Intuitive operation
and pilot training
when using marine
azimuthing
control devices

AZIPILOT

Report Title:

Deliverable 1.7 2.7 3.7 4.7:

Assimilate cross disciplinary knowledge from WPs

Contents

PUBLISHABLE EXECUTIVE SUMMARY

The aim of this report is to present the results of the “Assimilation” exercise of the AZIPILOT project.

The aim of this task is to incorporate summarized knowledge obtained in all 4 project workpackages. The objective is to integrate the obtained information and in doing so reduce any unnecessary rework.

The task has identified any short-comings and limitations by

- integrating knowledge through gap-analysis and task evaluation.
- digesting specific findings from workpackages
- digesting any revelations from cross-disciplinary input.

Concretely, for the four separated workpackages, the outcomes of the four specific tasks of the phase 1 “Review” and the phase 2 “Summarise” have been identified and extracted, and analysed in order to avoid any duplication or contradictions.

This analysis has been completed by the preparation of questionnaires addressing each category of stakeholders.

1 INTRODUCTION

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2 WORKPACKAGE 1 – HYDRODYNAMIC MODELLING

<u>**Task 1.1**</u> has reviewed the hydrodynamic knowledge with respect to the ability to model azimuthing control devices (ACD).

The main conclusions and results are the following:

Result #	***Results***	***Category***
1.1a	List of basic groups of interest List of terminology	Existing knowledge
1.1b	A survey of ships equipped with different types of azimuth propulsion has shown the **expansion on the segment of ships with azimuth propulsion.**	Existing knowledge
1.1c	Despite the existence of several finished European RTD projects related to pods, there are **very few public results** & reports that can be made available to external parties.	Gaps in knowledge
1.1d	**Critical appraisal of the applicability of IMO criteria** like turn circle, yaw checking and stopping manoeuvres to ships with azimuth propulsion.	New knowledge & recommendations

Task 1.2 has reviewed existing modelling & test methods for azimuth devices.

The main conclusions and results are the following

Result #	***Results***	***Category***
1.2	Identification of **existing modelling methods** and the extent to which these methods are valid, foe the following interactions: • Control device to ship hull ; • Among multiple control device; • Podded propeller to pod housing; • Effects on propeller working point; • Off design conditions.	Existing knowledge

Task 1.3 has reviewed the compliance to existing modelling and testing methods for ships equipped with azimuthing control devices with respect to the operations when the ship is in the at-sea condition and when the ship is navigating in harbours.

The main conclusions and results are the following:

Result #	***Results***	***Category***
1.3a	Survey on perceived benefits and negative effects when using azimuthing control devices in the at-sea condition.	Existing knowledge
1.3b	Review of existing modelling and testing methods for azimuthing control devices in the at-sea condition.	Existing knowledge
1.3c	Possibilities for the development of modelling the at-sea condition and model testing techniques.	New knowledge
1.3d	Discussion of the different needs for autopilots at sea condition for azimuth/conventional propulsion	New knowledge
1.3e	**Proposed further investigation**: • Calculation of the sinkage of the ship due to propeller activity, especially with ACD • Bank effect and additional influence of ACD: lack of specific data and modelling concerning ACD • Ship waves and wave impacts: need for more realistic modelling and visualisation	Gaps in knowledge and Recommendations

<u>Task 1.4</u> has reviewed the compliance to existing modelling validation methods for harbour and at-sea condition for ships equipped with ACD's. The objective was to establish the extent to which existing methods are validated for simulation purposes and to identify appropriate sources of validation data.

The main conclusions and results are the following:

Result #	***Results***	***Category***
1.4	Need to **get experimental and full scale data relevant to ACD** for: (1) Response under extreme steering, (2) Manoeuvring in ice, (3) Slamming effect	Gaps in knowledge and Recommendations

<u>Task 1.5</u> has encapsulated knowledge through up to date mathematical model

The main conclusions and results are the following:

Result #	***Results***	***Category***
1.5a	Dedicated mathematical modelling	Existing and new knowledge
1.5b	Needs of **dedicated investigations and measurements** of gap water pressure values and hub axial forces as functions of pod unit velocity and hub rate of revolutions supplemented by respective geometrical data of a pod unit.	Gaps in knowledge and Recommendations

<u>Task 1.6</u> has summarized modelling and testing methods capabilities.

The main conclusions and results are the following:

Result #	***Results***	***Category***
1.6	Gaps and therefore **needs for further investigations** in the following areas: • Details of flows along propulsor body; • Interactions between propulsor main elements; • Scale effect in performance predictions; • Interactions between multiple propulsors.	Gaps in knowledge and Recommendations

3 WORKPACKAGE 2 – MARINE SIMULATION

Task 2.1 has reviewed the existing simulator capabilities for azimuthing control devices.

The main conclusions and results are the following:

Result #	***Results***	***Category***
2.1a	Collection of data, information on full-mission-bridge-simulators and manned models simulators	Existing knowledge
2.1b	Few available data related to technical qualities of the Full-Mission-Bridge-Simulators which are in operation	Existing knowledge
2.1c	Analysis of the interaction effects which are taken into account into simulators	Existing knowledge

Task 2.2 has reviewed existing simulator capabilities with respect to the ability to simulate the most common influencing factors that affect ships when operating in close quarters including environmental effects such as effect of proximity of the shoreline, bank effect, effect of proximity of other ships and other effects experienced by ships equipped with azimuting control devices when manoeuvring in their most typical and critical situations.

The main conclusions and results are the following:

Result #	***Results***	***Category***
2.2a	All questioned simulator centres have capability to simulate shallow water effect.	Existing knowledge
2.2b	**The development of the shallow water effect with decreasing water depth is not always modelled correctly** and therefore further investigations are needed.	Gaps in knowledge and Recommendations
2.2c	**Lack of information/data on tugs operating** near the stern of pod driven ships. Further data should be collected.	Gaps in knowledge and recommendations

<u>Task 2.3</u> has reviewed existing simulator capabilities with respect to the ability to simulate the interaction between azimuthing control devices.

The main conclusions and results are the following:

Result #	***Results***	***Category***
2.3a	Most existing simulator modules for podded propulsive drives do take into account propeller thrust, transverse propeller forces, and lift and drag forces on the pod body. They also adequately model the interaction effects between different pod units, and shallow water effects on podded vessels. Interaction between two or more podded propulsors is important and it may affect the manoeuvring characteristics of a vessel in certain modes of control. When using large manned models for training this effect is automatically taken into account.	Existing knowledge
2.3b	The **installation of skegs and fins** improves dynamic stability, however at the same time making the turning ability characteristics slightly worse. **How this effect is taken into account in mathematical models is uncertain**, but some data from experiments with ship model tested without skegs or fins, and models tested with skegs or fins of different sizes installed are available and may be used.	Existing knowledge, gaps in knowledge and recommendations
2.3c	**Lack of data on wake and form coefficients for ships with podded propulsors**. Further investigation might be needed.	Gaps in knowledge and recommendations

<u>Task 2.4</u> has explored the use of existing bridge systems and review their relevance when operating ships equipped with azimuthing control devices.

The main conclusions and results are the following:

Result #	***Results***	***Category***
2.4a	**Official standardisation for operating systems must be consulted along with consultation of experienced users.** This should then be supported by educating and training at the very least by simulator training and, if possible, supplemented by onsite training.	Recommendations

2.4b	**ISO 13407 Human Centred Design Process for Interactive Systems** should be referenced.	Recommendations
2.4c	**Consultation with user experts** is an absolute requirement even though standardized elements have been identified and documents.	Recommendations
2.4d	The ASD system usage will become more widespread in the future, thus **education and training is a necessity.**	Recommendations
2.4e	Aside from the more academic factor of the positioning of bridge equipment, field of viewing is sometimes overlooked and requires attention. It is easy for the master while manoeuvring to find him/herself in a cognitive overload situation due to the fact that two levers must be used simultaneously and possibly in very different configurations. Again, **education and training in this area not only by simulation but also on-site** would be a great advantage, if not a necessity.	Recommendations
2.4f	The resultant thrust component is often difficult for the user to calculate/comprehend during operations. If a specific arrangement of thrusters is selected, this can present problems if the Conn is now changed to the bridge wing position. The joystick position on the bridge-wing (not yet connected) may not mimic the arrangement originally selected from the central conning position. This **may result in confusion or even in accidents.** When, and if, the Conn position is changed to the bridge wing the necessary information for manoeuvring must also be available. Tugs often change the Conn position from central looking forward to central looking aft. This is also an opportunity for **confusion for the user.** Further investigations are needed	Existing knowledge and recommendations

2.4e	Concerning the ergonomics of control systems, existing products differ in great extend from each other and are rather representing the individual view of the manufacturer than based on a general philosophy regarding implementation of relevant ergonomic rules. Each observed system has in one way or another a less optimal element in the design or layout of the ACD control components. For the future **more work has to be done to get more harmonized and optimal designed ACD control systems fully fit for the use by the ship handler in various manoeuvring circumstances**.	Existing knowledge and recommendations

<u>Task 2.5</u> has provided guidelines for the selection of appropriate controls for different types of azimuthing devices and provided guidance on their use.

The main conclusions and results are the following:

Result #	***Results***	***Category***
2.5a	For the future **more work has to be done to produce more harmonized and optimal designed ACD control systems** fully fit for use by the ship handlers in various manoeuvring circumstances.	Recommendations
2.5b	Official standardization for operating systems should be consulted further as well as further **consultation of experienced users** in order to come to a standardized bridge layout for ACD's.	Recommendations
2.5c	Use of ACD's and standardized bridge layout should be **supported by educating and training at the very least by simulator training and, if possible, supplemented by on-site training.**	Recommendations

Task 2.6 has summed-up existing Marine Simulator capabilities with respect to their capabilities regarding azimuthing devices and their application and including their validation and limitations.

The main conclusions and results are the following:

Result #	***Results***	***Category***
2.6a	In the range of small and moderate pods angles **modern simulators capture pods interactions with great realism**.	Existing knowledge
2.6b	Azipod Modeling and Simulations **for large pods angles** will require the comprehensive CFD computations combined with the specialized model and full-scale trial testing.	Gaps in knowledge and Recommendations
2.6c	Hydrodynamic Interaction of the **multiple pods** also requires the additional research efforts (including CFD) and validation test data.	Gaps in knowledge and Recommendations

4 WORKPACKAGE 3 – MARITIME TRAINING

Task 3.1 has reviewed training needs and requirements specifically for ships equipped with azimuthing control devices.

The main conclusions and results are the following:

Result #	***Results***	***Category***
3.1a	Review of training available for ACD’s using Full-Mission-Bridge-Simulation Methods, desktop Simulation Methods and Manned Model techniques	Existing knowledge
3.1b	Needs of **collaboration with ship owners** for training	Recommendations
3.1c	Importance of **universally accepted specific terminology and definitions**	Recommendations
3.1d	Need for **accurate models of the particular vessel** that is to be handled.	Gaps in knowledge and Recommendations

Task 3.2 has reviewed the existing training facilities and training programs and to evaluate both capacity and limitations respectively.

The main conclusions and results are the following:

Result #	***Results***	***Category***
3.2a	**Obvious need for specialized training of pilots and ship masters**, including tug masters for ships equipped with azimuthing propulsion devices. This could be accomplished either in Full Mission Bridge Simulators or Manned Models Simulators, with different training goals	Recommendations
3.2b	Limitations to the training programmes on FMBS and on MMS.	Existing knowledge
3.2c	Proposition of **sample template for specialized training courses** for ships fitted with azimuthing control devices.	Recommendations

Task 3.3 has reviewed the human physical and behavioural components by assessing the appropriateness of current techniques and providing feedback for new, more appropriate methods.

The main conclusions and results are the following:

Result #	***Results***	***Category***
3.3a	Task analysis: analysis of the various types of ship handling situations during the various phases of a voyage. Each handling situation examines the tasks required with respect to ACD handling on behalf of the navigator.	New knowledge
3.3b	Analysis of available **workload and fatigue** studies on board of sea going vessels.	Existing and new knowledge
3.3c	Review on the impact of **high-stress situations** on intuitive control.	Existing knowledge
3.3d	**More research is needed regarding stress influence on intuitive control.**	Gaps in knowledge and Recommendations
3.3e	**More research is needed regarding perceptions of azimuthing control devices by new and young personnel.**	Gaps in knowledge and Recommendations

3.3f	Continued development of the **visual accessibility, sound quality and actual physical movement** of/in the simulator should be considered when designing simulators for ASD tugs (the same goes for “ordinary” simulators).	Recommendations
3.3g	Certain **pedagogical methods** should be considered when designing the bridge layout.	Recommendations
3.3h	**Training onboard or in simulator before handling ACD´s** in real life should be thoroughly considered.	Recommendations

Task 3.4 has reviewed bridge systems and the human interface.

The main conclusions and results are the following:

Result #	***Results***	***Category***
3.4a	Need for development **simplified standardized explanation of operation,** such as a pilot manoeuvring card.	Recommendations
3.4b	Individuals should be **trained on human resource management** to help integrate into the bridge team and thereby create an optimal working environment.	Recommendations
3.4c	This is a clear opportunity for the **bridge resource management skills (BRM) to be exercised**, not only in normal operations but also in emergency situations. This should be seen as a necessity in order to minimize the inherent risks.	Recommendations

Task 3.5 has formulated and defined the methodology and design of new training programmes.

The main conclusions and results are the following:

Result #	***Results***	***Category***
3.5a	Proposition of model training programme on azipods driven ship for masters or pilots for full mission bridge simulators.	Recommendations
3.5b	Proposition of model training programme for ship masters and pilots on azipods driven ship for manned models simulators	Recommendations

3.5c	Proposition of model training programme for azimuth ASD and tractor tug masters and for escorting operations (FMBS and MMS)	Recommendations

Task 3.6 has summed-up existing Maritime Training capabilities with respect to their capabilities regarding ACS and their application and including their validation and limitations.

The main conclusions and results are the following:

Result #	***Results***	***Category***
3.6	Identification of basic training / specific requirement training (harbour/model/tugs)	Recommendations

5 WORKPACKAGE 4 – OPERATIONAL PRACTICE

Task 4.1 has reviewed existing manoeuvring recommendations and criteria and the compliance to existing recommendations and criteria specifically for ships equipped with azimuthing control devices.
The main conclusions and results are the following:

Result #	***Results***	***Category***
4.1a	**The IMO manoeuvring criteria are argued to provide a perfectly acceptable operational envelope;** within which all ships should perform. In addition, published results indicate that the application of the criteria to pod-driven ships should yield equitant results as for conventional ships.	Existing and new knowledge
4.1b	Manoeuvres not described by IMO are often preferred in practice.	Existing knowledge
4.1c	Neither SOLAS nor STCW contain items specific to ACD's.	Existing knowledge
4.1d	Concerning **manoeuvring information provided onboard ships**, their validity should be examined more deeply.	Gaps in knowledge and Recommendations

Task 4.2 has reviewed the piloting process within the context of ship manoeuvring performance design.

The main conclusions and results are the following:

Result #	***Results***	***Category***
4.2a	Pilot survey	New knowledge
4.2b	**Need to increase the sensitivity of the pilotage organizations and also of the shipping companies** with ships equipped with these propulsion systems, about the provision of training courses to their pilots (officers) in order to use azipods in the most effective way in all different kind of situations they could have to afford and to be sufficiently trained to avoid errors and incidents.	Recommendations

Task 4.3 has reviewed accident and incident reports; for ships equipped with azimuthing control devices and specifically for their operation.

The main conclusions and results are the following:

Result #	***Results***	***Category***
4.3a	Review of accident and incident reports for ships equipped with azimuthing control devices and specifically for their operation.	New knowledge
4.3b	Manoeuvring error and transfer of control issues are relevant in 60% of the incidents.	New knowledge
4.3c	Recommendations from accident/incident reports: • **Further training and familiarization** • **Improved onboard procedures** • **Improvement in equipment knowledge for the ships officers.**	Recommendations

Task 4.4 has reviewed bridge operational practice and the human interface; specifically within the context of ships equipped with azimuthing control devices.

The main conclusions and results are the following:

Result #	***Results***	***Category***
4.4a	**Suggested improvement of bridge interface:** Hardware (control handles) should be configured so that they can only be turned at the same rate as the pods can be moved.	Recommendations

4.4b	**Suggested improvement of bridge interface:** The consoles could be equipped with an alarm system (visual or acoustic) so that the operator could be supported during manoeuvres, being continuously aware of the situation and warned in time if something is going bad.	Recommendations
4.4c	There should be an agreement among all manufacturers of ACDs in a view **to standardize their equipments in terms of tools available, labels, wording used, etc.** In that way, operators could be familiar to the systems whatever ship they sail and risks of errors connected to misunderstanding could drastically be reduced.	Recommendations

<u>Task 4.5</u> has identified operational practice for pilots of ships equipped with azimuthing control devices; both in normal and emergency situations. Typical manoeuvres both in normal and emergency scenarios with a podded manned model has been carried in a manned training center

The main conclusions and results are the following:

Result #	***Results***	***Category***
4.5a	For turning circles: • The effect of twin pods on the turning diameter is similar to that of a rudder with twice the angle; • In case of failure of one pod, the turning diameter is less affected when the outside pod is still working.	New knowledge
4.5b	For crash stops: • The shortest stop is obtained when turning both pods 180° inboard at full positive rpm (the so-called "Pod way stop"); • Turning both pods 180° outboard is slightly less efficient and increases mechanical stresses; • The "Transverse Arrest stop" (turning both pods 90° inboard) is even less efficient and increases mechanical stresses; • Other crash stop scenarios are inferior to the ones mentioned above, except for the Turning Stop, which can be used if sufficient lateral area is available.	New knowledge
4.5c	**Suggestions to further use these actual results in in mathematical and physical modelling.**	Recommendations

Task 4.6 has summarized operational best-practice and limitations for pilots of ships equipped with azimuthing control devices; in both normal and emergency situations.

The main conclusions and results are the following:

Result #	***Results***	***Category***
4.6a	Existing manufacturers' guidelines and ship operators' guidelines on how pods should be operated.	Existing knowledge
4.6b	Identification of the most suitable ship handling procedures to validate operational best practice and the limitations of each manoeuvre.	Existing knowledge
4.6c	Authorities responsible for the provision of Pilotage services and Ship owners/operators should ensure that **personnel operating ACD units receive a through and comprehensive understanding of the theory behind the operation of such units** and be trained in their efficient and effective use to ensure the safety and security of life and property.	Recommendations

3 QUESTIONNAIRES

Questionnaires targeting the basic groups of interest of the project have been designed as an information gathering exercise that aims to assess the state-of-the-industry, with the objective of identifying the most advantageous routes forward.
Nine categories have been identified:

Q1 – Classification societies
Q2 – Maritime authorities
Q3 – Pilot organisations
Q4 – Unions
Q5 – Ship owners and operators
Q6 – Producers / manufacturers of ACD
Q7 – Insurance companies
Q8 – Simulation training centres
Q9 – Simulator manufacturers

While the project consortium did send many questionnaires through the partners' network, as well as via the AZIPILOT workshop organised in February 2010 in Rotterdam, we did not receive enough responses to meaningfully analyse.

Other more targeted questionnaires have been developed for specific project tasks, and their results are reported in the associated task reports.