# Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

**Report Title:**

## Deliverable 3.6:

## Summarise training capabilities and needs

# Contents

**Publishable Executive Summary**

The aim of this task is to sum-up existing Maritime Training capabilities with respect to their capabilities regarding Azimuthing control devices and their application and including their validation and limitations.

The task focused on:

Condense knowledge on existing Maritime Training capacity for ships equipped with Azimuthing control devices.

Condense knowledge on existing Maritime Training capacity for specific situations including inter-ship and shallow water effects, harbour specific issues and tug operations.

The task is culminated in task reports that delineates the above aims and objectives and constitute one deliverable.

## *1.* Introduction

The Azipod devices have existed for a long time but this type of propulsion is still not very popular. There are app. 7% vessels fitted with azimuthing propulsion. There are some factors with limited common knowledge about these devices but one of the main factors is that Azimuthing Control Devices are mostly used on cruise liners, off-shore vessels and tugs - the largest group. According to the research carried by our partners (Rees,2010) the findings are:

- 8044 pilots questioned on ACD training 100%
- 2334 responded (96% using azipods)
- 736 (32%) received some ACD training 9%
- a few received some instruction from manufacturers
- others received no ACD training at all.

The outcome is alarming: only 1 in 11 pilots are trained to pilot Azimuthing Control Device vessel.

The main training bodies and authorities such as Merchant Navy Training Board and Marine Coastguar Agency did not set any particular requirements such as a special needs for training using Azimuthing Control Devices. Although the training should help both mariners at sea and professional pilots it should comply with the requirements under STCW95 for handling vessels particularly ships ‘having unusual manoeuvring and handling characteristics’. Citation confirms that it is a very broadening definition and if ACD is fulfilling this definition or not – it is not answered.

Present research confirms that a lot of Simulation Training Centres for more than 10 years have provided training using Azimuthing Control Device. Most training centres use Full Mission Bridges. Also some limited training is provided by using stand-alone PC.

There are two big Manned Model centres in Port Revel (France) and Iława (Poland) providing Manned Model Ship-handling courses based on ACD equipped ship’s models.
As construction features, manoeuvring and handling characteristics of ships driven by Azimuthing propulsion units differ considerably from vessels with conventional propulsion and also their modes of operation are widely different, there is obviously a

need for specialized training courses. This was discussed in Task 3.2 Chapter 6.1 (Kobyliński, 2011).
The opinion of the majority of pilots who expressed their views such training is really necessary, and many of them were of the opinion that 5 days simulator courses on Azimuthing Control Device driven ships are the best solution.

Bearing this in mind, and taking into account that there are two types of simulators used at present for training, namely Full Mission Bridge Simulators (FMBS) and Manned Ship Models Simulators (MMS); two different training model programmes for (prospective) ship masters and pilots are proposed to be used in these simulators. On top of that, because recently in many parts of the world large ships carrying dangerous goods are required to be escorted by escort tugs equipped with Azimuthing propulsion devices and these operations require great skill in operating tugs and good co-operation with the tug master(s) and ship master or pilot, there is a need for specialized courses on escorting operations. Such model programme is also proposed.

## *2.* Legal Aspects of Maritime Training.

General requirements for Marine Training for ship handling were discussed in the report on Task 3.1 (de Grauaw 2010). Also in this report reference was made to the requirements of the IMO STCW Convention.

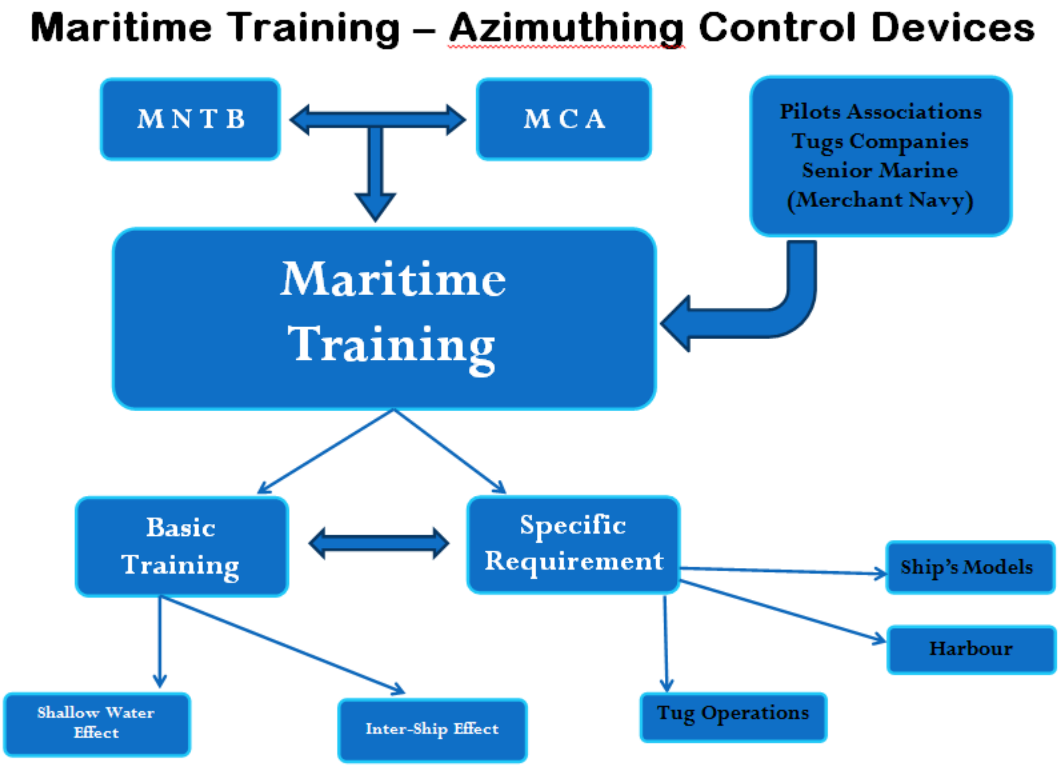
Maritime and Coastguard Agency is committed to preventing loss of life, continuously improving maritime safety, and protecting the marine environment: Safer Lives, Safer Ships, and Cleaner Seas. To work at sea, you must have the relevant qualification, training and expertise to perform your job. The Merchant Shipping (Training and Certification) Regulations 1997 set out minimum requirements for the training and certification of seafarers, and place a duty on employers to ensure these requirements are met.

MCA closely cooperate with Merchant Navy Training Board. The MNTB has responsibility for setting and approving the education and training frameworks. Each framework has been designed to meet international regulations laid down by the International Maritime Organisation (IMO) and enshrined in the Convention on Standards of Training, Certification and Watch-keeping for Seafarers (STCW). As well as the international regulations, the frameworks are underpinned by, and referenced to, the industry's National Occupational Standards.

At the moment MNTB and MCA do not set any formal requirements for ships equipped with Azimuthing Control Devices. Fortunately, the owners of the ships with ACD are providing training for staff using own Simulators (Tug Training) or cooperate very successfully with Marine Simulator Centres (Pilots, Senior Mariners, tug Captains). There is a wide spectrum of training from PC-based simulators up to Full-Mission-Bridge Simulators; and Manned Ship Models.

Training, education and experience help in decision making especially in complex dynamic situations. The Mariners gain practice which leads to more safer ship-handling in different weather conditions and specific port environments.

The overview of Maritime Training using Azimuthing Control Devices is displayed in the Flow Diagram below. This can apply to both: Full Mission Bridge Simulator and Manned Ship's Models.



### *3.* Simulation – Full Mission Bridges

Training using Marine Simulators is proven to be relatively in-expensive and very successful in types of training available to all Mariners.

Discussion of the technical qualities of simulators, taking into account which ship types they can handle, which types of maneuvers that can be simulated and if they can handle shallow water effect is discussed in WP 3.2 chapter 6 and 7.

It is well known that manoeuvring characteristics of Azimuthing propelled vessels are different from the vessels with conventional propellers. It is obvious that because of the widely different manoeuvring characteristics of ACD driven vessels it is the necessity to arrange special training courses for ACD driven ships.

Three main manoeuvring qualities are considered:

- Turning ability
- Course keeping ability
- Stopping ability.

### 4.1 Training in over/under loaded working conditions

The Maritime Training using ACD should start with training in over/under loaded working conditions. Review of these conditions was discussed in WP 3.3 chapter 3.3.3 - 3.3.7. In this part psychological elements and Bridge Team Management Training (MCA approved course) should be taken into consideration. There are some implications based on working environment and human processing system. The Mariner should be aware of these implications by theory and specially designed simulation exercises.
Maneuvering the ship with ACD very often creates high-stress situations. The basics of “intuitive control” should be provided prior to simulator exercises. This will lead to understanding of judgment and decision making under high stress – reviewed in WP3.3 chapter 3.3.3.

There are two main domains in ACD training:

- Basic training
- Specific requirement training.

This mixture of training elements depends on client requirements.

### 4.2 Basic training

Basic training with ACD should take into consideration steering and alteration of courses using Azimuthing Control Devices in combination with/without rudder. The other concern, very important for safety of the vessel, is to practice crash stop and steering the ship at the low speed. The exercises should be designed to practice all maneuvering aspects of the ship. The next step should be practicing mooring, side stepping, reverse rpm's etc. with extension to maneuvering the ship in ice.
The other considerations taken into account with effects of:

- Propeller momentum
- Diagonal propeller force
- Effort of forces of the AziPod
- Interactions between other AziPod unit(s)
- Interaction effects between AziPod and ship's body (hull)
- Shallow water effect
- Lift and drag forces of the AziPod.

The most shared influencing reasons that affect ships when operating in close quarters are:

- **Shallow water effect/Bank effect**
- **Ship-to ship interactions**
- Surface and submerged channel effects
- Steering with Azimuthing control devices when towing
- Steering with Azimuthing control devices when under tow
- Assisted braking including the indirect mode
- Tugs operating near the stern of AziPod driven ship.

Elements of proposed scenario for basic training can be used in Specific Training to enhance ship-handling procedures for Mariners who have already received ACD training. More details in WP 3.1, WP3.2, WP 3.5.

### Shallow Water Effect.

When the ship is sailing in shallow water or a canal with proximity of sea floor **then its resistance is rapidly increasing with increasing speed reaching local maximum at speed roughly corresponding to the critical speed**

Effects of shallow waters or channels:

- Increase of the ship resistance, causing reduction of ship's speed
- Changes of the ship trim,
- **Reduction** of Under Keel Clearance due to **squat,**
- Changes of the manoeuvring characteristics.

Influencing parameters:

- Depth of water,
- Depth of the water to draft of the ship ratio,
- Form of the hull,
- Speed of the ship,
- Hydraulic radius or blockage coefficient of the canal.

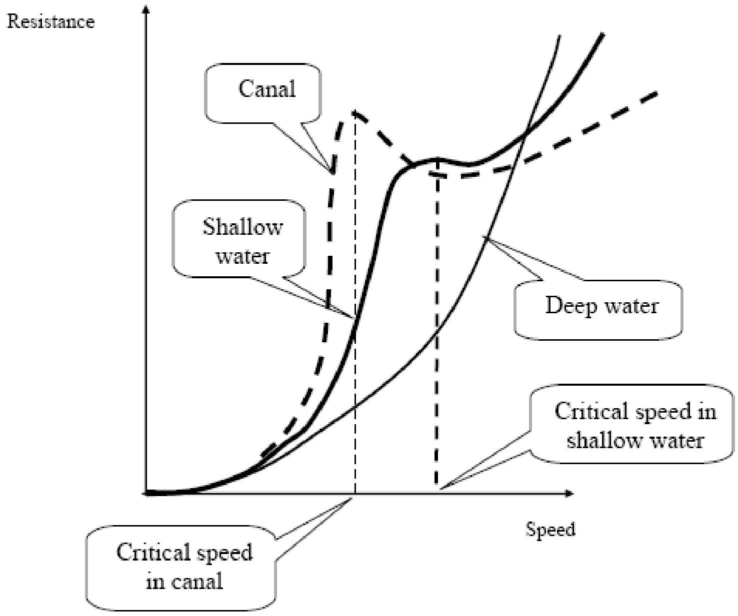



**Fig.2. Resistance curve in deep and shallow water and in the canal**

Usually the sea-going ships could not sail faster than about 60 to 70 % of the critical speed. Only high-powered small ships can reach the critical speed and exceed it.

### Bank, surface and submerged channel effects.

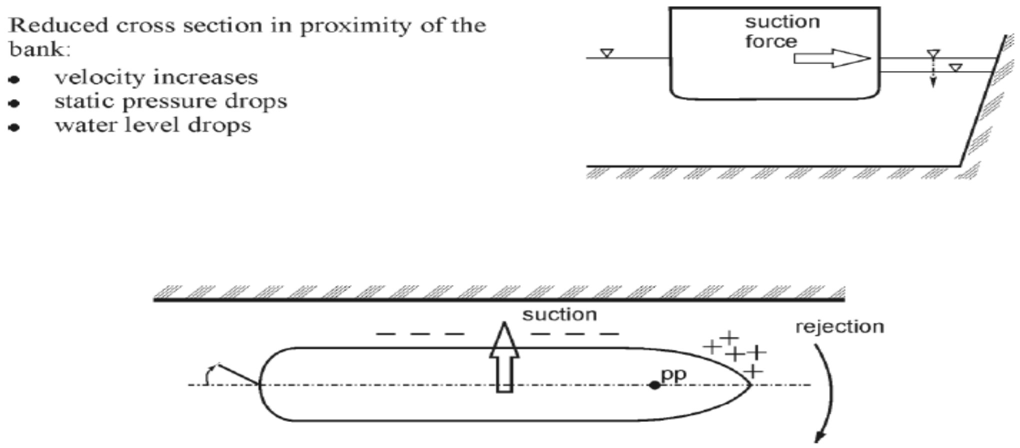



**Fig. 4. Effect of proximity of the bank**

Suction force draws the ship closer to the bank. (Marielle Labrosse, Mettle)

### 4.3 Specific requirement training

It is necessary to stress that experience in conducting training courses shows need for flexibility in arranging course programmes because in many cases programmes should be tailored to meet the particular requirements of the Pilots organizations and ship owners and tug companies. The specific requirement training is very popular and provides training on demand. Usually Senior Mariners, Pilots and Tug Captains come back to marine simulators to improve their abilities in maneuvering ACD ships and to keep up-to-date training with any changes in harbour environment or different ship's models or ACD control handles.

The training can be divided into three groups:

- **Harbours**
- **Model**
- **Tugs Operations**

#### 4.3.1 Harbours

Most of **simulation** comes from Port Authorities to assess Risk Management in case of special events. Appendix 1 presents example of this kind of Simulation, using a ship equipped with Azimuthing Control Devices. Very often Port Authorities would like to find port requirements to minimise damage to ageing infrastructure when using ACD. The other big part is to assess port requirements for Towage.

The live disscussion was carried out in Rotterdam during STC Conference about harbours envinronment during heavy weather together with usage of ACD. Prior to inviting the big ships with ACD to be berth in the harbour the Risk Assesment should be caried out to assest all the safety and economical issues.

The other areas of specific training could be expanded to the specific confined waters, busy anchor areas, narrow channels and short track ferry routes.

### 4.3.2 Models

In the Full Mission Bridge Simulators mathematical models of ships are used. There is a mathematical model of ship motion which represents proper motion of the real ship. There is the geographical data-base with the proximity of other objects (bank, shallow water effects and the effect of other ships), harbours and all required areas to practice ship-handling. The bank effects are still not being investigated sufficiently enough. Sophisticated computer programs that include calculations of hydrodynamic coefficients, use advanced methods requiring powerful computers and extremely large memory. Full Mission Bridge Simulators use simplified methods of model coding which is close enough to fulfill the purpose of training.

All modern FMBS are able to simulate proper maneuvering and ship handling characteristics in open water. Usually they are also capable of simulating the close proximity effects based on simplified theory.

### 4.3.3 Tugs Operations

Escort operations performed over long distances and relatively high speeds require escort tugs. All escort tugs tend to have Azimuthing propulsion units. The main advantage of escort tugs is the possibility to quickly develop high steering and braking forces to a ship when needed.
Steering forces can be developed at high speeds exceeding 10 knots. In this case tugs are working in the indirect mode (less than 6 knots direct forces are greater than indirect forces) (WP 3.5 chapter 1.2 and 1.3, Kobyliński 2010).

The other review connected to handling tugs equipped with Azimuthing devices was carried out by BSM in task 3.4.The interview with tug captain was presented and analysed according to steering the ASD tug, perception of automation of ASD tug handling with recommendations to task 3.4, chapter 2.4.

The conclusion revealed the fact that the automation feature on the ASD tugs is an autopilot. The autopilot is only a very simple automated system that can’t “handle” the tug as efficiently as manual handling. It can adjust azimuth propeller angle (or azimuth) in order to maintain present course (sailing direction) sets by the navigator. It can therefore be used for “steering” the tug but not handling the tug. It is an important and widely used feature for the long “legs” on a voyage and in navigation and situations where the tug is just another “normal” vessel. But it is not often used during any tug work, especially not if the tug is connected to (or in physical contact with) the vessel it assists. Furthermore automation of certain sub task of ASD tug handling is welcomed by the professionals but it must prove safer and more reliable than the known systems already available.

### 4.4 Conclusions base on Simulators.

Marine safety is always a top priority, and Simulator training allows Pilots, Tug Captains and Senior Mariners to practise manouvering techniques in a safe but realistic envinronment. Hydrodynamic effects have been carefully ivestigated in our project in WP 1. The magnitude of the effects is sometimes different but the expectations based on hydrodynamic theory are mostly satisfied. Unfortunately in some cases the development of the shallow water effect with decreasing water depth is not always modelled corectly.

Sometimes it is difficoult to collect precise model details because some companies are not sharing these informations. The ship-to-ship interaction effect shows reasonable development with the passing distance but some results are confusing during the time of the maneuvering.

The human factor methods prove useful to obtain data of task, environments and users on ASD tugs and in an ASD tug state-of-the-art simulator. ASD tug work can be defined as an over/under load environment and this can bring different challenges to the human processing system. Simulation of ASD tug maneuvering goes to the limit of human capability. Maritime training is needed for the experienced as well as the inexperienced mariner.

Gronarz (2010) investigated capabilities of four advanced FMBS to simulate ship-ship interaction, shallow water and bank effect. The conclusions of this investigation are:

- The magnitude of the effects is sometimes very different.
- The expectations from theory are mostly satisfied.
- The development of the shallow water effect with decreasing water depth is not always correctly simulated.
- The ship-ship-interaction effect shows reasonable development with the passing distance but some doubtful results during the time of the maneuver.

### *4.* **Manned Ship's Models Centres**

Information and feedback collected from:

Port Revel Ship-handling (France)

Ilawa Ship-Handling Research and Training Centre (Poland).

Manned Ship's Models use large models for training purposes in specially prepared lakes. The areas are designed as mock-ups of ports and harbours, locks, canals, bridges, piers and quays. Shallow water areas and other facilities are constructed and routes marked by leading marks or lights (for night exercises). Also in certain areas current and wind is generated. A monitoring system allows observation of track of the models. All areas are laid out in the same reduced scale as the models.

As there are basically two types of simulators in use that differ in many respects: Full Mission Bridges mock-up and working in real time, and Manned Ship Models working in model time in natural environment the objectives of courses and programme of practical exercises arranged on those simulators are different and geared to the characteristics and capabilities of those simulators. The main difference is that FMBS are working in real time where MMS are working in model time that is accelerated usually about five times in comparison with real time. The result is that in MMS it is possible to arrange during five days course about five times more practical manoeuvring exercises. Another important difference is that in FMBS there is mock-up of the bridge, usual with several additional consoles enabling to arrange team work, whether in MMS, there is no such arrangement and the model is controlled by one master/pilot eventually with the help of instructor and having at his disposal tug simulators or models of tugs either manned or remotely controlled.

Models are constructed according to laws of similarity, usually in scale 1:24 or 1:25. The purpose is to accommodate 2- 4 people (trainees and instructor). Models are controlled by the helmsman and are maneuvered by trainees.

Important feature of manned model exercises is that all maneuvers are performed not in real time, but in model time. This may pose some difficulties for trainees at the beginning who must adjust to the accelerated time scale. (Kobyliński, WP 3.5 chapter 1.5.3 and 2.3)

Both types of simulators have also some shortcomings. De Graauw (2010) points out that in FMBS when the model for a ship has to be developed for use in the simulator, extremely detailed information is needed about real vessel including all hydrodynamic coefficients needed in manoeuvring mathematical model equations and together with many operational data on rudder, engine and other characteristics. This information is usually exceedingly difficult to obtain, due to the fact that it is confidential or not available at all, because hydrodynamic coefficients may be obtained only by specially arranged model tests in towing tanks (planar motion mechanism). After the model has been developed with the information that is available, it is then rigorously tested and adjusted. This modification is not usually how the mathematical algorithms in the software are intended or designed to be used, leading occasionally to unexpected results

In MMS in order to simulate different ship, new model must be built that requires large investment and this, quite often, is impracticable. However, data on hydrodynamic coefficients are not needed in this case, although other data on engine and rudder characteristics and operational data are still necessary.

The model courses developed go beyond what is available today, but they take into account present and possibly in the near future capabilities of both types of simulators and also possible needs and requirements of Maritime Authorities, ship owner companies and other institutions as well as wishes of prospective participants that could be realistically met.

The scope and programmes of model courses that are proposed are intended to be 5 days courses with 40 to 52 hours of lectures and practical exercises. MMS courses may include few hours night training upon request.

## *5.* Training on the ship – based on interviews from Captains.

### 5.1 Gaining confidence

The best way to train mariners in manoeuvring is to perform training on board – on job training. This type of experience is acheived by using azipod devices on the vessels equiped with ACD (when you join the ship). It is the best training but sometimes might be very expensive if a proper manouvering scenario is not followed. Also if the tainer is not skilled then bad habits and poor operastional practice will be passed on. Mistakes can cost a lot of money to repair the damage causing by unexperienced practitioners.

### 5.2 Interview - Independence of the Seas

The Azipod M21 meeting was held on Independene of the Seas. During the meeting Captain Teo Stazicic openly answered all question from Azipod partners. Some questions have been related to training which the Captain received prior to managing the ships with Azipod Control Device. The answers are taken from video-recording during the interview.

*"First of all you will not try to train yourself on a 900 million dollar ship so we have to rely on experience of the people around us*"

*" I went to the simulator, 7 days I was actually intensively trained. After that I went for a week on a sister-ship and actually maneuvered the ship. And then I came here (Independence of the Seas) but in my mind, once you take a ship you need at least one week. I am confident from day one but I cannot take the maximum out of the ship"*.

What did the Captain think about training before and after the training and how did the training reflect his experience with his present ship :

*"It was absolutely necessary for me to go for training. ... It helped me. I* trained on *(did actually) the port I was going to on the simulator, all the Caribbean ports, Southampton etc. ....This is what you do in the simulator. It gave me the chance to get used to the controls, time to look for them without being afraid to lose* control *the ship. My whole point of being up there is to be aware of the complete situation. ..... So you have your experience by being familiar with all of* the controls *(these handles) and things because when you start manoueuvring you don't look at them, your hands are actually doing half of the job themselves*"

"*Do I feel I gained something from the simulator? I was getting compatibile with the azipods. Learning while docking. Seven days was more than enough together with my previous experience with conventional ships*."

Do you need further training later on:

"*I don't think so. Only if there is new type of ship that is dramatically different. Now I don't think I need training for the same class of ship, even if it has stronger pods. I don't need training for Freedom Class ship because they are the same..... What I* *would like to have is training for Oasis of the Seas (Allure of the Seas) class because ship is different, she is wider."*

Question from Pilot related to passing experience to junior pilots.

"*That would be good. When I was training there were other people who actually had experience. And they let me handle much more because they already had experience. We were together on that course so I was being supported by them and got their feedback*".

Captain opinion of manned ship models:

*"I think it is a very good idea. I have not been myself but it is obviously much better then sitting in a classroom."*

The interview with Captain Teo concluded that the best practise is to watch skilled mariners but this is very tiresome and a time consuming process. In addition to training on board ships there should be also simulator training.

However some ship handling critical scenarios might never occur during time on board so this way the question - how to deal with critical situations - will be not answered. In normal ships we try to avoid critical states as far as possible.

For the reasons above the simulator exercises should be properly designed to achieve all aspects of planned scenarios and to gain experience in the safety of ship handling.

## *6.* Limitations in respect of control of AZIPODS

Azimuthing propellers of the type Voith-Schneider propellers, Schottel propellers or conventional outboard motors having limited power (usually not more than 1MW) are known and operated for many years and their operational limitations are well known. It is different for innovative azipod propulsion units, where electric motor is situated in the underwater housing and the power may be as high as 25MW. Main suppliers are Rolls Royce Kamewa/Alstrom, Finland ABB Industry, Siemens-Schottel, and STN Atlas Marine/ John Crane-Lips.

Experience with operation of these high power azipod units, mainly in cruise liners, did reveal some difficulties from the structural point of view, the critical issues being seals and bearings the result might be leakage, insufficient lubrication etc. This is the result of very high forces created at azipod housing when the unit is rotated to large angles at high speed. Those forces may be to large the housing could withstand. Because of this and bearing in mind several accidents where some damage to the azipods happened, manufacturers imposed some limitations with regard to the operation of azipod driven ships. Those limitations may be different for different manufacturers but general recommendations of manufacturers are summarize well by Rees (2010). They are as follows:

- Operate pods as gently as possible
- Avoid reverse power (reverse rpm) Maintain positive rpm
- Crash stop to be avoided
- Avoid wash onto another pod
- Avoid applying large angles of rotation Maintain minimum revolutions
- Avoid large differences between rpm and ship speed
- Avoid unpowered rotation at low speed. (WP 3.2 chapter 7)

## *7.* Conclusion

Along with other causes of accidents at sea, casualties related to maneuverability happen quite often and analysis of casualties shows that CRG casualties (Collisions-Ramming-Groundings) constitute about 53% of all serious accidents leading to ship loss (Payer 1994). As about two thirds of all CRG casualties are caused by human error it is necessary to analyses factors which contribute to the efficiency of the operator. Avoiding causalities and preventing loss of life at sea are the most important goals and theses factors should be included in marine training (Balcer and Kobyliński 1997). Aims and objectives in all aspects of marine training should be based on knowledge and experience.

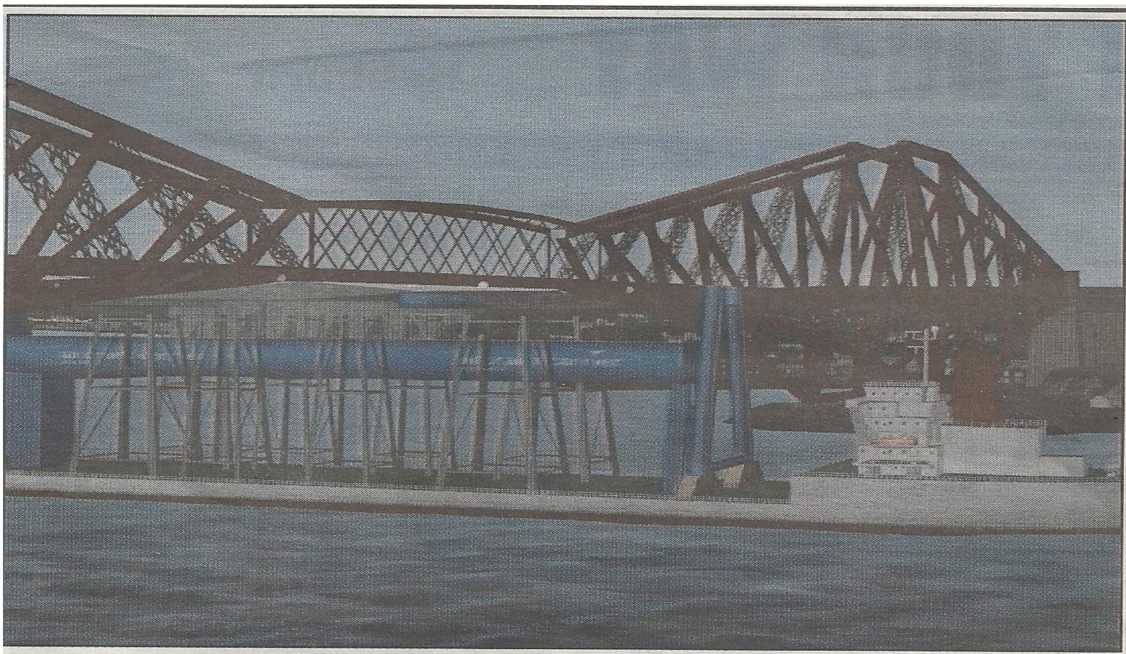
An important feature that is seriously affected by training is the way of handling a critical situation. A mishap is differentiated into three psychological stages: Action is planned and executed and the system is returned to normal operating status if the action is taken in time, otherwise system fails.

Azipod propulsion is a specialised type of propulsion. Review of basic construction and, operational features of ships fitted with Azimuthing propulsion units as well as their manoeuvring and handling characteristics shows that those features are substantially different from ships equipped with conventional propulsion units. Safe operation of ships equipped with Azimuthing propulsion units requires comprehensive acquaintance with this type of propulsion and its specific handling features.

Great number of pilots and ship masters interviewed expressed the opinion that there is the need for arranging special training courses on ships equipped with Azimuthing Control Devices, in particular in order to enhance knowledge and skill in handling ships in a safe and intuitive manner with Azimuthing propulsion devices in varying critical situations. This is necessary in order to improve safety at sea and when close to berth.

The existing problems related to structural loads are not well covered in the accident and incident reports. That indicates that these problems are important to highlight.
This is mostly related to the large Azimuthing Control Devices where predictions of loads are difficult.

## 8. APPENDIX.



ROOM WITH A VIEW ... images the simulator created to make sure the Goliath crane passed safely under bridges on the Forth.

# GOLIATH TASK FOR EXPERTS

## College helps guide crane to port

**MARINE experts in South Tyneside solved a giant problem for port bosses north of the boarder.**

The UK's largest crane, Goliath, arrived safely on :he River Forth in Scot- :and last month, thanks :o South Tyneside College.

Specialist staff at the college's narine simulation department vorked with engineering company Babcock, Forth Ports and Forth Pilots to make sure that he arrival of Goliath in the iver went without a hitch.

The £12.3m huge load was ransported from China on the ieavy lift ship, Zhen Hua 13.

And everything went according to plan after careful prepa- ation, using the marine col- ege's specialised equipment.

By LEAH STRUG

Last year, the college worked with Jacobs/Arup in a joint venture to assess the impact of a proposed new bridge over the Forth River.

This time, the simulation department was used to ensure the crane passed safely under the existing bridges and arrived at Babcock's Rosyth Dockyard in Fife, where Goliath was off loaded.

The crane was ordered by Babcock as a key part of the company's commitment to build the Royal Navy's two new aircraft carriers, HMS Queen Elizabeth and HMS Prince of Wales.

Chris Thompson, head of school for simulation, and senior marine at South Tyneside College, said: "We have done a lot of work on the Forth and already had a detailed database of the area.

"The passage of the Zhen Hua 13 up the Firth of Forth required precise timing as the vessel and its cargo needed to ballast down to pass under the bridges near low tide to ensure clearance.

"Marine safety is always a top priority, and our simulation department allows pilots to practice manoeuvring techniques in a safe but realistic environment."

Mike Murray, site development manager for the marine and technology division at Babcock International, added: "After watching the Goliath crane being fabricated, it was fantastic to see it coming under the Forth bridges. By working with South Tyneside College, this was achieved safely.

"The simulation department at the college is a fantastic facility which allows you to evaluate a plan before it is put into action."

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