mm x 30mmsizeand velocities up to 3.5m/s.

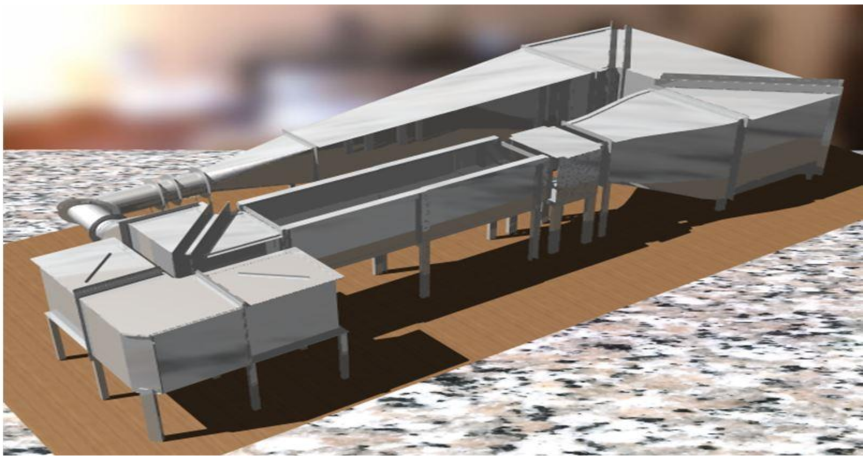

Figure 1: Rendered View of the CWC (model scale facility) using SOLIDTHINKING

2(B) Flow Analysis across the working section of the CWC using ACUSOLVE

The CWC is principally evaluated by assessing uniformity of fluid flow across the working section. The working section of the CWC, along with the parts upstream namely bend at corner and guide vanes, is modelled and meshed in HYPERMESH for 0.1 million nodes. A 10mm-thick 90º subtending angle vane is considered at the guide vane section of the CWC as shown in Figure 2. CFD analysis with one bend [2] is performed with ACUSOLVE for vane angles of 85°, 90°and 95°(the 95° vane angle inclines towards the test section of the CWC whereas 85° indicates away from it)for an inlet velocity of2 m/s. Spalart Allamaras turbulence model with standard wall function is used to model turbulence. 100 iterations are made to get converged solution. The analysis is further extended for full scale facility and two bends upstream of test section with 2m/s test section velocity [3].

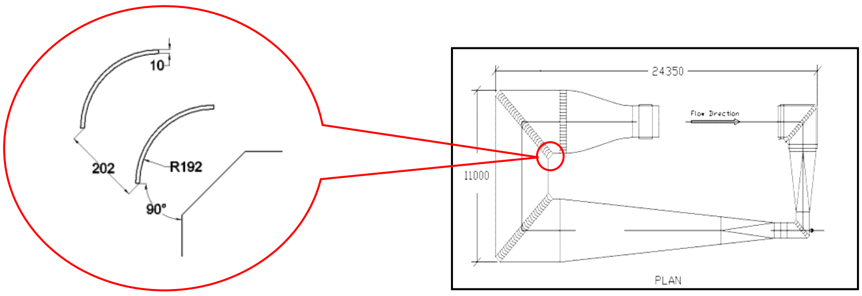

Figure 2: Vane angle of 90ºsubtending angle (full scale facility)

2(C) Developing a mechanism to generate ship motions using MOTIONSOLVE

The Planar Motion Mechanism (PMM), mounted across the working section of the CWC, incorporates in one device a means to experimentally determine various forces, moments and hydrodynamic coefficients for various model tests [4]. Based on the Scotch Yoke mechanism, it consists of one/two oscillators mounted on a platform, one at the bow and stern of the ship model, each imparting a transverse motion as the platform travels down the tank at a constant velocity. The phase between the bow and stern oscillator can be adjusted to produce straight line motion, drift, pure sway, pure yaw or its combination.

Two variants of the PMM are developed and are shown in Figure 3 - with two linear actuators, and, with one linear and one rotary actuator. The bodies are created in MOTIONSOLVE and appropriate joints are defined between the bodies. Linear and rotary motions are then defined for the carriage and crank(s) respectively.

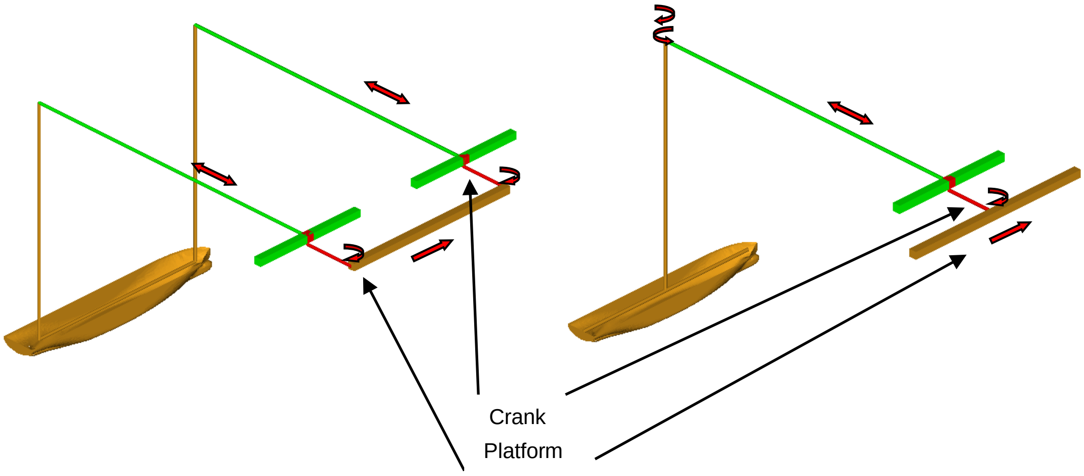

Figure 3: Alternative configurations of the Planar Motion Mechanism (schematic)

2(D) 2D Tank Sloshing using ALE and SPH techniques

One of the many experiments that can be conducted with the PMM is an internal tank sloshing test. Sloshing [5] must be considered for almost any moving vehicle or structure containing a liquid with a free surface and can be the result of resonant excitation frequency of the tank liquid, particularly in the vicinity of lowest natural frequency. A partially filled ship tank can experience violent liquid motion when the ship motion contains energy in the vicinity of the highest natural period for the liquid motion inside the tank. The consequences are tank roof impact, mixing of air & liquid, etc.

Fluid-structure interactions are studied for first two natural frequencies of a sloshing 2D tank for a filling ratio close to h/l=0.4, where h is the depth filled and l is the length of the tank. A bi-phase liquid-gas material with an ALE formulation is used to define the interaction between water and air in the tank [6].With the above mentioned parameters, SPH simulation is also carried out specifying appropriate boundary conditions, interfaces, and displacements [7]. The number of SPH particles is limited to 12480 particles due to limited computational resources. About 500 time steps are made to demonstrate interaction of the tank and SPH particles.

3. Results and Discussions

3(A) Flow Analysis across the working section of the CWC using ACUSOLVE

CFD analysis for one bend and one velocity is carried out altering the vane angle inclinations to assess flow uniformity across the working section. The velocity contours shown in Figure 4 indicate that a uniform velocity is achieved for all the three cases at working section. However, the plot for the 95° indicates a faster attainment of convergence of uniform velocity which might be due smoother incoming flow to the vanes.

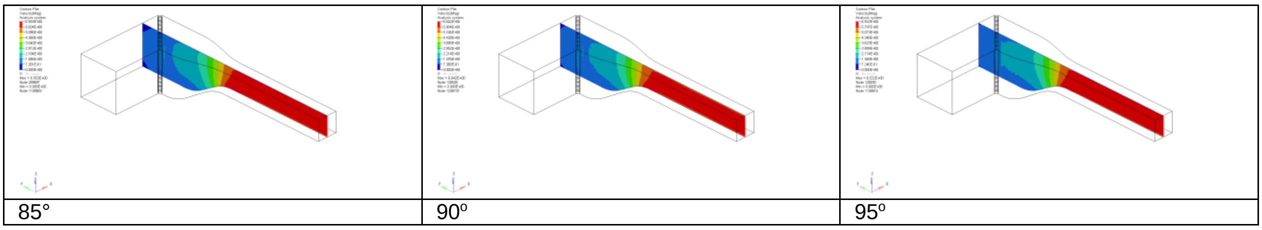

Figure 4: Velocity contour plots across working section (full scale facility)

Extending the above work, a CFD analysis for full scale facility with two upstream bends and working section and aforementioned vane angles is considered for 2 m/s coarsening the mesh due to limited computational resources. Velocity contour plots, similar to 1:4 scale model, are obtained for working section, while 95° angle shows slightly larger constant velocity downstream region as shown in Figure 5.

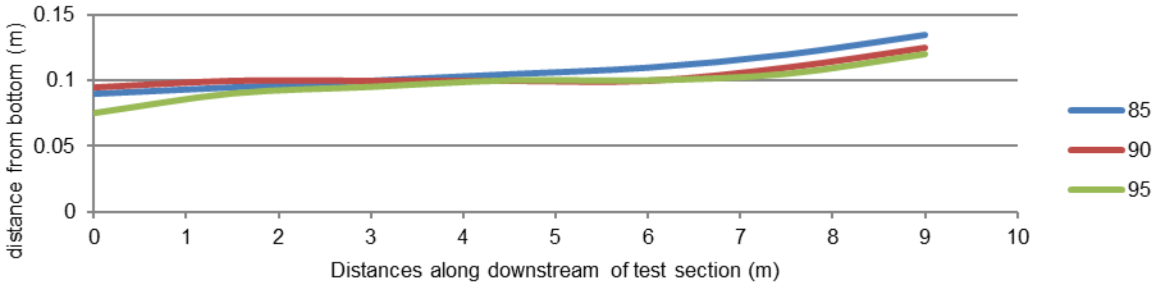

Figure 5: Iso-velocity plots of 2m/s along downstream of working section (full scale facility)

3(B) Developing a mechanism to generate ship motions using MOTIONSOLVE

Two configurations of the PMM are developed for three tests namely pure sway, drift and pure yaw. The paths traced by the ship model's forward and aft are generated and shown in Figure 6.

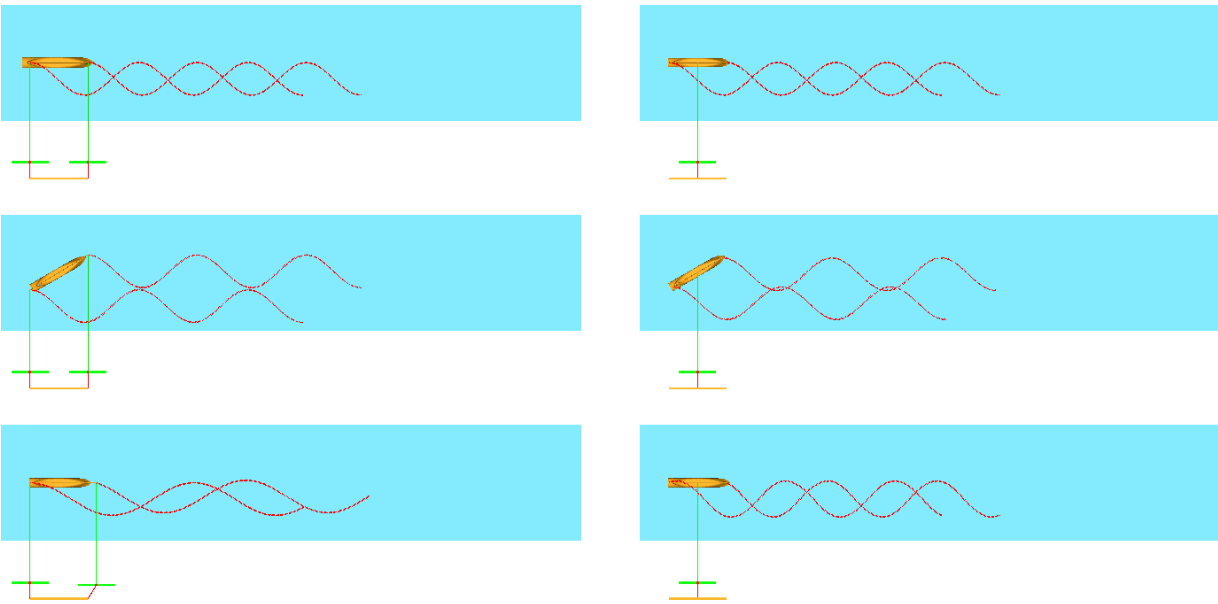

Figure 6: Path traced by ship model's forward and aft for pure sway, drift and pure yaw test for both configurations

While the PMM with double-linear actuator configuration can give advantages of stability and strength, the phase difference between both the cranks needs careful calculation to prevent redundant kinematic positions. Also, the actuators need to be designed for redundancy, robustness and maintainability, lest one failing, none of the above experiments can be conducted.

The linear-rotary actuator configuration can give advantage of ease of programming for actuator linear/rotary displacements, accurate ship paths and ease of visualization practically for the same path outputs, although it is limited to lower ship model weights and flow velocities due to lesser handling strength. In case of one actuator failing, this configuration can still be used to conduct one of the aforementioned tests.

3(C) 2D Tank Sloshing using ALE and SPH techniques

The results of the sloshing using ALE and SPH techniques generated for the first two fundamental frequencies as shown in Figures7&8.

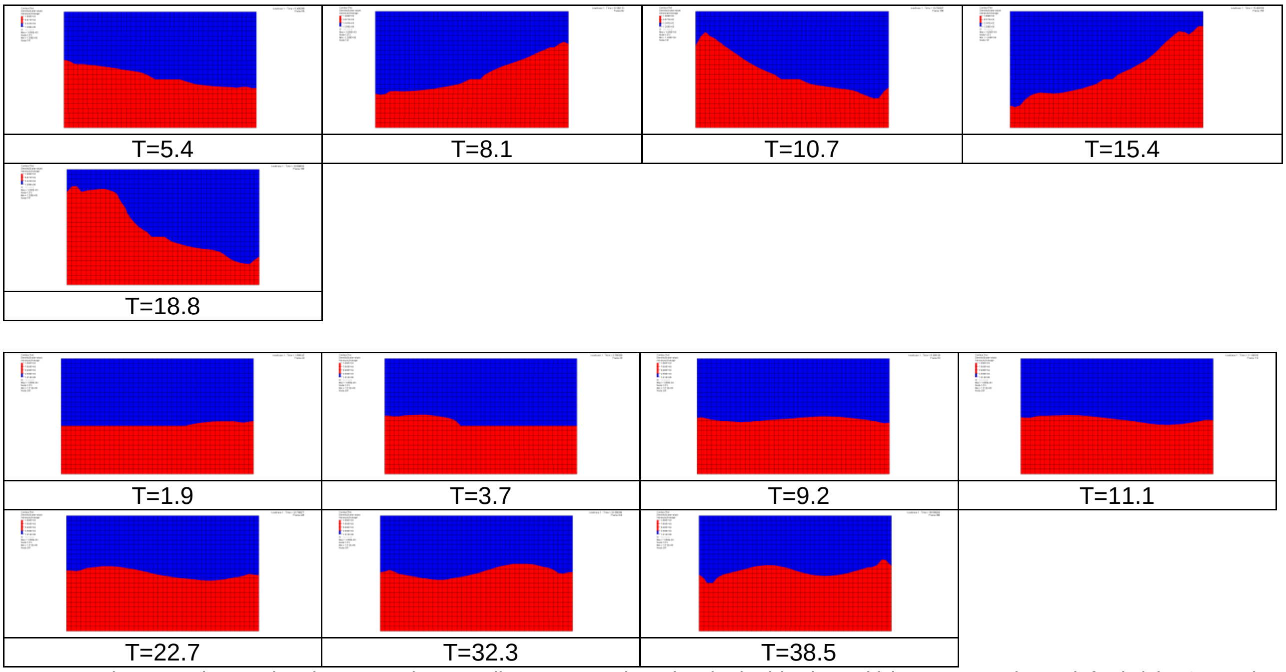

Figure 7: Time series demonstrating standing wave motions (Red=Liquid, Blue=Air) in a rectangular tank for h / l = 0.4 and excitation frequencies being equal to first (above) and second (below) natural modes for sloshing using ALE formulation.

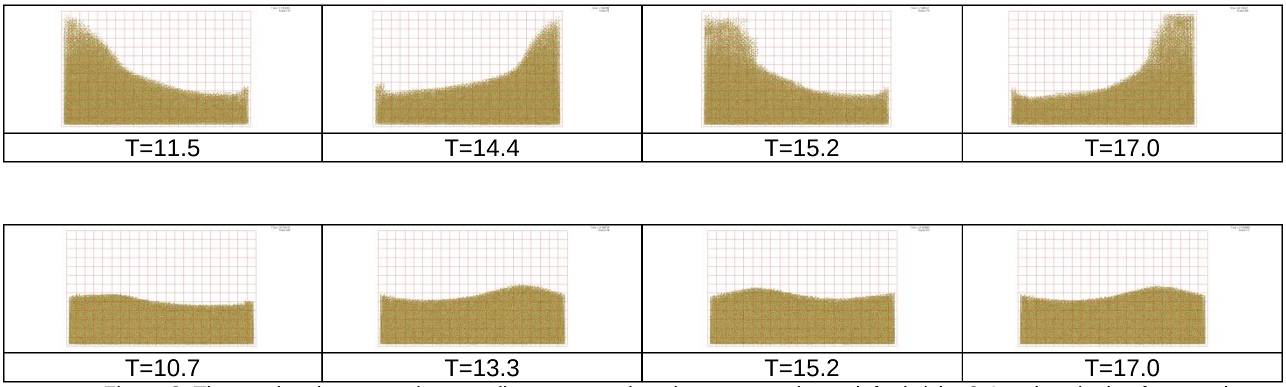

Figure 8: Time series demonstrating standing wave motions in a rectangular tank for h / l = 0.4 and excitation frequencies being equal to first (above) and second (below) natural modes for sloshing using SPH formulation.

The free surface elevations for the corresponding frequencies are comparable with analytical and experimental results [5].

4. Benefits Summary

The Circulating Water Channel project plays an important role in the growth of IMUV's long term research and academic activities. SolidThinking's unique Construction Tree History allows managing the assembly and subassembly details from concept development to the actual construction of the facility. The 3D model not only eased to see the technical issues, but helped us presenting the final impressions using high quality photorealistic rendering to the Ministry, prospective vendors and in various presentations. Since the structure mostly consists of flat plates of different dimensions, the software's "Copy+Paste" feature enabled to create and modify components accordingly with minimum modeling time.

While there are only three experimental facilities in India to perform experiments for ships, the capital cost, space, instrumentation and time required to conduct tests involves lot of effort. HYPERMESH&ACUSOLVEnot only reduces the capital cost, instrument cost and time but also helps to carry out CWC optimization/DOE tests for variations in design parameters which practically consume human resource, material and money.

IMUV proposes a new PMM with associated instrumentation, hardware and software with control & analysis developed, manufactured and made in India with minimum input from foreign collaboration. Recent initiatives by the Government of India under the ‘Make in India’ programme would be an added impetus to be built in India. Its value will increase as the IMUV gains more operational experience with sophisticated electro-mechanical equipment. MOTIONSOLVE’s ‘Path Traced' is an important parameter to visualize motion paths and approximate wall clearances across working section of the CWC. This eases vendors to understand and evaluate operating time, power consumed and costs.

RADIOSS ALE and SPH formulation helps to visualize and understand fluid surface interaction adding benefit of much lower computational power and time compared to other CFD techniques.

5. Conclusions and Future Plans

ALTAIR HYPERWORKS assists IMUV in fulfilling one of its major projects by providing a complete solution i.e., modeling, CFD Analysis, development of the PMM and study of fluid structure interaction. One major driving force at IMUV for numerical research with ALTAIR is the SPH formulation which opens up an entirely new field of study for free surface flows and fluid surface interactions.

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