TRUST JIP, Project Plan V1	MARIN Project No. 24000

Hydrodynamics of Thruster Interaction

Research Partners:

Objectives:

'To better understand thruster-interaction effects, to develop analysis methods and to apply these tools in the design process and in the analysis of the DP vessel's stationkeeping capabilities in operational conditions.'

MARIN Reference 24000, version 1, November 2009

1. Executive Summary

Background

During DP operations the effective force generated by the thrusters can be significantly smaller than what would be expected based on the thrusters' open water characteristics. This is a result of interactions of the thrusters with current, the vessel hull and the wake of neighbouring thrusters. The main question therefore is "How can you trust the thruster specification ?", since it only tells part of the story. The understanding and quantification of thruster-interaction (or: thrust degradation) effects is essential for an accurate evaluation of the stationkeeping capabilities of any DP vessel. The TRUST JIP aims at increasing the insight in the physical phenomena, quantifying thruster interaction effects and investigating possibilities for improvement.

Objectives

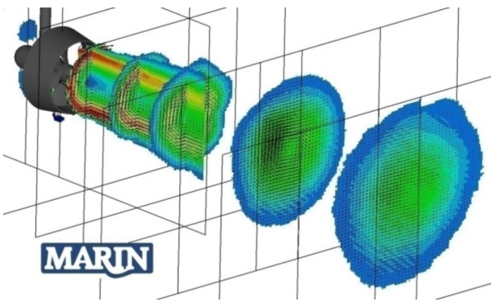
The TRUST JIP (Thrust Hydrodynamics JIP) aims at increasing the insight in the physical phenomena, quantifying thruster interaction effects and investigating possibilities for improvement. The TRUST Joint Industry Project will combine dedicated thruster-interaction model tests, full scale measurements and CFD calculations with existing data available from literature. The objectives of the TRUST JIP are as follows :

- Increase the insight in the physics of thruster interaction effects, including thruster-hull, thruster-thruster and thruster-current interactions.
- Deliver a DP capability and operational analysis tool, including extended and improved thruster-interaction data bases.
- Develop an analysis and design approach of combined CFD calculations and model tests, to optimise thruster configurations.

Scope of Work

The scope of work of the TRUST JIP is divided into a number of work packages.

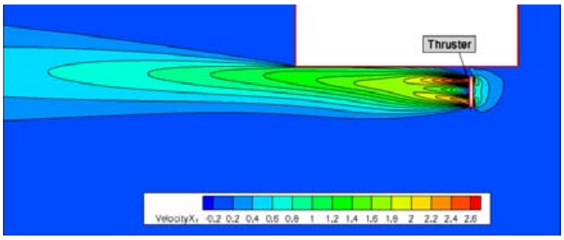
In WP1 existing thruster-interaction data will be collected, to give an overview of existing knowledge and find areas of thruster-interaction that have not been sufficiently investigated in the past ("blank spots"). The data will be used as input for WP3 and to optimise the scope of work for WP2.



In WP2 model tests, full scale measurements and CFD calculations are carried out. Different configurations of increasing complexity are investigated, each one focussing on specific aspects of thruster-interaction. The scope of work includes single azimuthing thruster and azimuthing thrusters under a schematic barge, as well as case studies of complete DP vessels with thrusters. The first configurations focus mainly on the basic physics, while the case studies aim at investigating the thruster-interaction effects of a complete vessel.

In WP3 the thruster-interaction results, available from existing data bases (WP1) and new data from the TRUST JIP model tests and CFD calculations (WP2), are incorporated in a new tool for DP capability and operational analysis. The data bases will have an open format, so that JIP participants can also include and apply their own model test or calculation results.

The objective of WP4 is to define a standard approach for the analysis of thruster-interaction effects and optimisation of the thruster configuration during the vessel design. Guidelines will be developed on how to use model tests and CFD calculations in the analysis of thruster interaction effects and the optimisation of thruster configurations on DP vessels. This unified step-by-step approach will be formulated to serve as a "best practice" description.



Deliverables

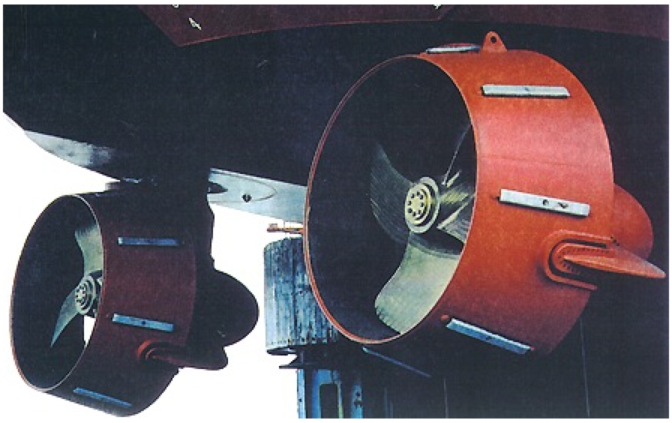
The main TRUST JIP deliverables are :

- ***Model test, CFD calculation and full scale measurement reports,***
  containing the measurement and calculation results, analysed data, time records in ASCII format, applied calculation grids and discussion of the results.
- ***DP capability and operational analysis tool OPERA,***
  including a data base of thruster interaction coefficients, for operational analysis and early design calculations.
- ***"Best practice" reference document,***
  describing the step-by-step analysis and design approach.

2. Background

During DP operations the effective force generated by the thrusters can be significantly smaller than what would be expected based on the thrusters' open water characteristics. This is a result of interactions of the thrusters with current, the vessel hull and the wake of neighbouring thrusters. The main question therefore is "How can you trust the thruster specification ?", since it only tells part of the story. The understanding and quantification of thruster-interaction (or: thrust degradation) effects is essential for an accurate evaluation of the stationkeeping capabilities of any DP vessel. The TRUST JIP (Thrust Hydrodynamics JIP) aims at increasing the insight in the physical phenomena, quantifying thruster interaction effects and investigating possibilities for improvement.

At present, thrust degradation effects can be quantified using data available from literature, or by carrying out dedicated model tests. Unfortunately, published data are often too general or not applicable to the specific design under consideration. Model tests, on the other hand, do provide detailed results, but are relatively expensive. And test results often become available relatively late in the design process, making it difficult to incorporate the results in the design. CFD calculations could be an alternative method, but there is little experience in the application of CFD as engineering tool for thruster-interaction effects.



In the TRUST JIP model test data, CFD calculation results and full scale measurements will be combined to provide the methods and tools for the hydrodynamic optimisation of a DP vessel's thruster configuration during the design. One of the deliverables is the DP capability and operational analysis tool OPERA, which combines traditional DP capability plots with the evaluation of other operational criteria, such as motions and accelerations. Finally, guidelines will be developed on how to use model tests and CFD calculations in the analysis of thruster interaction effects and the optimisation of thruster configurations on DP vessels.

3. TRUST JIP Objectives

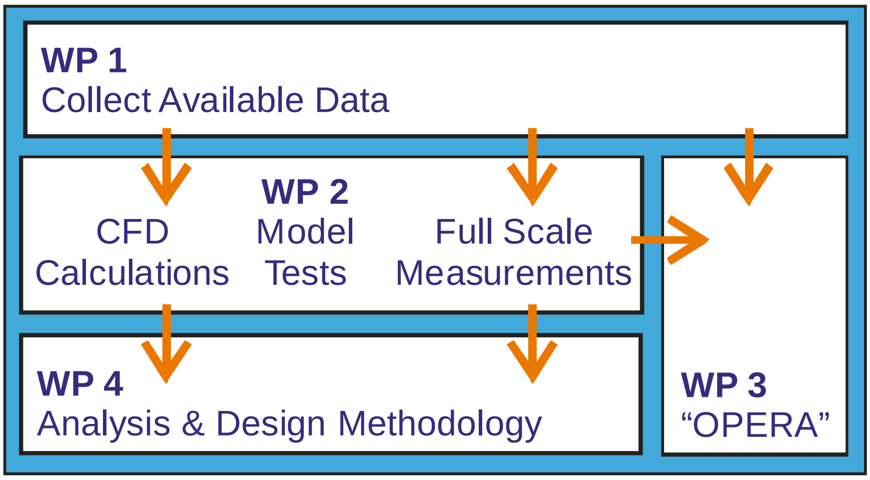
Past research has provided a lot of information on thruster-interaction effects, but to incorporate this knowledge in the design process is a complex task. The goal of the TRUST JIP is to better understand thrust degradation effects and to develop analysis methods. This knowledge can be applied in the design process and in the analysis of the DP vessel's stationkeeping capabilities in operational conditions. As part of the work in the TRUST JIP, the possible influence of scale effects on the thruster performance, a largely unexplored area, will also be investigated.

The TRUST Joint Industry Project will combine dedicated thruster-interaction model tests, full scale measurements and CFD calculations with existing data available from literature. The objectives of the TRUST JIP are as follows :

- Increase the insight in the physics of thruster interaction effects, including thruster-hull, thruster-thruster and thruster-current interactions.
- Deliver a DP capability and operational analysis tool, including extended and improved thruster-interaction data bases.
- Develop an analysis and design approach of combined CFD calculations and model tests, to optimise thruster configurations.

4. Scope of Work

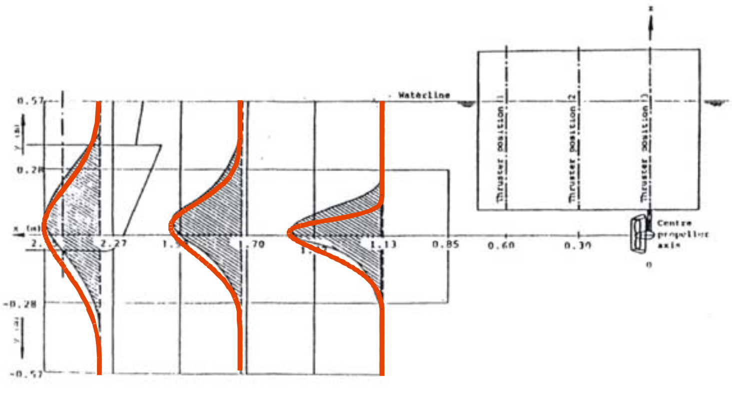
The complete scope of work of the TRUST JIP is divided into 4 work packages. The schematical outline of the project is shown in the figure below, showing the individual work packages and their main interactions.



Sections 4.1 through 4.4 provide a brief description of the work packages for the TRUST JIP. The detailed scope of work of WP2 and WP3 is presented in Appendix A and B of this project plan.

4.1. WP1 - Collect Available Data

In WP1 existing thruster-interaction data will be collected, e.g. published data from previous research projects. This will give an overview of existing knowledge and reveal areas of thruster-interaction that have not been sufficiently investigated in the past ("blank spots"). This inventory of available data can also help to optimise the scope of work of the model tests and CFD calculations in WP2.



Nienhuis' measurements compared with recent CFD calculations

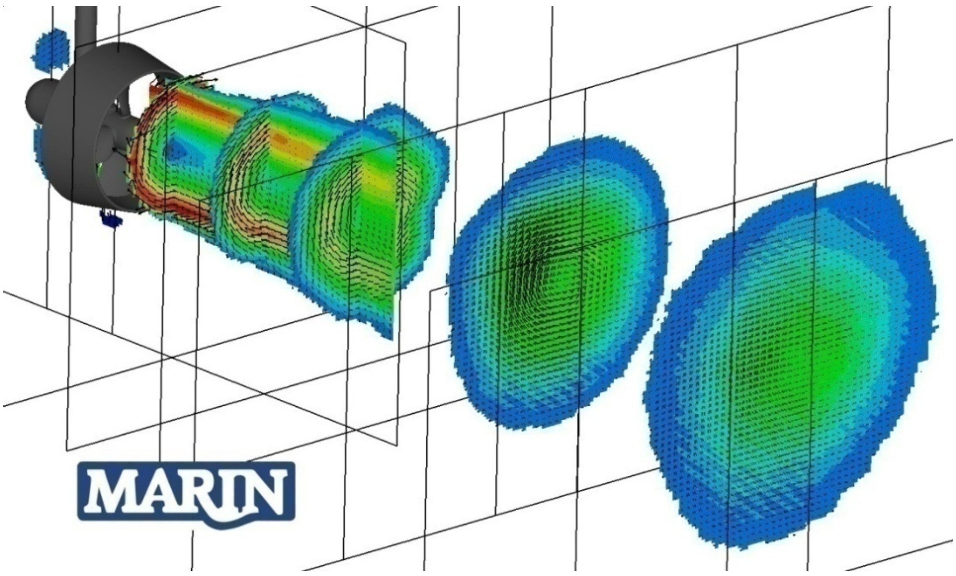
The available thruster-interaction data will be stored in a data base format that can be used by the DP capability and operational analysis tool OPERA, which will be developed in WP3. In addition, a format is defined for a data base with user-defined thruster-interaction coefficients.

4.2. WP2 - Model Tests, Full Scale Measurements and CFD

In WP2 model tests, full scale measurements and CFD calculations are carried out. Several different configurations of increasing complexity are investigated, each one focussing on different aspects of the physics of thruster-interaction. The scope of work will include investigations of a single azimuthing thruster and azimuthing thrusters under a schematic barge, as well as 2 case studies of complete DP vessels with thrusters. The first configurations will focus mainly on the basic physics and (CFD) modelling aspects, while the case studies will aim at investigating the thruster-interaction of a complete vessel. The scope of work of the model tests, CFD calculations and full scale measurements is described below and in more detail in Appendix A.

Model Tests

Thruster-interaction tests will be carried out on a number of different configurations, which are described in more detail in Appendix B. During the model tests a model equipped with thrusters will be rigidly connected to the basin carriage through a 6 component force frame, thus enabling the measurement of the total delivered thrust force. Furthermore, the thrust and torque of the individual thrusters are measured. In addition, PIV (Particle Image Velocimetry) measurements are carried out to document in detail the velocities in the thruster wake and around the floater hull. An example of such PIV measurements is shown in the figure below.



PIV measurements on an azimuthing thruster model at MARIN
(colours indicate axial speeds, vectors show in plane velocities)

The scope of work of the thruster-interaction model tests will include the investigation of the effects of the following parameters.

- Thruster positions (relative distance, distance to bilge)
- Thruster geometry (e.g. nozzle angle)
- Thruster settings (RPMs, azimuth angle)
- Hull shape (including e.g. bilge radius, semi-submersible pontoon spacing)
- Ship-type (mono hull and semi-submersible)
- Presence of current

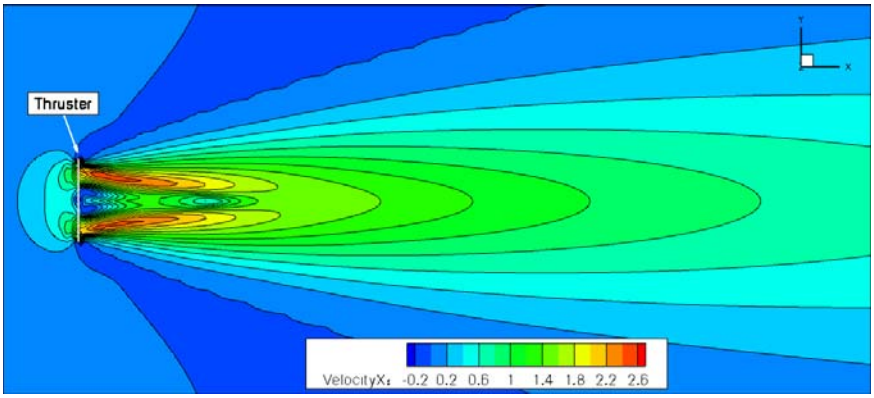
Furthermore, possible scale effects are part of the investigations.

The model test results will improve the understanding of the hydrodynamic phenomena relevant to thruster-interaction and will provide quantitative results in terms of thruster-interaction coefficients. The model test results will also be used for the validation of CFD models.

CFD Calculations

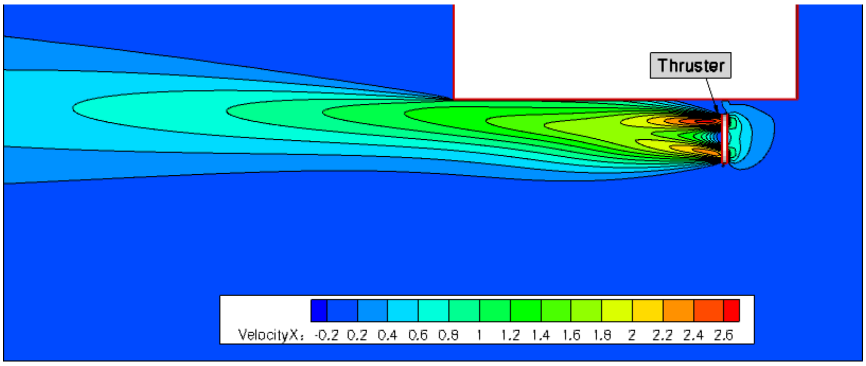
The application of CFD calculations for the analysis of thruster-interaction is still a largely unexplored area. At this moment CFD calculations of a floater, complete with all its thrusters, may seem too complex, but suitable modelling methods will be investigated and developed. Thorough validation of CFD models against measurement results is required and the TRUST JIP will play a role in that.

As a first step, CFD calculations will be performed to determine the velocities in the thruster wake. The accurate calculation of the velocities, especially at larger distances from the thruster, is crucial for an accurate prediction of thruster-interaction effects later on.



CFD calculation of the axial velocities in a thruster wake

Subsequently, a series of increasingly complex configurations is considered. In this manner, the performance of a thruster under a barge or ship hull can be investigated. Another example would be the calculation of the loads caused by the thruster wake on the opposite pontoon of a semi. The effect of current on the thruster wake can also be investigated in the CFD calculations.



CFD calculation of a thruster wake under a schematical hull

The applicability, accuracy and limitations of CFD for thruster-interaction will be investigated by comparing the model test results with CFD calculations. The CFD results and visualization of flow patterns might also be useful for interpreting and understanding the model test results.

Full Scale Measurements

Model tests at different scale ratios, including tests at a scale of 1:1 (full scale measurements), are part of the scope of work of the TRUST JIP. The objective of the full scale measurements is to help improve the insight in possible scale effects. Examples where scale effects might play a role are friction forces on the vessel keel and the deflection of the thruster wake as it flows past the curved surface of the hull, e.g. at the vessel bilge (Coanda effect).

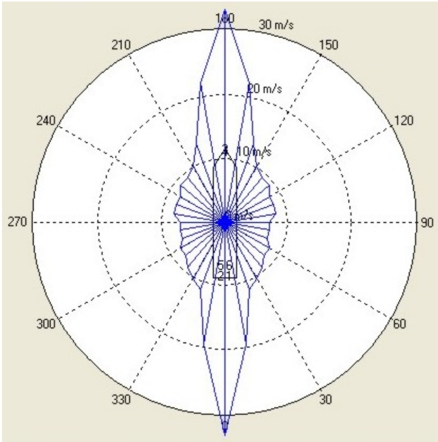
Measurements on full size thrusters can be carried out at the test basin of Thrustmaster of Texas, which is currently under construction. This basin will offer a number of unique possibilities to quantify the performance of full scale thrusters and compare these results with model test data. In addition, full scale measurements in a dedicated basin (compared to on board a ship) has a number of practical and economic advantages. The artist impression below shows the lay-out of the basin at the Thrustmaster of Texas factory in Houston.

Test Basin for Full Scale Testing of Thrusters at Thrustmaster of Texas in Houston

Possible alternative options for full scale measurements at the Thrustmaster of Texas factory are full scale measurements on a single thruster in MARIN's Depressurised Towing Tank, or full scale measurements on board a DP vessel.

4.3. WP3 - DP Capability and Operational Analysis Tool "OPERA"

In WP3 the thruster-interaction results, available from existing data bases (WP1) and new data from the TRUST JIP model tests and CFD calculations (WP2), are incorporated in a new tool for DP capability and operational analysis, suitable to evaluate stationkeeping performance of DP vessels. The data bases will have an open format, so that JIP participants can also include and apply their own model test or calculation results.



Besides traditional DP capability calculations, the tool will have an integrated evaluation of other criteria, such as (relative) motions or accelerations, making it a unique tool for early design calculations, as well as operational evaluations. The DP capability and operational analysis program will be called "OPERA".

A more detailed description of the calculation methods applied in the OPERA tool can be found in Appendix B.

4.4. WP4 - Analysis and Design Methodology

The objective of WP4 is to define a standard approach for the analysis of thruster-interaction effects and optimisation of the thruster configuration during the vessel design. Guidelines will be developed on how to use model tests and CFD calculations in the analysis of thruster interaction effects and the optimisation of thruster configurations on DP vessels. This unified step-by-step approach will be formulated to serve as a "best practice" description. The developed analysis and design methodology will typically consist of the following steps;

- ***Preliminary DP capability analysis***
  static analysis or time-domain DP calculations using thruster-interaction coefficients from a data base or earlier model tests
- ***CFD calculations***
  guidelines for thruster modelling, guidelines for grid generation, recommendations for numerical settings, recommendations for calculation scope
- ***Model tests***
  definition of the minimum required scope of work, recommendations for modelling and instrumentation

By following this systematic approach the performance of the vessel's thrusters can be optimised during the design, without carrying out any unnecessary calculations or model tests.

5. Deliverables

Below an overview is given of the main TRUST JIP deliverables:

- ***Model test reports,***
  containing the measurement results, analysed data, time records in ASCII format and discussion of the results.
- ***CFD calculation reports,***
  containing the calculation results, analysed data, applied calculation grids (on CD-ROM) and discussion of the results.
- ***Full scale measurement report,***
  containing the measurement results, analysed data and discussion of the results.
- ***DP capability and operational analysis tool OPERA,***
  including a data base of thruster interaction coefficients, for operational analysis and early design calculations.
- ***"Best practice" reference document,***
  describing the step-by-step analysis and design approach.

6. Cost

Budget

Below a first estimate of the project cost is presented.

General JIP management	EURO	50,000.=
WP1 - Collect available data	EURO	25,000.=
WP2 - Model tests (Task 1-5)	EURO	275,000.=
WP2 - CFD calculations (Task 1-5)	EURO	350,000.=
WP2 - Full scale measurements (Task 3)	EURO	250,000.=
WP3 - DP capability and operational analysis tool OPERA	EURO	125,000.=
WP4 - Analysis and design methodology	EURO	25,000.=
Total	***EURO***	***1,100,000.=***

Participation Fees

The TRUST JIP aims at the following participants:

- DP vessel operators
- Engineering companies
- DP manufacturers
- Thruster manufacturers

At present a participation fee is foreseen of EURO 75,000.= (excluding VAT) for oil companies, EURO 55,000.= for other companies (excluding VAT) and EURO 35,000.= (excluding VAT) for classification societies and small engineering firms (at request only). This is the total participation fee for the complete project. The payment of the participation fees can be divided over 3 years (1/3 each year).

7. Schedule

An informative project meeting is organised at the FPSO JIP week in San Francisco in November 2009. The final project plan and kick-off meeting are foreseen for spring 2010. The total duration of the project will be 2-3 years.

8. Contract

The contract for the TRUST JIP will be similar to the contract for the Current Affairs JIP and the HAWAI JIP. A draft Letter of Intent is attached at the end of this document.

9. Contact Information

If you are interested in the TRUST JIP, please contact:

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Bas Buchner : B.Buchner@MARIN.nl, +31 317 493 333

10. References

[1] "Analysis of Thruster Effectivity for Dynamic Positioning and Low Speed Manoeuvring", U. Nienhuis, PhD-thesis, Delft University of Technology, 1992.

[2] "*Hydrodynamic Research Topics for DP Semi-submersibles*", J.L. Cozijn, B. Buchner, R.R.T. van Dijk, OTC10955, OTC Conference, Houston, 1999.

[3] "*What Happens in Water - The use of Hydrodynamics to Improve DP*", R.R.T. van Dijk and A.B. Aalbers, DP Conference, Houston, 2001.

[4] "*Wake Adapted Ducted Propellers*", M.W.C. Oosterveld, PhD-thesis, Delft University of Technology, 1970.

[5] "Hydrodynamic Aspects of Steerable Thrusters", J. Dang and H. Laheij (Wartsila Propulsion Netherlands B.V.), MTS DP-Conference, September 2004.

[6] "Developments in Dynamic Positioning Systems for Offshore Stationkeeping and Offloading", A.B. Aalbers, R.B.H.J. Jansen, R.J.P.E. Kuipers and F. Van Walree (MARIN), OMAE 1995.

WP2 - Model Tests and CFD (MARIN / other JIP partners)

In WP2 scale model tests, CFD calculations and full scale measurements are carried out. The scope of work consists of a number of tasks of increasing complexity, each investigating different aspects related to the performance of the thruster, thruster-interaction effects and CFD modelling. The investigated configurations range from a single thruster in open water conditions to a complete semi-submersible or mono-hull, including all thrusters. The considered aspects will include the influence of the hull shape and thruster configuration, as well as the presence of current. Furthermore, possible scale effects are part of the investigations.

Objectives

The main objectives of WP2 are listed below.

- Increase insight in the hydrodynamics of thruster interaction effects
- Collect thruster-interaction data
- Investigate modelling methods for CFD calculations
- Validate CFD methods
- Investigate scale effects

Methodology and Scope of Work

In WP2 the following approach is applied. Model tests, CFD calculations and full scale measurements are combined in a number of tasks of increasing complexity. In the first task an azimuthing thruster in open water conditions is considered, while in each next task additional aspects are added. The foreseen tasks are listed in the table below.

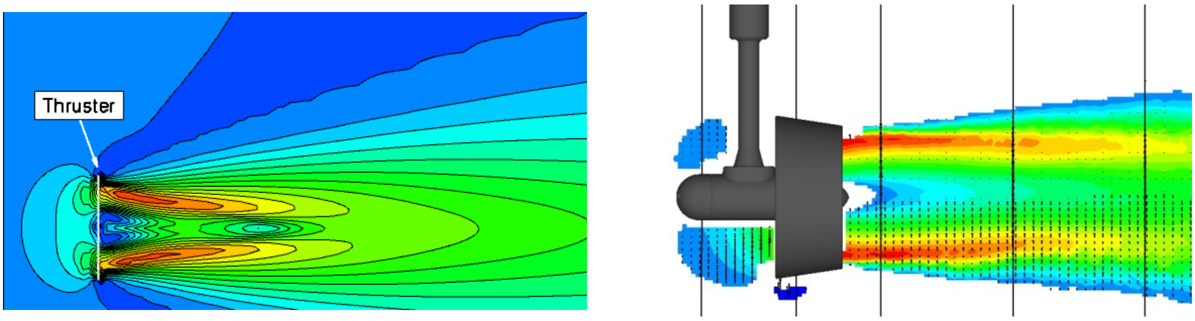
Task	**Model Tests (a.)**	**CFD (b.)**	**Full Scale (c.)**
1. Thruster in open water conditions	X	X	X ([2])
2. Thruster under plate	X	X	----
3. Thruster under barge	X	X	X ([1])
4. Case study - Semi-submersible	X	X	---- ([3])
5. Case study - Drilling Vessel	X	X	---- ([3])
6. Bow tunnel ventilation (optional)	X	X	----

([1]) At its factory in Houston thruster manufacturer Thrustmaster of Texas is constructing a basin to test thrusters directly after fabrication. This basin could be used for full scale tests on azimuthing thrusters under a barge.
([2]) Alternatively, multiple scale model tests on a single thruster can be carried out in MARIN's Depressurised Towing Tank (VT, at atmospheric pressure) in Ede.
([3]) If available, the results of full-scale measurements on board DP vessels could be included in the analysis of thruster-interaction effects.

Task 1 - Thruster Alone

An azimuthing thruster in open water conditions is considered. Model tests at multiple scales and CFD calculations are carried out and the results are compared. The objective is to investigate and compare different methods for modelling thruster in CFD calculations. The following aspects are investigated :

- Thruster open water performance
- Thruster-current interaction
- Effect of nozzle tilt
- Practical modelling methods for thrusters in CFD calculations
- Scale effects in thrust and torque



Azimuthing thruster in open water conditions
CFD calculations vs. PIV measurements

Task 1a. - Model tests

Model tests are carried out on an azimuthing thruster in open water conditions. The measured signals include propeller thrust and torque, nozzle thrust and unit thrust. PIV measurements are carried out to determine the flow patterns in the thruster wake. Special attention will be paid to the modelling of the thruster model geometry.

Task 1b. - CFD calculations

CFD calculations are carried out on an azimuthing thruster in open water conditions. Different methods to model the thruster are compared, e.g. modelling of the complete thruster and nozzle and modelling of the thruster as an actuator disc. Attention will be paid to modelling of geometric details such as nozzle shape, struts and the propeller hub. The velocities in the thruster wake are calculated for comparison with PIV measurements (see Task 1a.).

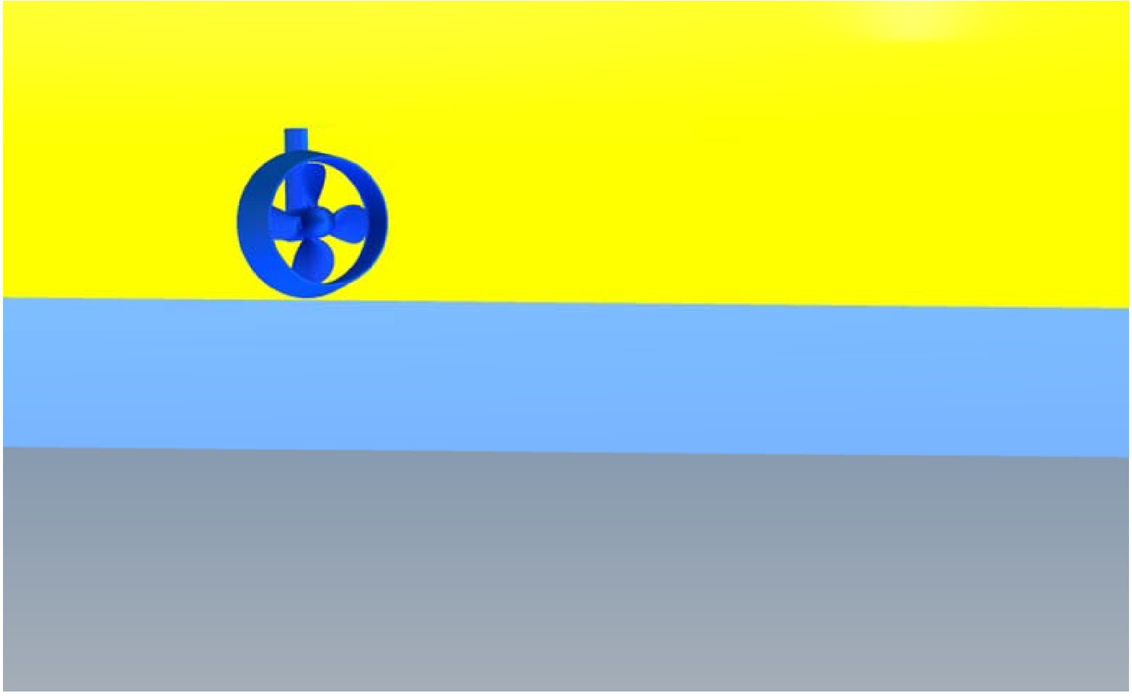
Task 1c. - Full-scale / multiple scale measurements

Measurements at full scale (or at multiple model scales) are carried out in MARIN's Depressurised Towing Tank (VT). The results of thrust and torque measurements at different model scales are compared to investigate possible scale effects. These tests are considered as an alternative option for the full scale measurements on a thruster under a barge (see Task 3c).

Task 2 - Thruster under Plate

An azimuthing thruster under a flat plate is considered. The presence of the plate will influence the shape of the thruster wake and the high fluid velocities will cause friction forces on the plate. This configuration could be considered as a thruster under a barge with zero draft. However, in this case no deflection of the thruster wake due to the Coanda effect will occur, since the plate has no sides. Model tests and CFD calculations are carried out for this configuration and the results are compared. The following aspects are investigated :

- Thruster-hull interaction (effect of plate on thruster wake, friction forces on plate)
- Effect of nozzle tilt



Azimuthing thruster under a flat plate

Task 2a. - Model tests

Model tests are carried out on an azimuthing thruster under a flat plate. The measured signals include propeller thrust and torque, nozzle thrust, unit thrust and total loads on the plate. PIV measurements are carried out to determine the flow patterns in the thruster wake.

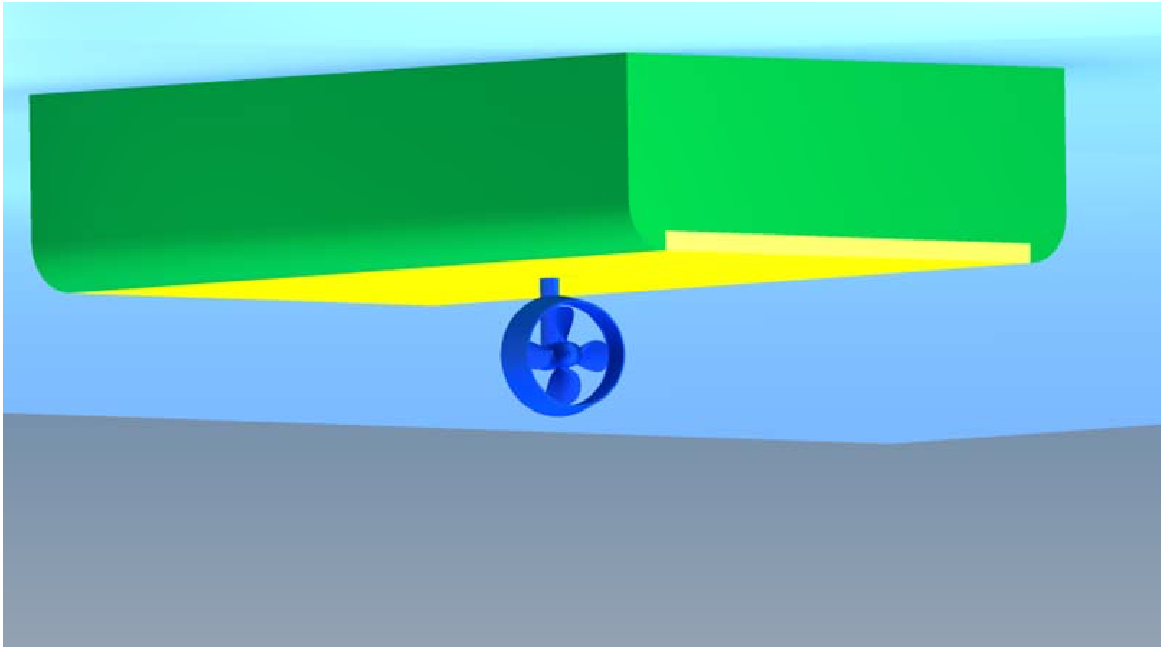
Task 2b. - CFD calculations

CFD calculations are carried out on an azimuthing thruster under a flat plate. The velocities in the thruster wake are calculated for comparison with PIV measurements (see Task 2a.). The friction force on the plate will be calculated and compared with model test results. These calculations are carried out at different Re numbers to investigate scale effects.

Task 3 - Thruster under Barge

A set of azimuthing thrusters is considered, built into a (schematical) barge. For a single thruster, the configuration is somewhat similar to a thruster under a flat plate (Task 2), except that the plate has a zero draft. Model tests, CFD calculations and full scale measurements are carried out for this configuration and the results are compared. The following aspects are investigated :

- Thruster-hull interaction (effect of barge on thruster wake, friction forces, Coanda effect)
- Thruster-thruster interaction
- Thruster-current interaction
- Effect of nozzle tilt



Azimuthing thruster under a barge

Task 3a.

Model tests are carried out on a set of azimuthing thrusters under a barge. The measured signals include propeller thrust and torque, nozzle thrust and unit thrust. The barge model is connected to the basin carriage to measure the overall loads. PIV measurements are carried out to determine the flow patterns in the wake of the thrusters.

In addition, model tests are carried out on a floating barge with a single thruster in a basin, reproducing at 1:10 model scale the situation in the test basin at Thrustmaster of Texas (see also Task 3c.).

Task 3b.

CFD calculations are carried out on a set of azimuthing thruster under a barge. The velocities in the thruster wake are calculated for comparison with PIV measurements (see Task 3a.) and the total delivered thrust force is calculated and compared with the measured loads. The calculations are carried out at different Re numbers to investigate scale effects in the friction forces and the Coanda effect (deflection of the thruster wake near the bilge).

In addition, CFD calculations are carried out on a floating barge with a single thruster in a basin, reproducing the situation in the test basin at Thrustmaster of Texas (see Task 3c.).

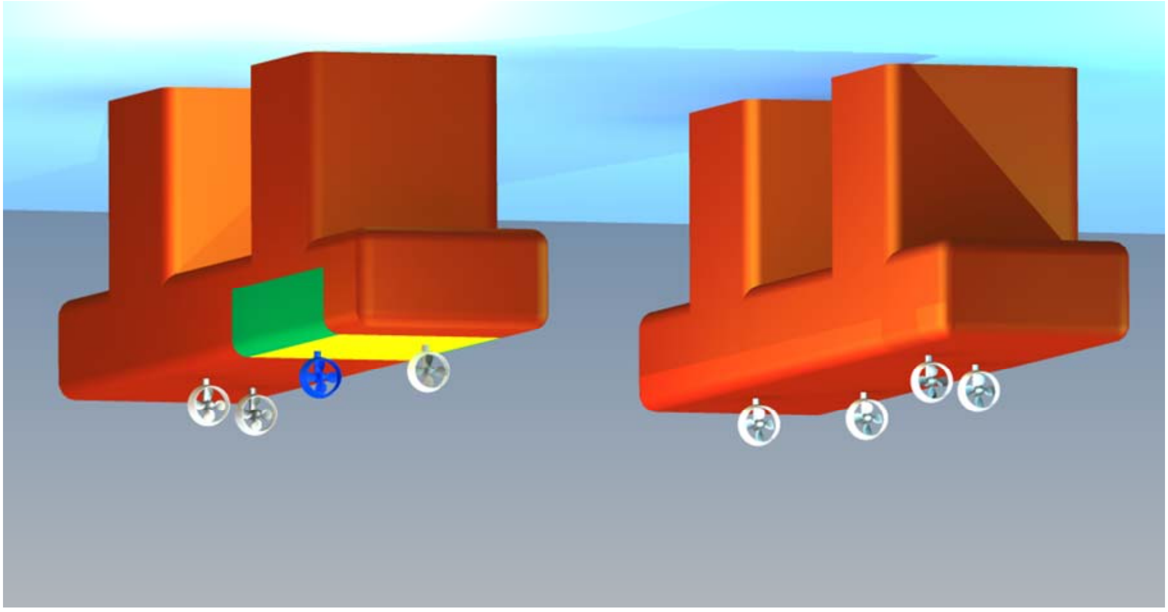
Task 3c.
At its factory in Houston thruster manufacturer Thrustmaster of Texas is constructing a basin to test its thrusters directly after fabrication. In this basin full scale tests on a single azimuthing thruster under a barge could be carried out. Measured parameters include thruster RPMs, thruster power and mooring loads on the barge. The results of the full scale measurements will be compared with the model tests (Task 3a.) and CFD calculations (Task 3b.) for the same configuration.

Test basin at Thrustmaster of Texas (Houston, TX)

Task 4 - Case Study - Semi-Submersible

The first of 3 case studies on practical configurations concerns a semi-submersible with (8) azimuthing thrusters. Model tests and CFD calculations are carried out and the results are compared. The following aspects are investigated :

- Thruster-hull interaction
  (hull friction, Coanda effect, loads on opposite pontoon, effect of current)
- Thruster-thruster interaction
- Thruster-current interaction



Azimuthing thrusters under a semi-submersible

Task 4a.

Model tests are carried out on a semi-submersible with azimuthing thrusters. The measured signals include propeller thrust and torque, nozzle thrust, unit thrust and total loads on the captive model. PIV measurements are carried out to determine the flow patterns in the wake of the thrusters and around the semi-submersible hull.

Task 4b.

CFD calculations are carried out on a semi-submersible with azimuthing thrusters. The total delivered thrust force is calculated and compared with the measured loads. Furthermore, the velocities in the thruster wake are calculated for comparison with PIV measurements (see Task 4a.) and the.

Task 5 - Case Study - Drilling Vessel

The second case study concerns a mono hull drilling vessel with (6) azimuthing thrusters, a bow tunnel thruster and a skeg. The azimuthing thrusters at the stern are placed below the vessel keel on an almost flat surface. The azimuthing thrusters at the stern, however, Thruster interaction model tests and CFD calculations are carried out to and the results are compared. The following aspects are investigated :

- Thruster-hull interaction (hull friction, Coanda effect, loads on skeg)
- Thruster-thruster interaction (at bow and at stern)
- Thruster-current interaction
- Bow tunnel performance (including effect of current)

DP drilling vessel with azimuthing thrusters

Task 5a.

Model tests are carried out on a mono hull drilling vessel with azimuthing thrusters and a bow tunnel thruster. The measured signals include propeller thrust and torque, nozzle thrust, unit thrust and total loads on the captive model. PIV measurements are carried out to determine the flow patterns in the wake of the thrusters and around the vessel hull.

Task 5b.

CFD calculations are carried out on a mono hull drilling vessel with azimuthing thrusters and a bow tunnel thruster. The total delivered thrust force is calculated and compared with the measured loads. Furthermore, the velocities in the thruster wake are calculated for comparison with PIV measurements (see Task 5a.).

Task 6 - Bow Tunnel Ventilation (optional)

The third case study concerns ventilation of bow tunnels. Large relative motions at the bow may cause bow tunnel thruster to emerge from the water. In such cases part of the water may flow out of the tunnel, causing temporary loss of thrust. The complex process of water flowing in and out of the bow tunnel will be investigated through model tests and CFD calculations. The following aspects are investigated :

- Effect of motion amplitude and frequency
- Bow shape and tunnel geometry
- Thruster loading

Bow tunnel thrusters on a DP shuttle tanker

Task 6a.
Model tests are carried out on a (schematical) bow section with a bow tunnel thruster. The bow section will be oscillated to simulate the relative motions at the bow. The thruster is running and the thrust and torque are measured, as well as the water level in the tunnel. Both regular and irregular motions can be applied to the model.

Task 6b.
For the same configuration CFD calculations are carried out. It is noted that the simulation of bow tunnel ventilation will require multi-phase (water / air) CFD modelling. The thruster loading, as well as the water flow in and out of the bow tunnel will be compared.

Deliverables WP2

The deliverables of WP2 are listed below :

- ***Model test reports***
  The model test reports contain the results of the thruster interaction tests from Task 1-6, as well as descriptions of the models, instrumentation, test set-up, test programme, data analysis and a summary discussion of the results.
- ***CFD reports***
  The CFD reports contain the results of the thruster interaction CFD calculations from Task 1-6, as well as descriptions of the calculation input, applied grids, data analysis and a summary discussion of the results.
- ***Full scale measurement report***
  This reports contains the results of the full scale measurements from Task 1 or 3. Furthermore, the report contains descriptions of the test set-up, instrumentation, test programme, data analysis and a summary discussion of the results.
- ***Thruster-interaction data bases***
  The thruster-interaction data from model tests and CFD calculations are stored in a data base format, for use in the DP capability tool, to be developed in WP3.

WP3 - DP Capability and Operational Analysis Tool "OPERA" (MARIN)

In WP3 the thruster-interaction results, available from existing data bases (WP1) and new data from the TRUST JIP model tests and CFD calculations (WP2), are incorporated in a new tool for DP capability and operational analysis, suitable to evaluate stationkeeping performance of DP vessels. The data bases will have an open format, so that JIP participants can also include and apply their own model test or calculation results. Besides DP capability calculations, the tool will have an integrated evaluation of other criteria, such as (relative) motions or accelerations, making it a unique tool for early design calculations, as well as operational evaluations. The DP capability and operational analysis program will be called "OPERA".

Objectives

The objective of WP3 is to develop a DP capability and operational analysis tool. The input and output of the program are summarised below.

Output
The program will generate the following results :

- DP capability plot (traditional)
- DP capability plot, including thruster interaction effects
- DP capability plot, including thruster interaction and estimated dynamic margin
-

The above results are presented together in a single graph, creating a plot with several lines, instead of a single line footprint plot.

Input
The following data are required as input for the calculations :

- Vessel data (main particulars, loading condition)
- Dimensionless wind and current load coefficients
- Hydrodynamic data base file (HYD-file)
- Thruster data (thruster type, dimensions, characteristics, position, forbidden zones)
- Thruster-interaction coefficients
- Environmental data (wind / wave / current properties, wind-wave relation)
- Calculation control settings (number of headings, iteration settings)

The applied calculation methods are described in the following section.

Methodology and Scope of Work

The calculations performed by the DP capability and operational analysis program OPERA are described below. The main strengths of the program are its data base with thruster-interaction effects and the possibility to include user-defined thruster interaction coefficients, e.g. obtained from model tests, enabling more accurate DP capability calculations. In addition, the integrated evaluation of other (motion) criteria enables an operational analysis based on more than just the available thruster capacity.

- ***Mean environmental loads***
  The mean wind and current loads are calculated using dimensionless load coefficients. The mean wave loads are calculated based on quadratic transfer functions (QTFs) for the mean wave drift forces. The QTFs are included in hydrodynamic data base files (HYD-files).
- ***DP capability calculations***
  The program will perform a traditional static DP capability calculation, using the mean environmental and mean thruster loads. For each heading, the maximum wind velocity and associated wave spectrum are determined at which the available thrusters can still counteract the environmental loads. In these calculations the current is assumed constant.
- ***Thruster-interaction effects***
  The program will perform a second static DP capability calculation, taking into account the thruster-interaction effects, which generally lead to a reduction in the generated thrust force. The thruster-interaction coefficients can either be used from the program data base or specified as input by the user.
- ***Dynamic effects***
  In traditional DP capability calculations a fixed margin (e.g. 20%) of the available thrust is applied to account for dynamic behaviour of the vessel caused by variations in the environmental loads. The program OPERA will determine a suitable margin for each individual calculation, based on the specified environmental conditions. The resulting margin may be smaller (e.g. in current dominated cases) or larger (e.g. in wave dominated cases).
- ***Additional operational criteria***
  Besides the DP capability analysis, a number of user-specified operational criteria will be evaluated. These can include e.g. maximum allowable motions, velocities and accelerations, as well as relative motions. The motions, velocities and accelerations are calculated in the frequency domain using motion RAOs. The data necessary to determine the motion RAOs are included in hydrodynamic data base files (HYD-files).

Deliverables WP3

The deliverables of WP3 are listed below :

- ***DP capability and operational analysis tool OPERA***
  The program can carry out DP capability calculations, including thruster-interaction effects. At the same time, the program performs an evaluation of operational criteria related to motions, relative motions and accelerations.
- ***OPERA user manual***
  A user manual is delivered with the program. The manual includes a description of the calculation input and output, as well as a description of the applied mathematical models.

TRUST JIP response form / letter of intent

(deadline 1 December 2009)

Please e-mail or fax to : **MARIN, Hans Cozijn and Bas Buchner**

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Company/organisation : …………………………………………

Contact person : …………………………………………

E-mail address : …………………………………………

Signature : …………………………………………

Please tick:

O We intend to become a TRUST-JIP participant.
However, we have the following comments to proposed scope of work:

O We do not have interest in this JIP, please remove us from the contact list.