

Virtual Prototyping in Ship Design

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Abstract

Simulation and Virtual Prototyping got into many difficulties before becoming a part of the traditional ship building processes.

However the greater complexity of constructions and boarded systems demand more complete design verifications.

Even if a boarded system is analogous to the land one, it must stand the high intensity of the induced ship motion.

The forecasting of the ship motions has always been a problem of the ship design, and a lot of software was developed in the past to study this topic. On the other side the analysis of the systems/mechanisms subjected to this movements is very challenging, so that these simulations are often approximated by elementary shapes of motion.

The task of this study was to simulate an apparatus without simplifying the environment in which it operates.

The object of our investigation was a bridge-crane arranged to the well-dock of a new amphibious ship. This crane will be used during the in-docking phase of a 42 tons landing craft, and the embarkation/disembarkation tasks must be operative till sea state four.

From a dynamic point of view this system is not particularly complex, but what is meaningful is the integration of two different calculation codes : SMP (Ship Motion Program) , which supplies the ship motions, and ADAMS, which was able to accept them in its Body Motion environment.

SEQARABIC *Introduction*

Ship development is acknowledged to be particularly challenging because of the added complexity resulting from the sheer size and numbers of interdependent systems requiring integration. Furthermore, especially in technological ships, the design phase can take long time since continuous modifications and improvements are added to the original project. In this scenario, a tool able to check design corrections, improvements and added features can really minimise the risk of inserting also design mistakes and incoherencies.

Design - simulate - modify - build is surely better than design - build - test - modify [1].

Typically in the ship design process, several simulation or physical analysis are performed: sea-keeping, structural analysis, power management simulation. All these kind of elaboration are usually an integral part of the whole design process, but designers and engineers usually use simulation systems and tools which result are not explicit and which have to be explained through diagrams, drawings, technical spreadsheet during complex technical meetings. A good level of reciprocal comprehension must be reached to be able to technically evaluate the results and to verify design constraints [2].

In other words, tools able to give an intuitive and general understanding of the results are not generally available. The basic idea of Virtual Prototyping is to encourage all principal partners in the ship development process to work together closely. These partners would more readily integrate their activities while performing their respective functions concurrently and communicating freely and efficiently.

To complicate the scenario, in ship design the interaction of several "living" components has to be taken into account in order to study operative requirements or functional behaviour of the product. A static 3D view or fly through can be insufficient to point out problems deriving from moving objects on deck or interaction between correlated components.



Figure 2 - Ship sailing in a rough sea

The “ICARO” Project

One of the last exercises we faced was a feasibility study targeted to the simulation of the operability of a new ship. In particular this study aimed at assessing the feasibility of the embarking and disembarking operations of landing crafts.



Figure 3 - The amphibious ship model

Background

The main task of an amphibious ship is to support amphibious operations. Landing crafts operations play an important role in this support, and therefore is of paramount importance to ensure that the ship design meets the relevant requirements.

The use of simulation in the design of amphibious ships was and still is based on physical model tests performed in towing tanks with radio controlled models. The aim of these tests is mainly to investigate the hydro-mechanic aspects of embarking and disembarking of landing crafts in order to obtain knowledge and data for use in design and optimisation of well deck configuration.

Due to the complex dynamic phenomena, it is often decided not to rely on calculations but to investigate the hydro-mechanic aspects by means of physical model tests.

Project Tasks

A simulation of a typical embarking/disembarking operation can be schematized as follow:

- In-docking study of the landing craft into the well deck;
- Study of the interaction of the landing craft and ship during the leaving and entering operations;
- Study of the manoeuvrability of the landing craft during the leaving and entering operations.

ADAMS was selected to study the in-docking phase when the landing craft is lowered by a bridge crane in the well deck of an amphibious ship.

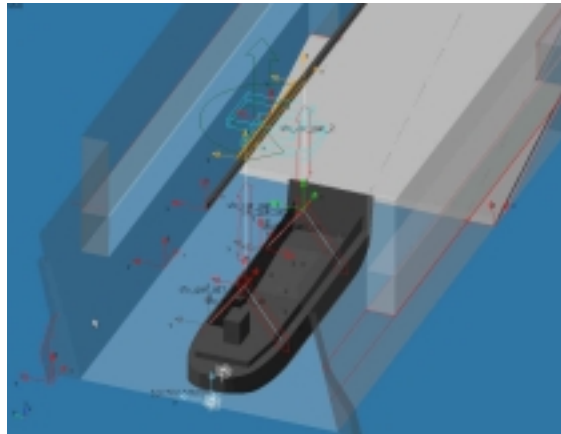


Figure 3 - In-docking

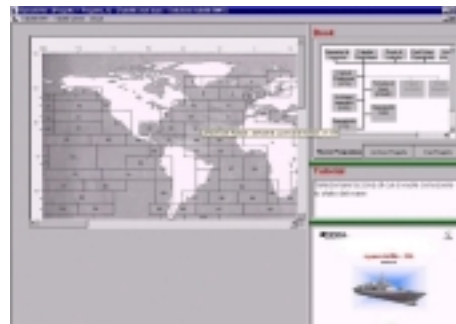
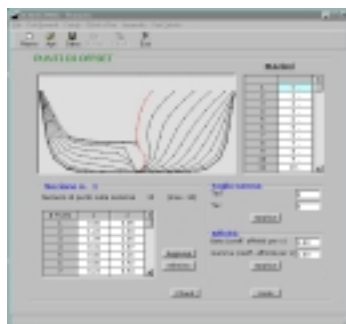
For this purpose we had to implement the integration of two different calculation codes : SMP (Ship Motion Program) , which supplies the ship motions, and ADAMS, which was able to accept them in its Body Motion environment.

Besides the implementation of ship movements in particular sea conditions, our work was focused on the movements co-ordination of the in-docking boat and the ship. This is particularly important if we want to achieve a realistic assessment of the ship-boat interactions during the in-docking operations, and a real evaluation of the crash probability of the two vessels.

Ship Motion

Any onboard activity cannot be separated from the ship movements. Great part of the simulation studies faced during design may become too approximate if approached using a "still ship". Usually these movements are the direct responsible of problems related to operability of system and devices.

A complete Ship Motion and Operability workspace has been developed during the years by FINCANTIERI and CETENA Hydrodynamic and Information Technology Departments.



Figures 4,5 - Hull geometry and sea states panels (*Operability Suite*)

Ship Motion in ADAMS

Before this work we were used to read the time history of the COGs positions contained in a file generated off-line. This procedure was very simple but it had two main disadvantages.

- The statistic nature of the ship motions was not preserved. The simulations were produced mainly using the same time history or a limited set of time histories. In fact it is rather difficult to produce an infinite number of files.
- Changing sea state or ship parameters (wave height, modal period, ship heading and velocity) was time expensive.

Due to these reasons we decided to implement the induced motion time history directly in the simulation tool.

The sea model at a first step was developed using a Jonswap/Bertschneider function, that returns the wave spectrum according with the formulation below:

$$S_{\eta}(\omega) = f(H_s, T_p, \gamma, \omega_e)$$

where

ω : frequency of wave [rad/s]

ω_e : frequency of encounter, depending from the velocity and heading of the ship [rad/s]

T_p : modal (peak) wave period [s]

γ : Enhancement factor

Using this formulation we can obtain different wave-spectrums corresponding to different values of the significant wave height, peak wave period and direction of the sea.

To implement the induced motions both of the ship and the boat we developed a function which returns the time history of the six DOF motions, velocity and accelerations of the ship.

This is roughly the mathematical description of the function:

$$x(t) = \sum_{i=1}^{N-1} f(S_{\eta}(\omega_i), \dot{A}(\omega_i), \omega_e)$$

where

N : number of quantization intervals of the frequency range of the wave spectrum

$\dot{A}(\omega)$: is the complex term representing the amplitude and phase of the Ship Response
Amplitude Operator of the x DOF for a particular sea state

$x(t)$: is the time history of the x DOF

To simplify the use of the simulation tool we developed a graphical user interface, integrated in the virtual prototyping environment. The user can interactively change the wave parameters (spectrum or frequency, wave height, heading angle) and ship heading and speed and immediately view the effects of the changes on the ship motions.

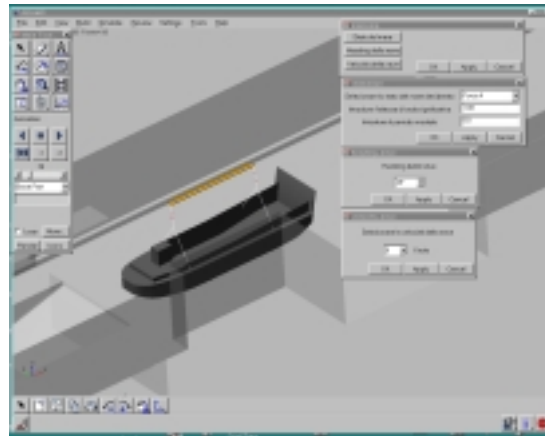


Figure 6 - User interface in ADAMS

SOFTWARE VIRTUAL SHIP MODELS

The first stage in the development of a 3D simulation of a naval process is the generation of a 3D CAD geometry for the ship structures and equipment of interest [3]. In our system architecture we obtain the ship 3D model from the CAD System database (Bentley - Microstation).

In ADAMS we used a simplified model representing only the portion of the ship directly involved in the operation we want to analyse.

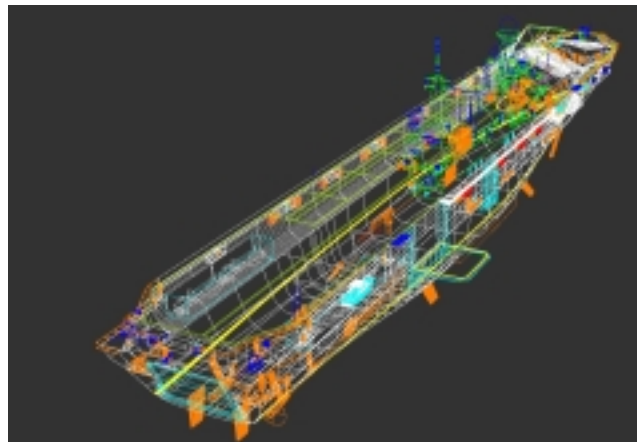


Figure SEQARABIC7 - Microstation 3D Model

SOFTWARE ARCHITECTURE

From the first beginning we started to study and develop the software structure of our virtual prototyping environment. This software architecture comprises essentially two main components: simulation macro programs associated to the simulated devices and Application Services. Application Services are a set of real time generic procedures that can be used from different simulation macro programs. These services are based on two different databases: the Ship 3D Model Database and the Attribute Database.

The Ship 3D Model Database provides the models of the ship and its components. The Attribute Database include geometry, mass, RAO coefficients, trims, etc.

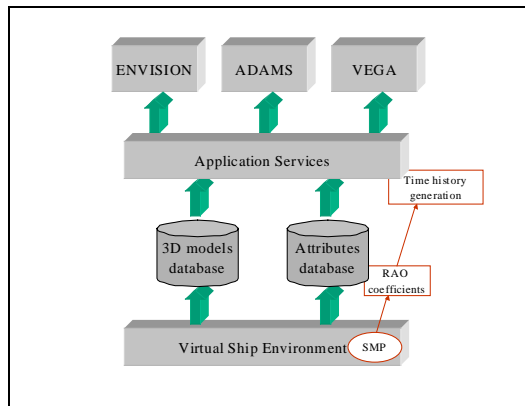


Figure 8 - The Software Architecture

CONCLUSIONS

Working on this project FINCANTIERI had the opportunity to use Virtual Prototyping tools since the design phase.

In the near future it is reasonably possible that more operational tests can be requested by the client in order to verify the ship operational requirements. Virtual Prototyping seems to be a good way to answer to the question, especially while co-operation of several objects has to be studied and tested in an unstable environment like sea.

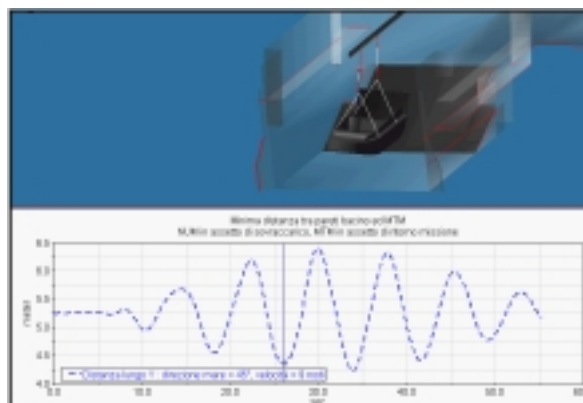


Figure 10 - Results

In the future to main items will be developed:

- The introduction of physical interfaces : to improve the interaction with the virtual environment;
- The integration of ADAMS with other Virtual Prototyping tools.

Ship designer and ship owners will appreciate the availability of tools able to display accurately the final product operating in a synthetic environment with detailed physical phenomena simulations. This may give a good opportunity to collect suggestion from different field experts so that the final product can take into account more detailed and functional aspects otherwise available only after the ship has been already built.

REFERENCES

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[2] A. Zini, A. Rocca, M. Raffa "The Integration of Virtual Prototyping in Ship Design". "COMPIT'2000 - Computer Applications and Information Technology in the Marine Industries ". Potsdam, 29.3. - 2.4.2000. Pages 490 - 502.

BIOGRAPHY

MARCO RAFFA graduated in Naval and Mechanical Engineering in 1979, he started working with FEM software for structural analysis and verification in FINCANTIERI. In 1985 he was responsible for the study and implementation of the graphical system for functional and detailed design based on commercial software with particular focus on the realisation of a complete 3D ship model. From 1990 to 1994 he has been responsible of the hull building yard. This experience has been used from 1994 to 1998 in the hull design and manufacturing for the new fast ferries.

From 1998 he's responsible for the management and development of technical information systems in FINCANTIERI and he's nowadays directly involved into the evaluation of cost/benefits deriving from the use of Virtual Prototyping techniques in the ship design process.

ROBERTO COSTA qualified as a Naval Technician is working presently in Fincantieri - Cantieri Navali Italiani S.p.A as member of CAD Office in the Military Ships Division. He's involved in the support for software and information technologies architectural

problems concerning the Project Management Area. Nowadays he's working on Virtual Prototyping development and testing for internal and Italian Navy's projects.

ALDO ZINI born in Genova in 1963 and graduated in Electronic Engineering at Genoa University in 1990, since 1991 he has been working in CETENA dealing with information technologies problems. In particular he was involved in several projects dealing with I.T. applications in shipbuilding and shipping areas: CAD systems, Neural Networks, Ship Survivability Analysis, Virtual Prototyping, Expert Systems, Database, dynamic WEB sites, technical computational code, graphical interfaces.

He's participating to the NATO NG6 Specialist Team on Simulation Based Design and Virtual Prototyping and to the NIAG Sub Group 60 on SBD & VP.

He was involved as scientific responsible in several European research Projects, among which HYDROSES and MATSTRUTSES.

His present position is Head of the Information Technology Department of CETENA.

ATTILIO ROCCA Born in 1972 graduated in Electronic Engineering in 1997 at University of Genova, discussing a Degree Thesis "*A bidimensional solution to electromagnetic inverse problem using Genetic Algorithms*" ("*New results in microwave imaging using a genetic algorithm*", S. Caorsi, M.Pastorino, A. Rocca. PIERS 1998).

He is at present in CETENA S.p.A., Information Technology Department. He his working on software development and is involved in the application of Virtual Prototyping in ship design.

His previous experience was in Arinox S.r.l. (high precision stainless steel strips) as Maintenance Engineer (1997-1998), responsible for the maintenance and development of internal software for management of industrial process.

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