Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

Report Title:

Deliverable 2.1:

Review of ability to simulate azimuthing devices

Contents

PUBLISHABLE EXECUTIVE SUMMARY

The aim of this task is to review the existing simulator capabilities for azimuting control deices. The review will include the capabilities all simulators from PC-based simulators up to full-mission-bridge-simulators and in addition manned model centres. The main focus will be to perform a: survey of existing simulators and capabilities regarding azimuting control devices, to compile list of subjects specific terminology and definitions and to discuss the technical qualities of these simulators taking into account subjects such as which ship types they can handle, which types of manoeuvres that can be simulated and if they can handle shallow water effects.

The survey of the Full-Mission-Bridge-Simulators (FMBS) and manned models simulators (MMS) was based on direct and indirect information received from various sources, namely:

- Visits in some training centres where FMBS are installed or in MMS training centres;
- Direct information received from various training centres and marine academies and
- Indirect information available in web site , pamphlets, journals, advertisements etc.

This information will be supplemented based on the responses received to the questionnaires distributed to owners of simulators, mainly marine academies, naval consultants., training facilities and research institutions. The questionnaire form was developed and included in the Annex to this report. At the time of preparing of this report the responses to the questionnaire were not yet received, therefore this information was not available.

The information collected, including information from people being acquainted with FBMS simulator work indicates, that the majority of simulator facilities have the capability to simulate manoeuvring characteristics and handling of ships equipped with azimuting control devices although the detailed information related to those capabilities is scarce. No direct information from institutions using of PC based simulators regarding their capabilities is available, but from indirect information it may be concluded that at least some of them are capable to simulate manoeuvring characteristics of pod-driven ships and also they may take into account shallow water effect.

Regarding facilities using manned models, both Port Revel and Ilawa training centres provided information that they are capable of simulating azimuting control devices and that they actually doing this. They have also arranged shallow and restricted water training areas where pod-driven ships may perform different manoeuvres.

Specifically developed questionnaire form intended to bee send to Maritime Academies and Naval Consultants is appended to the report.

List of subjects specific terminology and definitions is attached to the report on Task 3.1.

1.INTRODUCTION

The aim of this task is to review the existing simulator capabilities for azimuting control deices. The review will map the capabilities from PC-based simulators up to Full-Mission-Bridge-Simulators (FMBS). In addition manned model centres will also be considered. The objective is to approach Maritime Academies and Naval Consultants using a specifically developed questionnaire form. The main focus will be to perform a:

- **Survey of existing simulators and capabilities regarding azimuting control devices.**
- **Compile list of subjects specific terminology and definitions.**
- **Discuss the technical qualities of these simulators taking into account subjects such as which ship types they can handle, which types of manoeouvres that can be simulated and if they can handle shallow water effects**

The task will culminate in task report that will delineate the above aims and objectives and will constitute one deliverable.

2. SURVEY OF EXISTING SIMULATORS AND CAPABILITIES REGARDING AZIMUTING CONTROL DEVICES.

2.1.General

The survey of the Full-Mission-Bridge-Simulators (FMBS) and manned models simulators (MMS) is based on direct and indirect information received from various sources, namely:

- Visits in some training centres where FMBS are installed or in MMS training centres;
- Direct information received from various training centres and marine academies and
- Indirect information available in web site , pamphlets, journals, advertisements etc.

This information will be supplemented based on the responses received to the questionnaires distributed to owners of simulators, mainly marine academies, naval consultants., training facilities and research institutions. The questionnaire form was developed and included in the Annex to this report. At the time of preparing of this report the responses to the questionnaire were not yet received, therefore this information was not available.

The information collected, including information from people being acquainted with FBMS simulator work indicates, that the majority of simulator facilities have the capability to simulate manoeuvring characteristics and handling of ships equipped with azimuting control devices although the detailed information related to those capabilities is scarce.

Regarding facilities using manned models, both Port Revel and Ilawa training centres provided information that they are capable of simulating azimuting control devices and that they actually doing this. The other training centres that use manned model including Warsash Training Centre did not provide relevant information, however knowing that this centre has long experience with training pilots and ship masters on manned models they have certainly the capability of training using models equipped with azimuting propulsion devices as well.

No direct information from institutions using of PC based simulators regarding their capabilities is available, but from indirect information it may be concluded that at least some of them are capable to simulate manoeuvring characteristics of pod-driven ships and also they may take into account shallow water effect.

2.2.Full mission bridge simulators (FMBS)

Practically all FMBS capable to simulate manoeuvring characteristics and ship handling in the real time are also capable to simulate manoeuvrability of pod driven ships provided respective data on hydrodynamic derivatives of pod driven ships are available and fed into the computer programs

Direct or indirect information on the capability to simulate manoeuvrability of pod driven ships taking account of the majority influencing factors is available from the following FMB simulators:[1]

- Maritime Institute of Technology & Graduate Studied (MITAGS) (Appendix 1)
- TRANSAS (Appendix 2)
- NS 5000 simulator by Rheinmetall Defense Electronics (Reference 5) (it is not known which simulator centres use this type of simulator)
- DMI -Danish Maritime Institute, Lyngby (visit)
- Australian Maritime College (Reference 1)
- Development Centre for Ship Technology and Transport Systems (DST) Duisburg (visit).

Special simulation programs of azipod driven tugs are available in the majority of the above centres. On top of that, according to the information provided by TRANSAS at following simulator centres such programs are also available (Appendix 2):

- MITAGS, Washington Di, USA: 2 Full-Bridge 360 degree view Simulators and Tug simulator. This arrangement is shown in Appendix 1
- Pacific Maritime Institute, PMI, Seattle, USA: 2 Full-Bridge Simulators and Tug Simulator
- Marine Engineering School, MEBA, Easton, Maryland, USA: 2 Full- Bridge Simulators and 2 Tug simulators
- Georgian Great Lakes Maritime College, Canada, 4 Full-Scale Bridge Simulators in Network. Bridge layouts allow simulation of practically any ship types including tugs with all existing drives (FPP, CPP, Steering Nozzle, Pods, Voith – Schneder, etc), tows, and many others.

The above lists are not complete and certainly all well developed simulator centres have capability to simulate manoeuvrability characteristics of ships fitted with azimuting devices.

2.3. Manned model centres (MMS)

Sufficient information is available from both Port Revel and Ilawa training centres on the possibility to simulate azimuting devices. Both centres did show that they use manned models fitted with azimuting devices in their current work. No information is available on whether Warsash training centre is currently using models fitted with azimuting devices.

However, actually all manned model centres have capability to include pod driven models into their fleets, because there are no technical difficulties involved in building such models if they decide to do so.

3. COMPILE LIST OF SUBJECTS SPECIFIC TERMINOLOGY AND DEFINITIONS.

Terminology related to POD control modes is included in the Report on Task 3.1 prepared by Port Revel Shiphandling (PRS). Appendix 3 to that paper contains the paper by Baken & Burkley (2008) on Azipod Manoeuvring Terminology– (Reference 2). It contains comprehensive list of various terms on manoeuvring and handling of azimuting control devices.

[1] More information will be available after responses to the questionnaire send to simulator centres will be returned.

Appendix 4 to that paper contains Port Revel's "Control Modes" where slightly different terminologies are used (Reference 3). Both papers are not reproduced here .

The problem of terminologies is sufficiently dealt with in the report on Task 3.1. (Reference 4)

4. DISCUSS THE TECHNICAL QUALITIES OF THESE SIMULATORS TAKING INTO ACCOUNT SUBJECTS SUCH AS WHICH SHIP TYPES THEY CAN HANDLE, WHICH TYPES OF MANOEOUVRES THAT CAN BE SIMULATED AND IF THEY CAN HANDLE SHALLOW WATER EFFECTS

4.1.Full-Mission-Bridge-Simulators (FMBS)

There are few data related to technical qualities of the Full-Mission-Bridge-Simulators which are in operation around the world. It is anticipated that many of them are capable of simulating azimuting control devices. The details regarding technical qualities of those simulators are, however, not known in majority of cases and the information which types of ships are simulated and on whether or not shallow water effect is included in the program is not available. This information may be available when responses to the questionnaire prepared (Annex 1) will be available. However some information in relation to the types of ships simulated in different FMBS and on whether they can simulate shallow water effect is available from different sources.

The Development Centre for Ship Technology and Transport Systems (DST) in Duisburg installed a special shallow water navigation simulator SANDRA capable to simulate various maneouvres including manoeouvres of ships fitted with podded propulsion in shallow water of different depth- to- draft ratio. The capability of this simulator was demonstrated during the meeting of the members of the consortium in Duisburg where also capability of simulation manoeuvrabiity of inland waterways ships of different types fitted with podded propellers was demonstrated.

Detailed information on these effects was published by de Mello Petey (2008) (Reference 5) and by Heinke (2004) (references 6) on the simulation module ANS 5000 developed by Rheimetall Defence Electronics GmbH, Bremen, simulating manoeuvring capabilities of POD driven ships. This simulation code takes into account the following:

- Propeller thrust
- Transverse propeller force
- Lift and drag forces of the POD body
- Interaction effects between different POD units
- Interaction effects between POD and hull, and
- Shallow water effects

The method of taking account interaction effects between two POD units and between POD and the ship hull is described in the report on task 2.3 and is not repeated here. The method of taking account of shallow water used in the simulation module referred to is not known.

The high level of accuracy achieved by the simulation module in simulating basic manoeuvres was proved by validation tests performed with pollution control ship ARKONA (L= 69.2m). The example of comparison of simulated and measured results of the stopping manoeuvre where at full speed both POD were commanded to zero RPM is shown in fig. 1 (Taken from this reference).

The tables 1 to 5 show a comparison between simulated and measured characteristics of turning circle tests and of zig-zag tests (remark: t90 is the time required for a 90^0 heading change, t180 for a 180^0 change etc) of the passenger ship EUROPA (L=198.6m) Those test however, were conducted in the presence of Beaufort 5 to 6 wind which may influence the results. But in general the accuracy of simulation appears to be good.

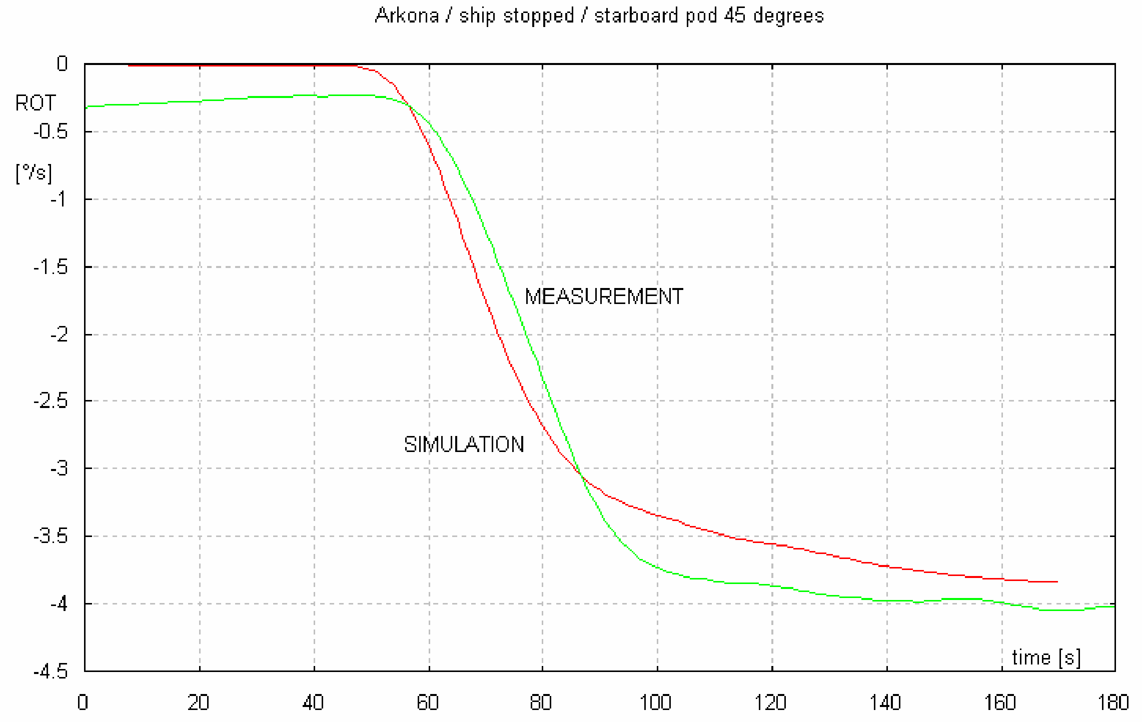

Fig 1. Comparison of simulated and measured characteristics of stopping moeuvre ARKONA ship (Ref. 5))

Table 1. Turning circle tests with both pods at an angle 35^0 (EUROPA)

	Manoeuvre to port		Manoeuvre to starboard	
	Simulated	Actual	Simulated	Actual
Starting speed [knots]	21.40		11.40	
Engine[%]	100		60	
Rudder angle [deg]	35.0		-35.0	
Adcance [m]	404.0	379.6	333.0	364.0
Transfer [m]	165.0	159.1	167.0	164.3
Tactical diameter [m]	375.0	392.1	382.5	398.7
Turning circle diameter [m]	320.0	313.7	323.5	320.3
Steady speed at turn [knts]	6.40	6.59	3.90	4.38
t90 [s]	56	54	91	96
t180 [s]	117	120	182	203
t270 [s]		192		314
t360 [s]	260	264	397	425

Table 2. Turning circle tests with starboard pod only at 35^0 (EUROPA)

	Manoeuvre to port		Manoeuvre to starboard	
	Simulated	Actual	Simulated	Actual
Starting speed [knots]	10.50		10.50	
Engine[%]	80		80	
Rudder angle [deg]	35		-35	
Adcance [m]	399.0	430.6	402.0	434.0
Transfer [m]	205.0	210.5	201.0	210.7
Tactical diameter [m]	497.0	480.3	466.0	492.2
Turning circle diameter [m]	496.0	403.2	506.0	419.7
Steady speed at turn [knts]	4.80	5.04	4.80	5.06
t90 [s]	115	118	117	121
t180 [s]	217	234	244	242
t270 [s]		356		368
t360 [s]	471	478	529	494

Table 3. Turning circle tests with starboard pod only at 60^0 (EUROPA)

	Manoeuvre to port		Manoeuvre to starboard	
	Simulated	Actual	Simulated	Actual
Starting speed [knots]	10.50		10.50	
Engine[%]	80		80	
Rudder angle [deg]	60		-60	
Adcance [m]	309	377.5	322	376.1
Transfer [m]	133	143.6	136	139.3
Tactical diameter [m]	287	293.0	253	276.4
Turning circle diameter [m]		53.3		33.5
Steady speed at turn [knts]	1	0.46	2	029
t90 [s]	99	112	102	114
t180 [s]	191	206	198	207
t270 [s]		294		296
t360 [s]	402	377	423	382

Table 4. Zig-zag test $10^0/10^0$ with both pods. (EUROPA)

	Simulated	Actual
1st overshoot [deg]	6.5	6.8
2nd overshoot [deg]	8.1	9.0
3rd overshoot [deg]	7.9	8.3
$t_{(1st\ overshoot)}$ [deg]	36	29
$t_{(2st\ overshoot)}$ [deg]	94	76
$t_{(3st\ overshoot)}$ [deg]	146	135

Table 5. Zig-zag test $10^0/10^0$ with starboard pod only. (EUROPA)

	Simulated	Actual
1st overshoot [deg]	3.9	3.9
2nd overshoot [deg]	5.1	6.0
3rd overshoot [deg]	4.0	5.1
$t_{(1st\ overshoot)}$ [deg]	71	69
$t_{(2st\ overshoot)}$ [deg]	180	178
$t_{(3st\ overshoot)}$ [deg]	298	295

TRANSAS provided information on simulation capabilities of several pod driven cruise ships in deep and shallow water. Detailed information on the comparison of simulated and measured manoeuvring characteristics of those ships in deep and shallow water was included in the report on Task 2.2 (Reference 7).

Gronarz (reference 8) in his contribution provided analysis of the responses from four simulator centres (FMBS) on the simulation results in deep and shallow water. The full report is incorporated in the report on Task 2.2. (Reference 7) and is not repeated here. The conclusions of this report are *inter allia:*

- All questioned simulator centres have capability to simulate shallow water effect
- The development of the shallow water effect with decreasing water depth is not always modelled correct
- The magnitude of the effects is sometimes very different
- The method of simulation of shallow ate effect is not known

4.2 Manned models simulators

4.2.1. General.

Detailed information is available from both training centres, namely Port Revel Shiphandling and Ilawa Ship Handling Research and Training Centre that use manned models for training mariners on models equipped with azimuting control devices.

When using manned models technique models perform maneuvers in shallow water, confined areas, port and harbor areas etc propelled by scaled down propulsion devices. Therefore effect of shallow and confined water, is automatically included.

4.2.2. Port Revel Shiphandling (PRS)

The model of a container single screw vessel used in the PRS, of the capacity 4400 TEU may be converted to azimuting propulsion by removing propeller and installing two azimuting control devices of 21,5 MW (full scale). The parameters of the model and full scale ship are shown in the table 6 (references 9 and 10 and information provided by PRS).

The model is then controlled from the wheelhouse and control panel is located in the forward part of the model. Fig 2 shows photograph of the model. The location of the control desk close to bow was chosen in order to simulate the arrangement specific to those used in cruise liners, therefore this model is intended to simulate approximately ship of the type of cruise liner.

The PODs are controlled the same way as those of a real ship with all the real automatic limitations notably depending on orientation. Fig. 3 shows control desk of the model. They can be controlled by the port or starboard lever or be coupled.

Table 6 Parameters of the model (PRS)

Parameter	Ship	Model
L_{PP} [m]	261.0	10.45
B [m]	37.1	1.48
Displacement [tons]	75000	4.67
Draft [m]	12.48	0.5
Shaft Horsepower [HP]	52000	-
Block coefficient	0.60	
Model scale	25	

)

Fig 2. Model of container vessel with azimuting propulsion (Port Revel Shiphandling)

Fig 3. Control panel of the model shown in Fig.2.

Training areas in PRS comprise large shallow water areas of different depth in which various maneuvers could be performed when training ship masters and pilots. They include shallow water docks and harbor basins, canal of restricted cross-section and unrestricted width shallow water areas. Therefore all manoeuvres with azipod propelled model could be performed in those areas with shallow water effect automatically included.

4.2.3. Ilawa Ship Handling Resesarch and Training Centre (SHRTC)

In SHRTC model of the gas carrier of capacity 140 000 m^3, fitted with two POD propulsion units is available for training. The model was build in model scale 1:24. Fig. 4 shows the photograph of the model, and the dimensions of the model are shown in the table 7. (references 11 and 12 and information from SHRTC)

Fig.4. Model of POD driven gas carrier in SHRTC

Table 7.Dimensions of the model used in SHRTC

Dimension	Real ship	Model
Length [m]	277.45	11.56
Breadth [m]	43.2	1.80
Draft [m]	12.0	0.50
Block coefficient [-]	0.79	0.79

The PODs have pulling propellers as shown in fig.5, and the dimensions of the propellers are given in the table 8. The PODs are controlled the same way as those of a real ship with all the real automatic limitations notably depending on orientation. Fig. 6 shows control desk of the model. They can be controlled by the port or starboard lever or be coupled.

Table 8.Dimensions of the propellers

Parameter	Pulling propeller
Diameter [m]	0.250
Number of blades [-]	4
Exp. area ratio [-]	0.5184
P/D at r/R=0.7 [-]	1.0155
Power (at design speed) kW	0.190

Fig.5 POD propellers in the model of gas carrier in SHRTC

Fig.6. Control desk of the model of gas carrier in SHRTC

The SHRTC uses also the POD driven models of tugs. They are equipped with two propulsion units, one with pushing propellers, the other with pulling propellers at the bow, that are controlled separately, no reverse revolutions, but they can be rotated 360 deg. The models are shown in fig 7 and 8. The tug models are used in escorting operations. Fig 9 shows escorting tug at work with the model of the large tanker.

Fig. 7. POD driven tug used in SHRTC

Fig. 8 POD driven tug used in SHRTC

Fig.9. POD driven tug model working with the tanker model at SHRTC

In SHRTC there is a number of artificially prepared training areas that, comprise routes particularly suitable for training ship handling in shallow water areas, in canals and other restricted areas. They include:

- restricted cross-section canal of the length 140m (corresponding to 3.3 km in reality), called Pilot’s Canal.
- wide (corresponding to about 360m width in reality) shallow water fairwaqy of the length corresponding to about 1.5 km, where current could be generated from both sides, called Chief’s
- wide shallow water area corresponding to about 750m x 500m in reality
- shallow water dock
- shallow water area for anchoring exercises

The above arrangement of training areas provide ample opportunities to train ship masters and pilots to handle ships in shallow water, canals and other restricted water areas.

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ANNEX - QUESTINNAIRE

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

Q8 – SIMULATOR CENTRES

All replies will be treated in confidence. It would be helpful if the person completing this form provide his/her contact details so we may contact him/her directly for further information if required.

Thank you in anticipation for your reply and help in this project.

Q8.1	**What is the name of your organization?**
Q8.2	**What are your contact details?**
Q8.3	**What is your job title (job description)?**
Q8.4	**Is the training centre part of a maritime college?(Yes/No)**
	☐YES ☐NO Please specify:
Q8.5	**Is the training centre part of a shipping company?(Yes/No)**
	☐YES ☐NO Please specify:
Q8.6	**Is the training centre independent?(Yes/No)**
	☐YES ☐NO
TYPE OF BRIDGE SIMULATOR	
Q8.7	**Do you operate a bridge simulator?**
	☐YES ☐NO

	If yes: Name of simulator: Name of manufacturer: Year of installation: Last update (year): Software:
Q8.8	**Can your simulator operate ships equipped with azimuthing control devices?**
	☐YES ☐NO
Q8.9	**If yes, how many different handles for ships equipped with azimuthing control devices can you offer?**
	Number:

MAIN CHARACTERISTICS OF BRIDGES

Q8.10	**Please indicate the main characteristics of your bridges in the next table.**

Bridge No.	Type of bridge				View Type		Details of view		Radar	ACD-controls	Remarks
	Full mission	Auxiliary	Cubicle	PC-Station	Projection	Monitor	No of viewing systems	Total angle			

TYPES OF TRAINING AVAILABLE FOR SHIPS WITH AZIMUTHING CONTROL DEVICES

Q8.11	**How many types of vessel equipped with Azimuthing devices are simulated in your centre (including tugs and cargo ships)**
Q8.12	**For each types of simulated vessel equipped with Azimuthing devices, please indicate the following details:**
	VESSEL 1 Simulator Type: Simulator Manufacturer: Year of installation: Last update (year): Software: Vessel type: Vessel name: Lever manufacturer: Azimuthing device: Is a Joystick/UniLever present? ☐YES ☐NO Dimensions of simulated vessel: If Tug, Bollard Pull: If Cargo ship, Deadweight: Other vessel type, Loa:
	VESSEL 2 Simulator Type: Simulator Manufacturer: Vessel type: Vessel name: Lever manufacturer: Azimuthing device:

	Is a Joystick/UniLever present? ☐YES ☐NO Dimensions of simulated vessel: If Tug, Bollard Pull: If Cargo ship, Deadweight: Other vessel type, Loa:
	VESSEL 3 Simulator Type: Simulator Manufacturer: Vessel type: Vessel name: Lever manufacturer: Azimuthing device: Is a Joystick/UniLever present? ☐YES ☐NO Dimensions of simulated vessel: If Tug, Bollard Pull: If Cargo ship, Deadweight: Other vessel type, Loa:
	VESSEL 4 Simulator Type: Simulator Manufacturer: Vessel type: Vessel name: Lever manufacturer: Azimuthing device: Is a Joystick/UniLever present? ☐YES ☐NO Dimensions of simulated vessel: If Tug, Bollard Pull: If Cargo ship, Deadweight: Other vessel type, Loa:
	VESSEL 5 Simulator Type: Simulator Manufacturer: Vessel type: Vessel name: Lever manufacturer: Azimuthing device: Is a Joystick/UniLever present? ☐YES ☐NO Dimensions of simulated vessel: If Tug, Bollard Pull: If Cargo ship, Deadweight: Other vessel type, Loa:
	VESSEL 6 Simulator Type: Simulator Manufacturer: Vessel type: Vessel name: Lever manufacturer: Azimuthing device: Is a Joystick/UniLever present? ☐YES ☐NO Dimensions of simulated vessel: If Tug, Bollard Pull: If Cargo ship, Deadweight: Other vessel type, Loa:
Q8.13	**Has the course related to azimuthing control devices content originated from a Lead Body?**
	☐YES ☐NO If yes, by from whom which body:
Q8.14	**Has any of the training related to azimuthing control devices been accredited?**
	☐YES ☐NO If yes, accreditated by: ☐ A National Training Organisation (please specify):

	☐ A National Safety Agency (please specify): ☐ Other (please specify):
Q8.15	**Do simulators/models related to azimuthing control devices meet STCW standards?**
	☐YES ☐NO
Q8.16	**Do simulators/models related to azimuthing control devices meet DNV standards?**
	☐YES ☐NO
Q8.17	**Do simulators/models related to azimuthing control devices meet other standards?**
	☐YES ☐NO If yes, which standards:
Q8.18	**Does the facility have a procedure of best practice in training?**
	☐YES ☐NO
Q8.19	**Is the training based more on the personal experience of each instructor?**
	☐YES ☐NO
Q8.20	**Are there methods in place for monitoring and developing training courses?**
	☐YES ☐NO Please explain:
CAPACITY OF FACILITY	
Q8.21	**How may people can attend at once a simulator course on azimuthing devices?**
Q8.22	**How many simulator courses can be run simultaneously for azimuthing devices?**
Q8.23	**With respect to azimuthing devices, what percentage of time does the training centre run at full capacity?**
	%
TYPES OF TRAINING COURSES RELATED TO AZIMUTHING CONTROL DEVICES AND DURATION	

Q8.24

Please describe in the next table your courses related to azimuthing control devices

Title of course related to azimuthing control devices	Brief Description and duration

Q8.25	**Does the training facility fill the training needs and requirements of azimuthing control devices? Please briefly discuss the limitations of the centre in this area. E.g. Has the training facility experienced certain needs from customers that are difficult to fulfil?**
Q8.26	**Please list the most frequent obstructions to training.**
Q8.27	**Are there some aspects of using azimuthing controlled devices that can only be learned during a period at sea?**
Q8.28	**Are there certain aspects of operating azimuthing controlled devices that can only be safely done in a simulator/training facility?**

Q8.29	**Can you think of any improvements that would increase the operators' awareness of the ships handling?**
MODELS USED IN SHIP SIMULATORS EQUIPPED WITH AZIMUTHING CONTROL DEVICES	
Q8.30	**Are simulated models realistic?**
	☐YES ☐NO
Q8.31	**If not, can the training centre:**
	a) Change the mathematical model? ☐YES ☐NO **b) Change the operating System?** ☐YES ☐NO
Q8.32	**On ship simulators equipped with azimuthing control devices, please indicate a preference for:** **Very briefly please explain your preferences.**
	☐ Propulsors Why: ☐ Control Why:
Q8.33	**Is any training done for mismatches of controls and Machinery? E.g. Different manufacturers of lever and propulsor.**
	☐YES ☐NO
	If so, what percentage of simulation runs, and what implication do you think this can have compared to operating azimuths in reality?
	Percentage: Implications:
Q8.34	**Does the training vary depending on the type of control lever used?**
	☐YES ☐NO **If so, in what way?**

Q8.35	**Does the facility realistically model *(Tick boxes that apply):*** ☐ Propeller/Hull interaction ☐ Propeller/Propeller interaction ☐ Propeller/Quay Wall interaction ☐ Propeller/Depth of water ☐ Vibration & adverse reactions ☐ Ship/Bank interaction ☐ Ship/Ship interaction ☐ Other:

APPENDIX 1


MITAGS
MARITIME INSTITUTE OF TECHNOLOGY & GRADUATE STUDIES
THE LEADER IN MARITIME TRAINING
Tractor Tug Familiarization
16
• State-of-the-art equipment
• Greater control
• More operating options
• Simple commands
• More fun
MITAGS is internationally certified as a Maritime Simulation & Training Center by Det Norske Veritas
692 MARITIME BOULEVARD, LINTHICUM, MARYLAND 21090
TELEPHONE: (410) 859-5700 I ADMISSIONS TOLL-FREE TELEPHONE: (866) 656-5568
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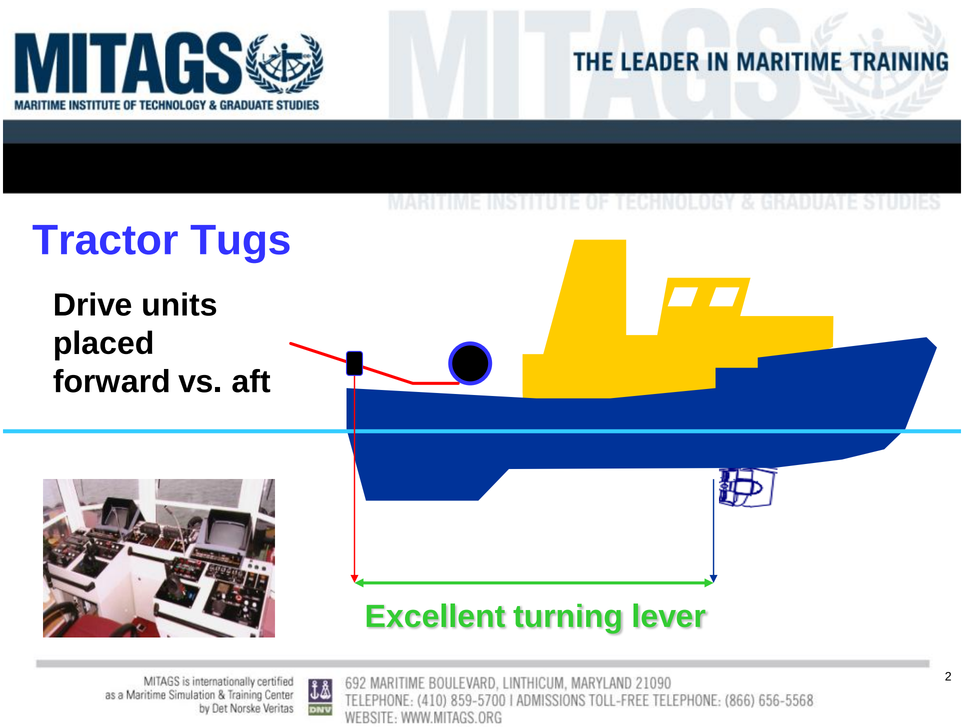
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Tractor Tugs
Drive units placed forward vs. aft
Excellent turning lever
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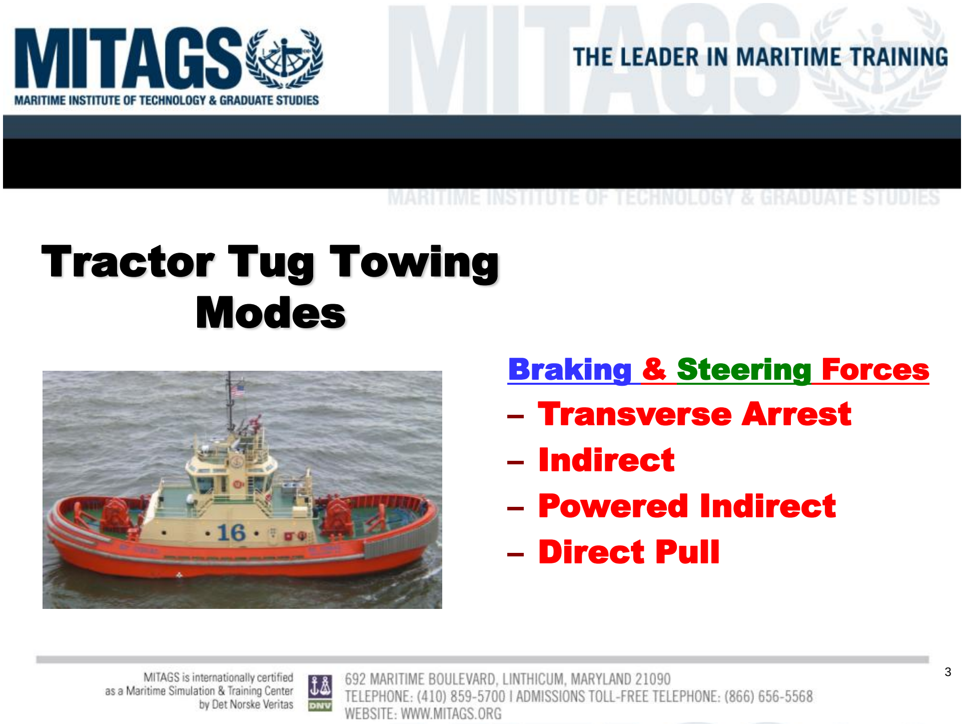
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Braking & Steering Forces
– Transverse Arrest
– Indirect
– Powered Indirect
– Direct Pull
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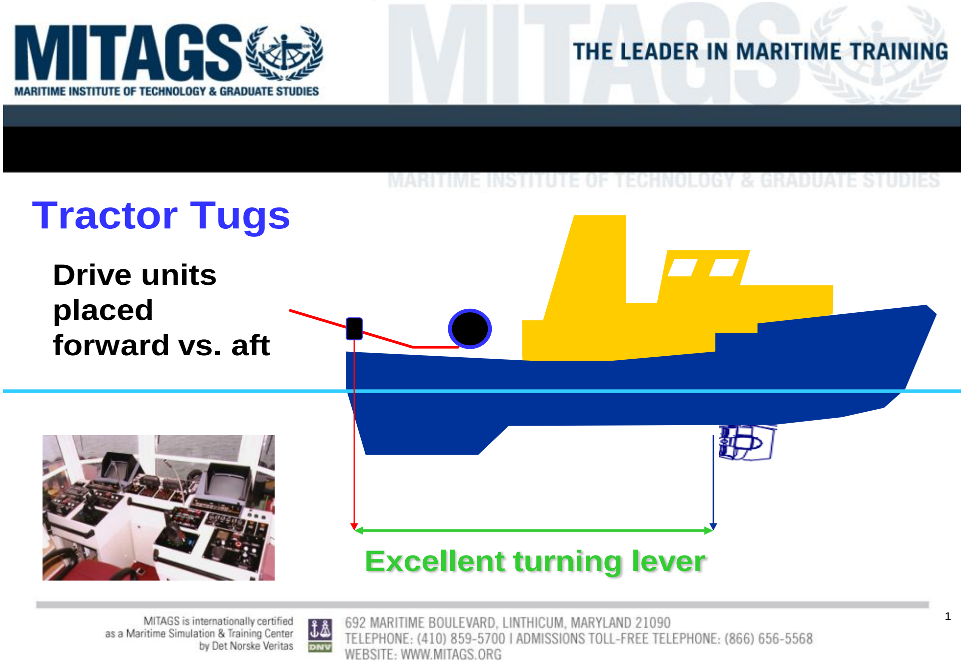
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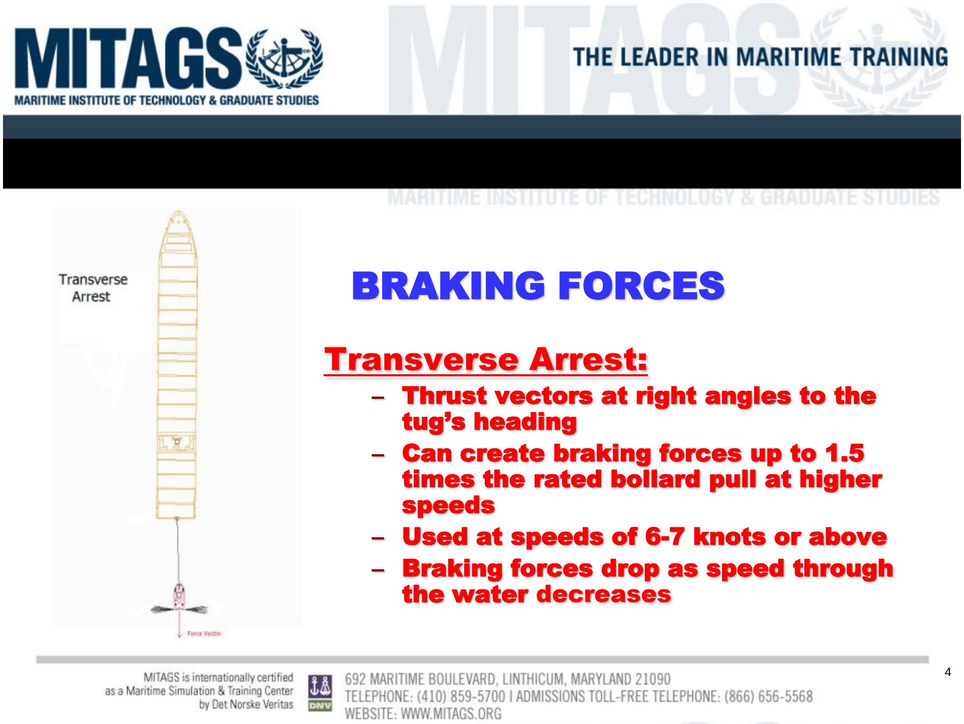
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THE LEADER IN MARITIME TRAINING
Transverse Arrest
BRAKING FORCES
Transverse Arrest:
– Thrust vectors at right angles to the tug's heading
– Can create braking forces up to 1.5 times the rated bollard pull at higher speeds
– Used at speeds of 6-7 knots or above
– Braking forces drop as speed through the water decreases
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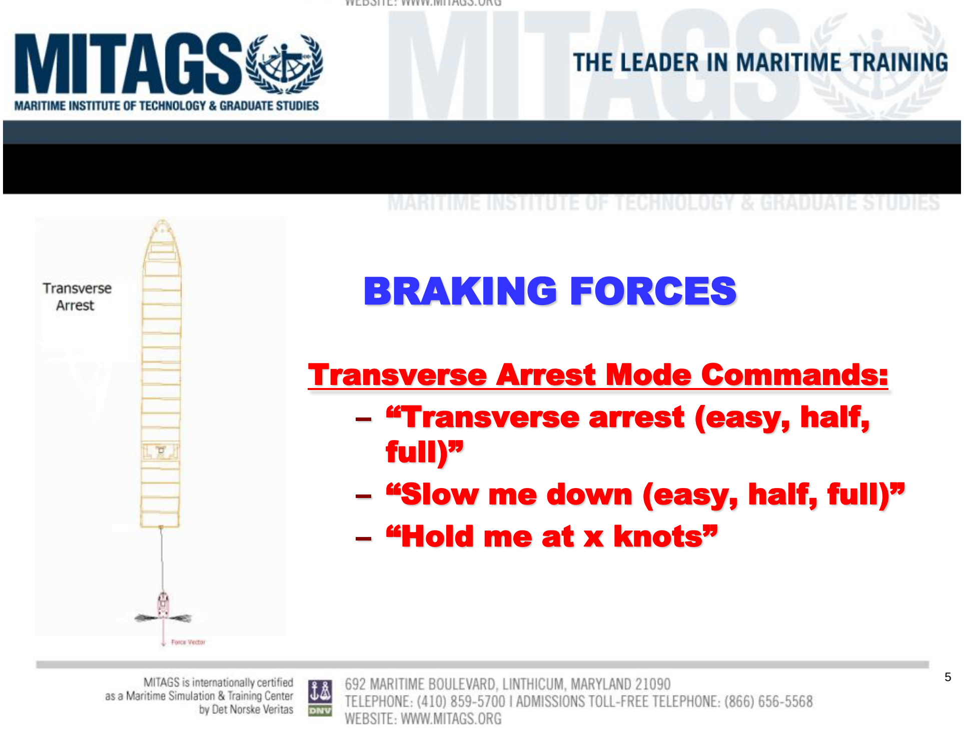
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THE LEADER IN MARITIME TRAINING
Transverse Arrest
BRAKING FORCES
Transverse Arrest Mode Commands:
– "Transverse arrest (easy, half, full)"
– "Slow me down (easy, half, full)"
– "Hold me at x knots"
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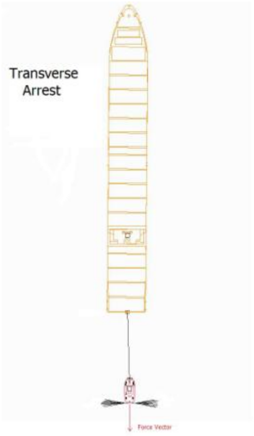

BRAKING FORCES

Transverse Arrest Mode Commands:

- **"Transverse arrest (easy, half, full)"**
- **"Slow me down (easy, half, full)"**
- **"Hold me at x knots"**

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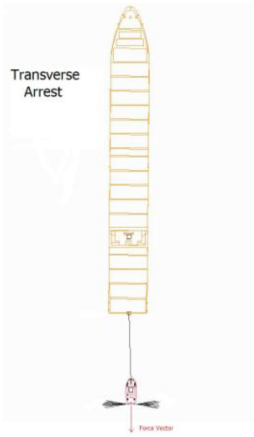

BRAKING FORCES

Transverse Arrest:

- **Thrust vectors at right angles to the tug's heading**
- **Can create braking forces up to 1.5 times the rated bollard pull at higher speeds**
- **Used at speeds of 6-7 knots or above**
- **Braking forces drop as speed through the water decreases**

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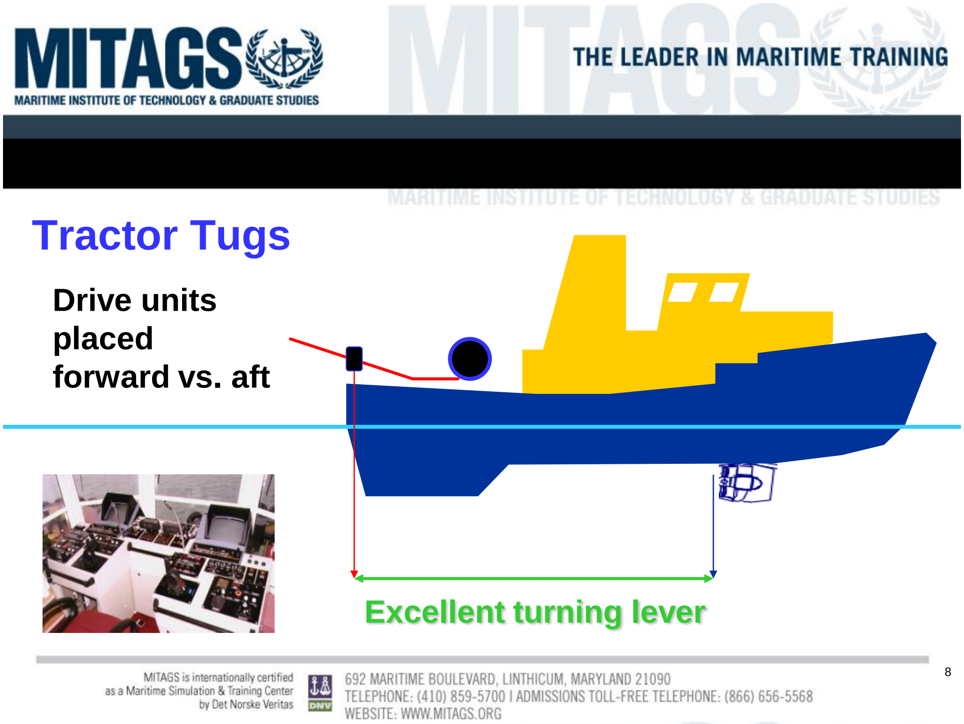
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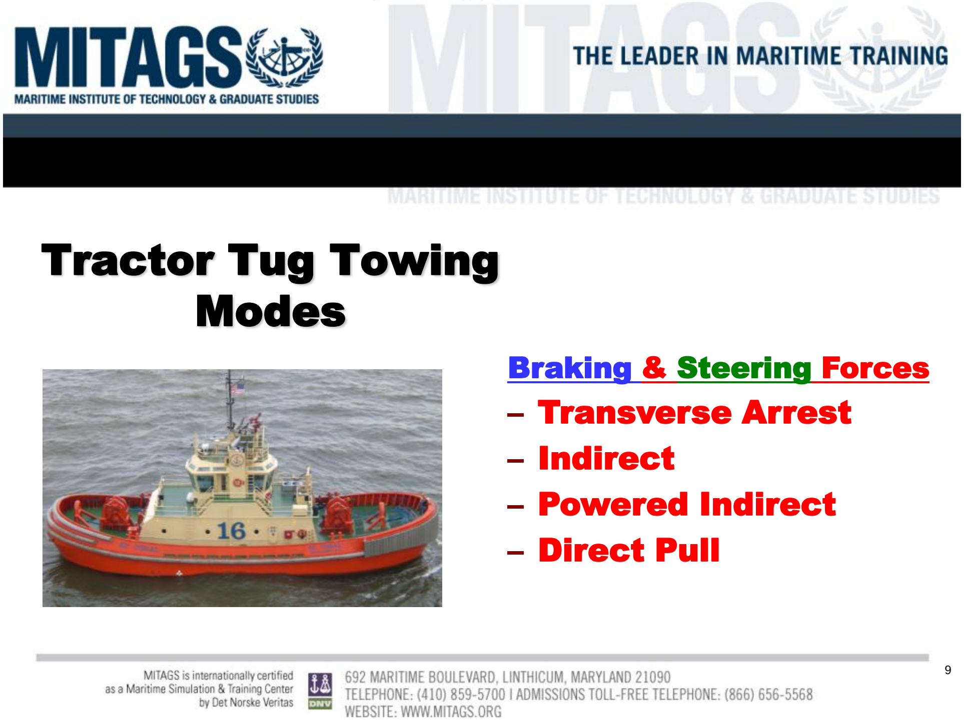
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Braking & Steering Forces
– Transverse Arrest
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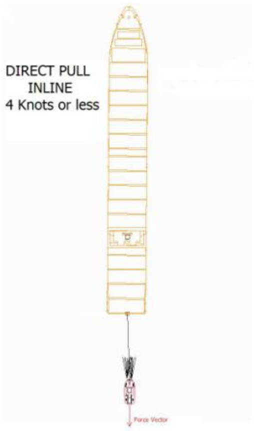

BRAKING FORCES

Direct Pull Mode

- Thrust vectors are directed toward the ship
- Used at speeds of 4 knots or less

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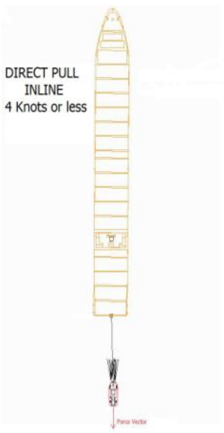

BRAKING FORCES

Direct Pull Commands:

- "Direct pull aft (easy, half, full)"
- "Pull straight aft (easy, half, full)"
- "Slow me down (easy, half, full)"
- "Hold me at x knots"
- "Stop and drag"

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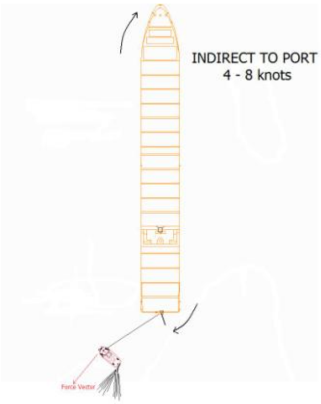

STEERING FORCES

Indirect Mode:

- Towline positioned at 45° angle to the ship's transom
- Tug positioned at 30^0 angle to the water flow to maximize hull's hydrodynamic lift.
- Used at speeds of 4-5 kts and above
- Can generate forces almost twice the rated bollard pull

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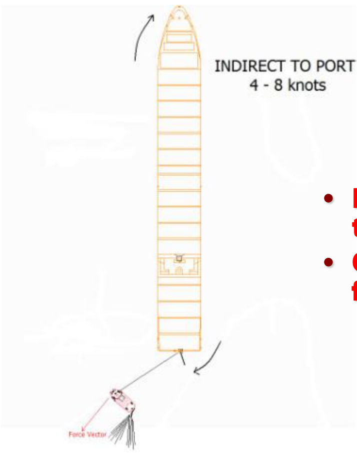

STEERING FORCES

- Indirect maneuver is used to steer the ship
- Can overcome hard over rudder failure IF act quickly!
  - Recognition is key. No tug will be able to stop a high rate of turn

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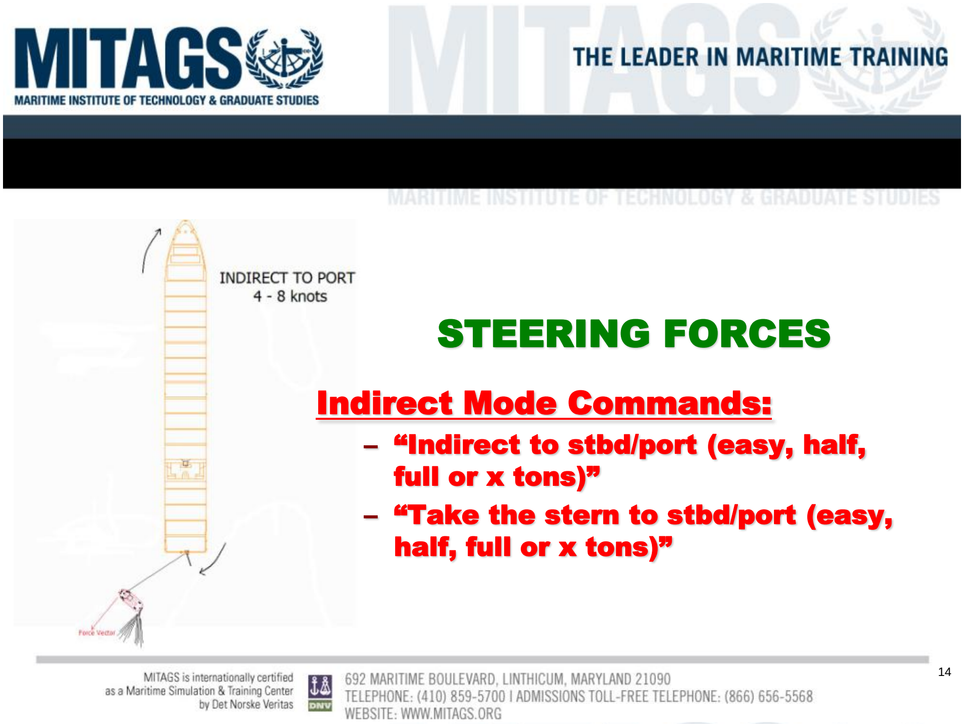
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THE LEADER IN MARITIME TRAINING
INDIRECT TO PORT
4 - 8 knots
STEERING FORCES
Indirect Mode Commands:
– "Indirect to stbd/port (easy, half, full or x tons)"
– "Take the stern to stbd/port (easy, half, full or x tons)"
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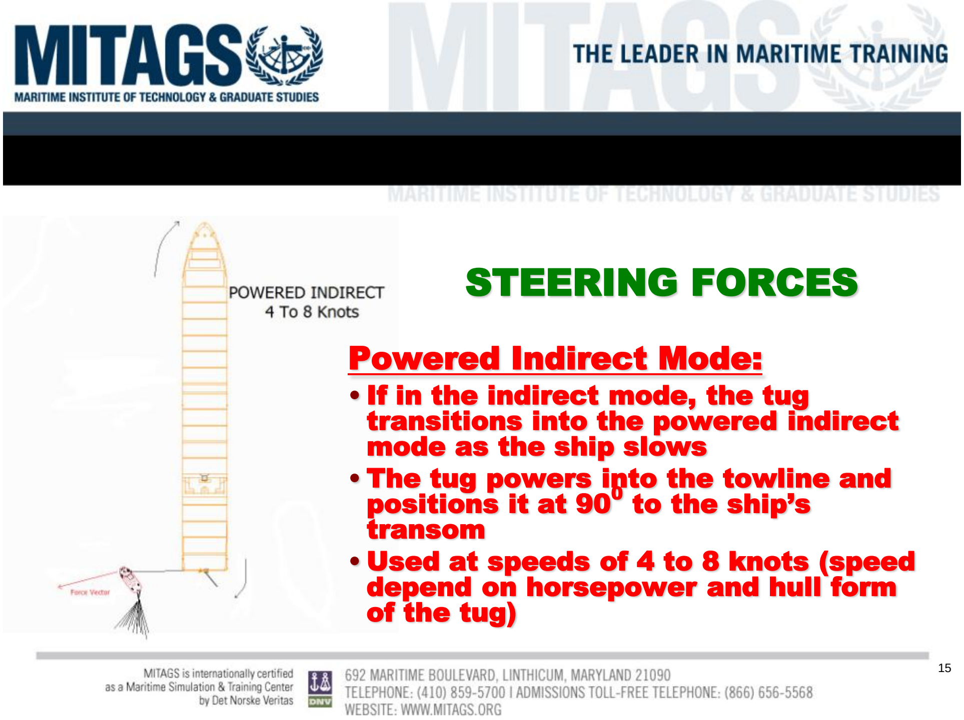
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THE LEADER IN MARITIME TRAINING
POWERED INDIRECT
4 To 8 Knots
STEERING FORCES
Powered Indirect Mode:
• If in the indirect mode, the tug transitions into the powered indirect mode as the ship slows
• The tug powers into the towline and positions it at 90° to the ship's transom
• Used at speeds of 4 to 8 knots (speed depend on horsepower and hull form of the tug)
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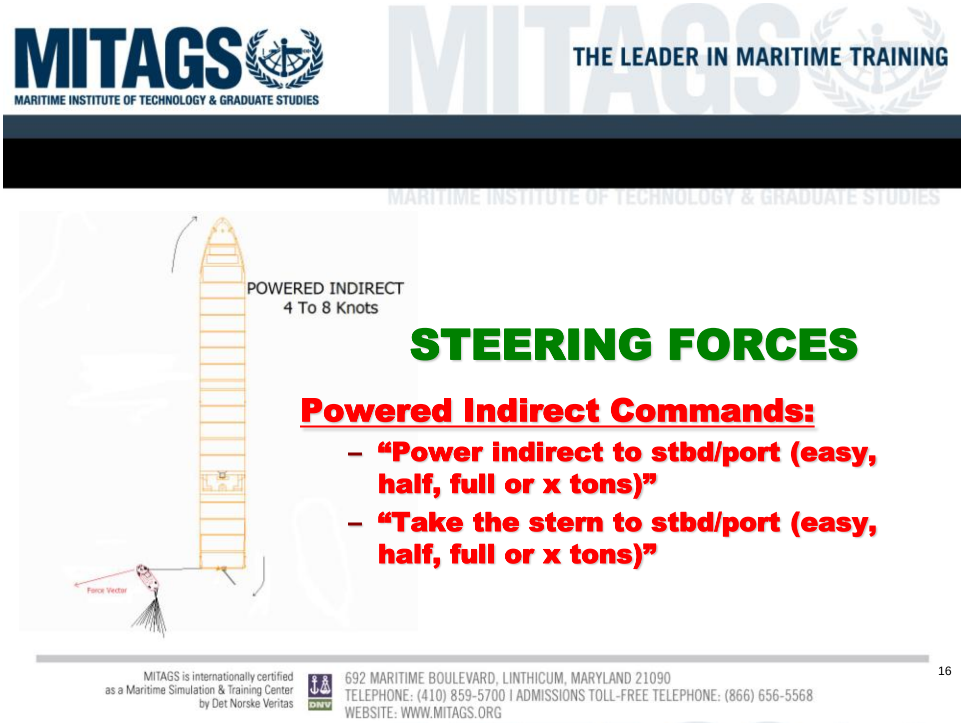
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POWERED INDIRECT
4 To 8 Knots
Force Vector
STEERING FORCES
Powered Indirect Commands:
– "Power indirect to stbd/port (easy, half, full or x tons)"
– "Take the stern to stbd/port (easy, half, full or x tons)"
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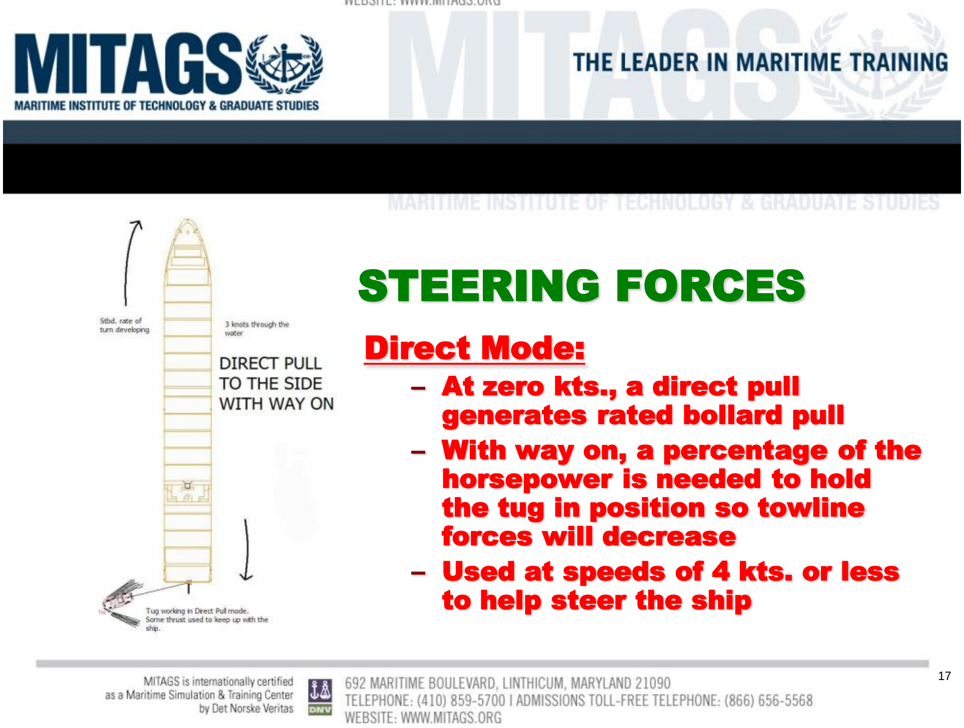
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Stbd. rate of turn developing
3 knots through the water
DIRECT PULL TO THE SIDE WITH WAY ON
Tug working in Direct Pull mode. Some thrust used to keep up with the ship.
STEERING FORCES
Direct Mode:
– At zero kts., a direct pull generates rated bollard pull
– With way on, a percentage of the horsepower is needed to hold the tug in position so towline forces will decrease
– Used at speeds of 4 kts. or less to help steer the ship
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STEERING FORCES

Direct Mode Commands:

- **"Pull direct to port/ stbd at x degrees (easy, half, full, or x tons)"**
- **"Take the bow/stern to port/stbd (easy, half, full, or x tons"**

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Additional Tractor Tug Working Commands:

- **"Toward or push" (easy, half, full, or x tons)**
- **"Away or pull" (easy, half, full, or x tons)**
- **"Minimum or Dead Slow" in addition to easy, half, and full**
- **"Come to push/pull mode and stop"**

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Discussion?
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APPENDIX 2

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

EC AZIPILOT PROJECT

WP 2: Task 2-2 Review of Simulation Capabilities

TRANSAS
SETS THE STANDARD

Survey of steering with azimuthing control devices when towing.

- *Explore issues associated with assisted breaking including the indirect-mode.*
- *Discuss issues related to tugs operating near the stern of pod-driven ships.*
- *Survey of steering with azimuthing control devices when under-tow.*

DR. V. ANKUDINOV, DIRECTOR, HYDRODYNAMICS AND RESEARCH, TRANSAS

CONTENTS

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

- Introduction
- Visual outlines and principal manoeuvring characteristics of vessels equipped with the azimuth propellers
- Brief review of existing technical simulation capabilities and simulation facilities able realistically to simulate TUGS with azimuth devices and their performance on simulation ship models
- Review of validation methods for TUGS with azimuth devices and simulation TUG performance near the stern of pod-driven ships
- Review of Capabilities of the Existing Simulators to simulate Direct and Indirect Towing modes.
- Steering with azimuth control devices when under –tow.

TRANSAS
SETS THE STANDARD

INTRODUCTION

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

This presentation briefly describes the major findings of the review of the simulations techniques related to model and simulate azimuth driven TUGS (including existing software, hardware and physical azimuth devices and ship models with azimuth devices) at several US simulation facilities.

TRANSAS SETS THE STANDARD

INTRODUCTION: THE FOLLOWING SIMULATION FACILITIES PROVIDED INFORMATION RELATED TO SIMULATION AND TRAINING WITH AZIMUTH DRIVEN TUGS

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

- Maritime Institute of Technology, MITAGS, Washington DC, USA: 2 Full-Bridge 360 degree view Simulators and Tug simulator
- Pacific Maritime Institute, PMI, Seattle, USA: 2 Full-Bridge Simulators and Tug Simulator
- Marine Engineering School, MEBA, Easton, Maryland, USA: 2 Full- Bridge Simulators and 2 Tug simulators
- Georgian Great Lakes Maritime College, Canada, 4 Full-Scale Bridge Simulators in Network. Bridge layouts allow simulation of practically any ship types including Tugs with all existing drives (FPP, CPP, Steering Nozzle, Pods, Voith – Schneder, etc), Tows, and many others.

TRANSAS SETS THE STANDARD

VISUAL OUTLINES AND PRINCIPAL MANEUVERING CHARACTERISTICS OF VESSELS EQUIPPED WITH AZIMUTH DEVICES LIKE LARGE CRUISE SHIPS SHOWN BELOW

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

TRANSAS SETS THE STANDARD

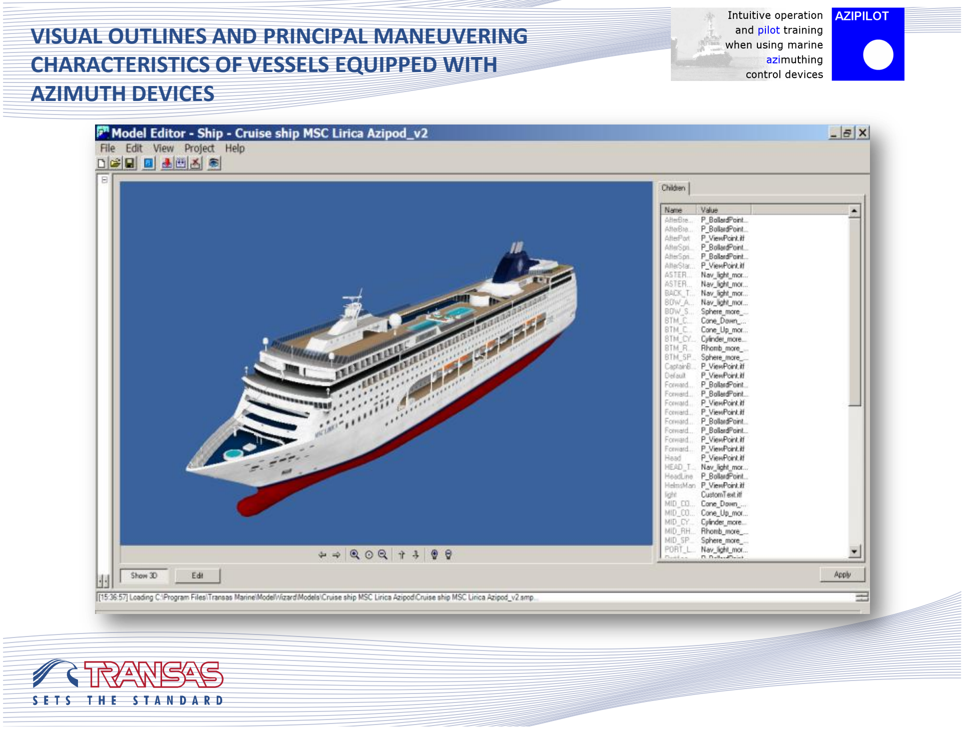
VISUAL OUTLINES AND PRINCIPAL MANEUVERING CHARACTERISTICS OF VESSELS EQUIPPED WITH AZIMUTH DEVICES

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

TRANSAS SETS THE STANDARD

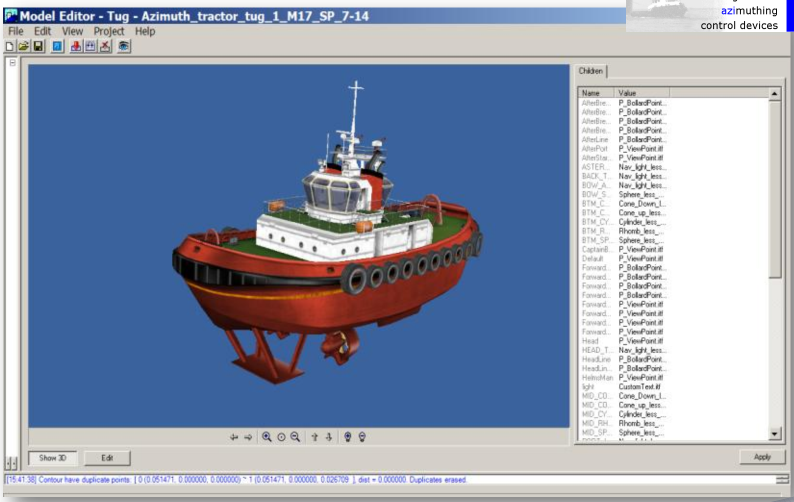

VISUAL OUTLINES AND PRINCIPAL MANEUVERING CHARACTERISTICS OF VESSELS EQUIPPED WITH AZIMUTH DEVICES - TYPICAL LARGE ASD TUG OPERATING AT PACIFIC AREA
Intuitive operation and pilot training when using marine azimuthing control devices
AZIPILOT
Model Editor - Tug - ASD_Valor_Class2_v3
File Edit View Project Help
TRANSAS
SETS THE STANDARD


VISUAL OUTLINES AND PRINCIPAL MANEUVERING CHARACTERISTICS OF VESSELS EQUIPPED WITH AZIMUTH DEVICES
Intuitive operation and pilot training when using marine azimuthing control devices
AZIPILOT
Model Editor - Ship - Cruise ship MSC Lirica Azipod_v2
File Edit View Project Help
TRANSAS
SETS THE STANDARD

VISUAL OUTLINES AND PRINCIPAL MANEUVERING CHARACTERISTICS OF VESSELS EQUIPPED WITH AZIMUTH DEVICES - THE NEW TUG IN SUPPORT OF LNG OPRATIONS IN GULF AREA.

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

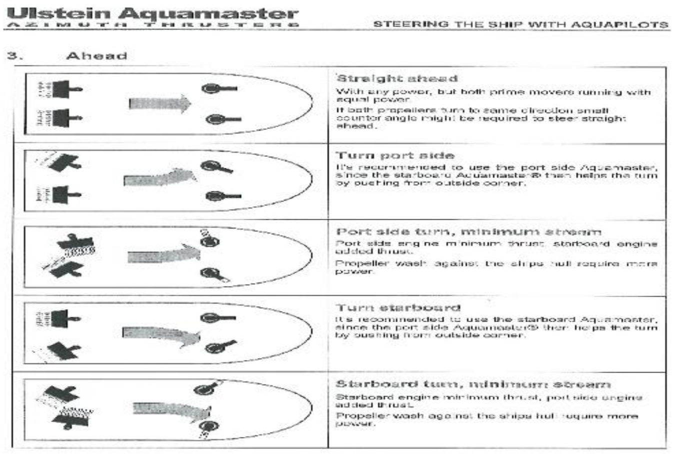


TRANSAS
SETS THE STANDARD

AHEAD MANEUVERING FOR A TUG WITH AZIMUTH PROPELLERS

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT



Ulstein Aquamaster
AZIMUTH THRUSTERS

STEERING THE SHIP WITH AQUAPILOTS

3. Ahead

Straight ahead
With any power, but both prime movers running with equal power.
If both propellers turn to same direction small counter angle might be required to steer straight ahead.

Turn port side
It's recommended to use the port side Aquamaster, since the starboard Aquamaster® then helps the turn by pushing from outside corner.

Port side turn, minimum stream
Port side engine minimum thrust, starboard engine added thrust.
Propeller wash against the ships hull require more power.

Turn starboard
It's recommended to use the starboard Aquamaster, since the port side Aquamaster® then helps the turn by pushing from outside corner.

Starboard turn, minimum stream
Starboard engine minimum thrust, port side engine added thrust.
Propeller wash against the ships hull require more power.

TRANSAS
SETS THE STANDARD

AZIMUTH PROPELLER DRIVES

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

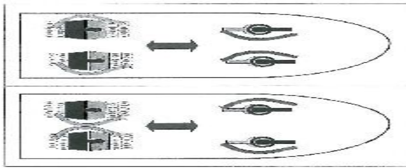
Ulstein Aquamaster
AZIMUTH THRUSTERS

STEERING THE SHIP WITH AQUAPILOTS

7. Astern from ahead (Fast stop)

NOTICE!	*Fast (Crash) stop maneuver is allowed only in emergency situation. Fast stop is to be done via decreasing the rpm of the prime mover in stages to slow rpm and then turn the units also in stages following the decrease of the vessels speed. This maneuver should be recorded into the vessels operating manual.*

- This is performed when changing fast the movement of the ship to the opposite direction or when stopping the ship quickly.
- Try to turn the Aquapilot® levers whit the same speed than the propeller Aquamasters are actually turning, this way You can steer the ship during this manoeuvre. If both Aquamasters maximum turning rates aren't equal they should be adjusted.
- However, if there occurs high vibration astern of the ship or overload danger of the prime mover, cut down the rpm of the prime mover.



Astern from ahead, fast stop

Turn the propellers to the direction where the ship is moving. The port side-Aquamaster® is turned clockwise and the starboard-Aquamaster® counterclockwise.

Both engines are running with equal power. Always turn the Aquapilot® lever inside.

Astern from ahead, no wash

Both engines are running with equal power. Always turn the Aquapilot® lever outside.

The Aquamasters may be turned with decreasing limited power.

TRANSAS
SETS THE STANDARD

ASD MANEUVERING PRINCIPLES IN LEARNING PROCESS DURING SIMULATION TRAINING

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

- **Taking Control:** Before taking command of the control, one should confirm that Z-drive systems are up and running
- **How one has to steer an ASD Tug:**
  - The stern drives the tug
  - Steering and Speed. Steering and Propulsion are inextricably linked. One cannot change one without it affecting the other
  - Manage the balance of thrust
- **How do you stop an ASD tug?**
- **How do you walk an ASD tug?**

TRANSAS
SETS THE STANDARD

BASIC MANEUVERS OF THE ASD TUGS ON SIMULATOR:

Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT

- Stopping and Turning – reverse arrest
- Managing the Speed
- Turning
- Putting Steering and Speed Together
- Rotating without Advancing
- The “Flip”
- Walking (flanking)
- Transitions
- Undocking
- Berthing and Anchoring
- Cycling and Tandem
- Maneuvering in Current

TRANSAS SETS THE STANDARD

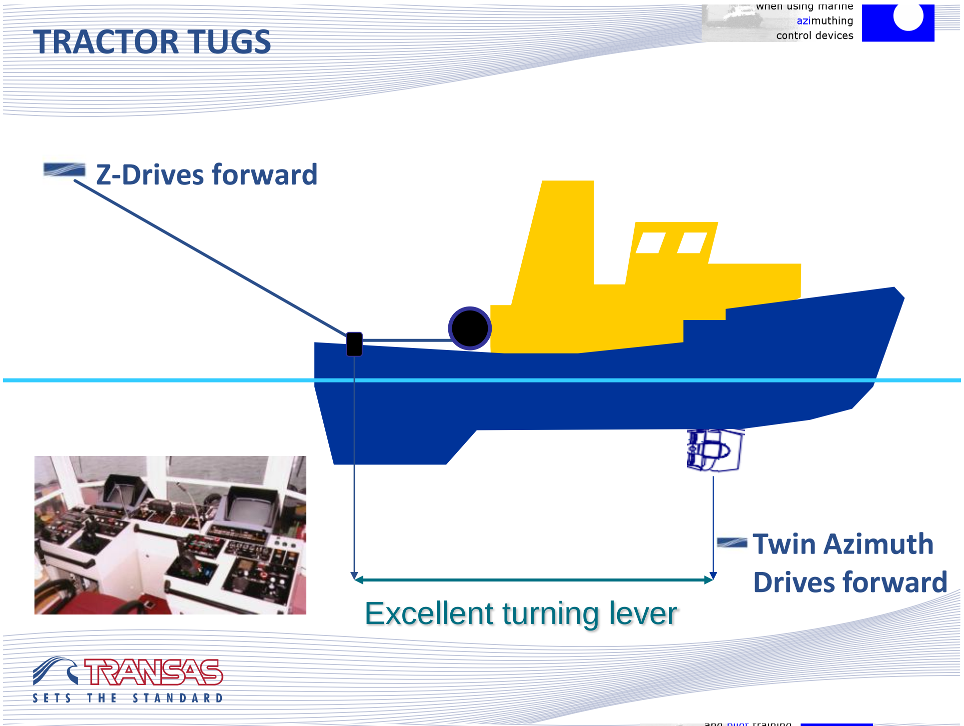
AZIPODS RELIABILITY GUIDELINES

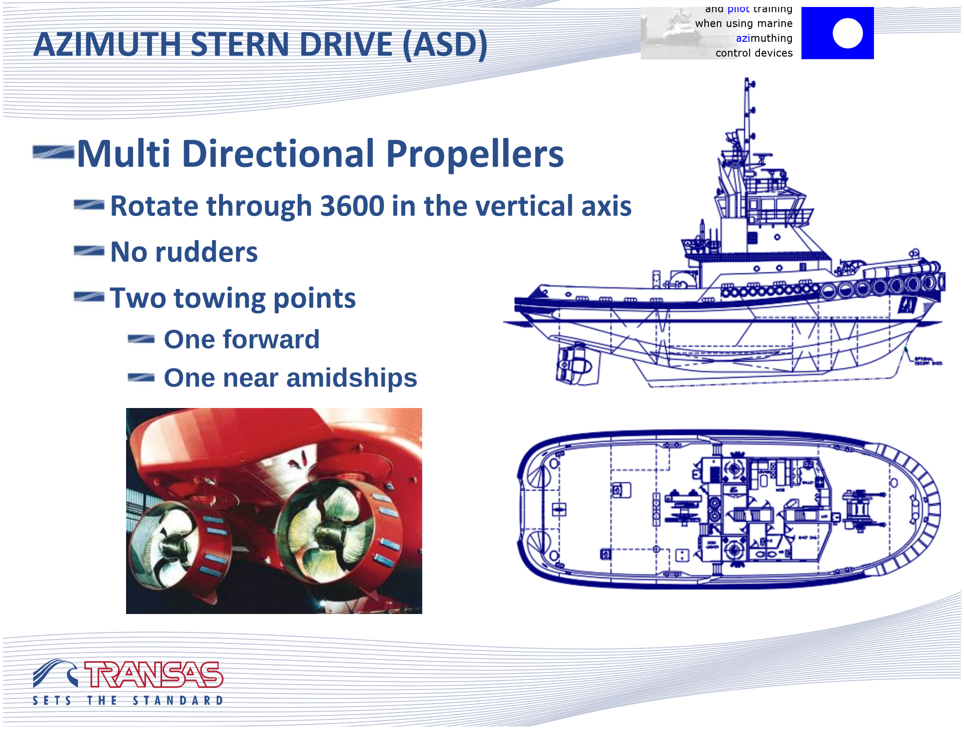
Intuitive operation and pilot training when using marine azimuthing control devices

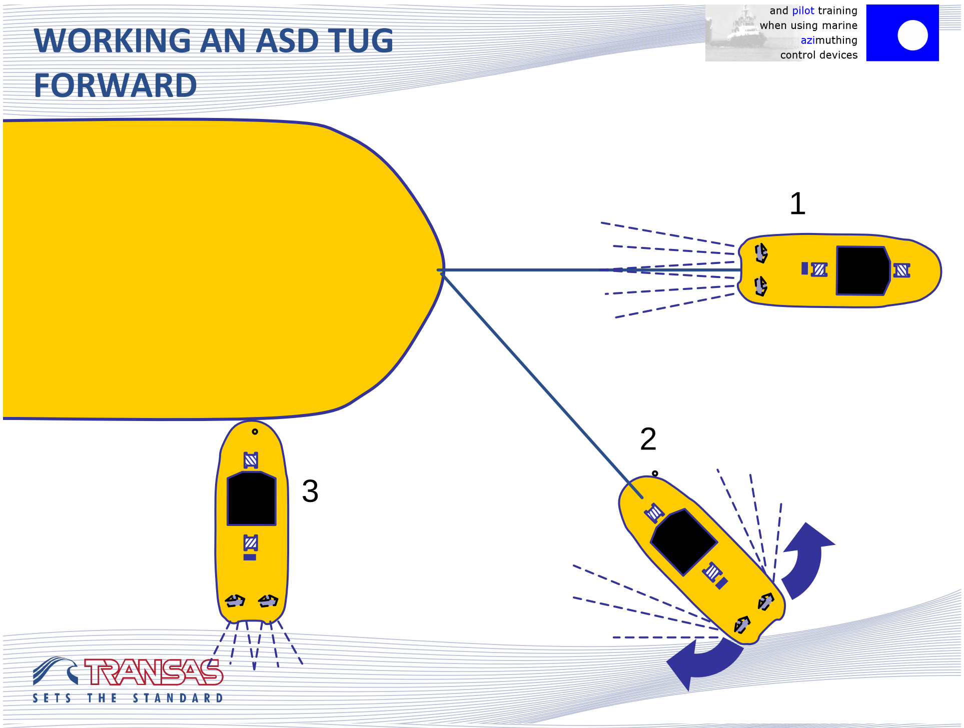
AZIPILOT

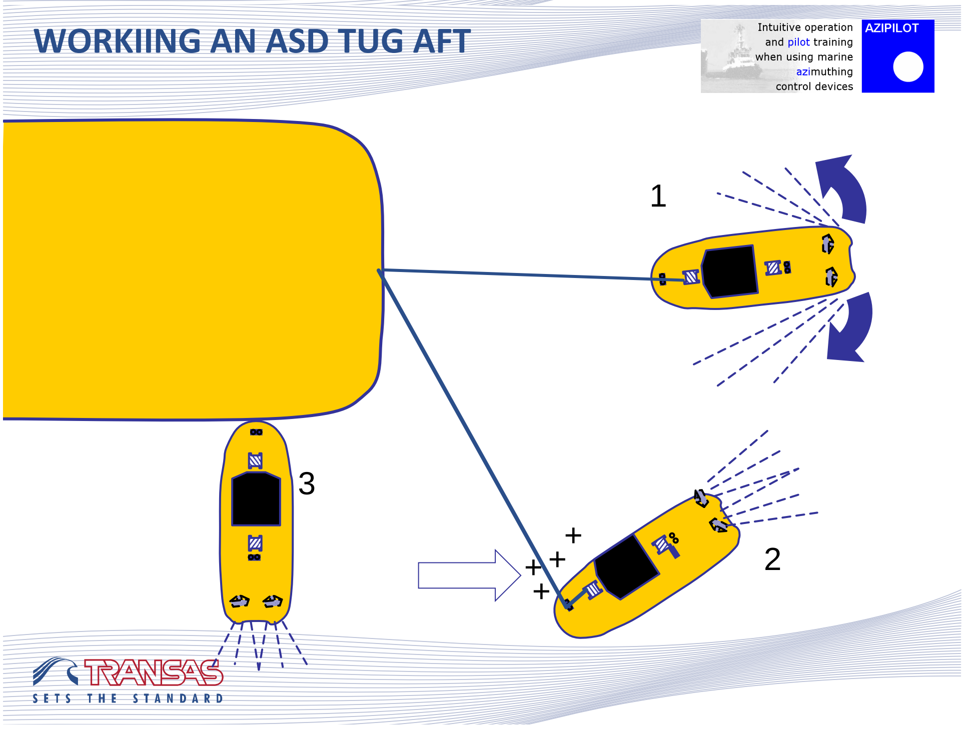
- Pods should be kept turning in a positive or ahead direction throughout maneuvers
- Pod Propeller revolutions should be kept above a minimum
- The thrust from a pod should not be directed on to another pod
- It is always best practice to operate the pods as gently as possible, to reduce the vibration and stress on the mechanical components

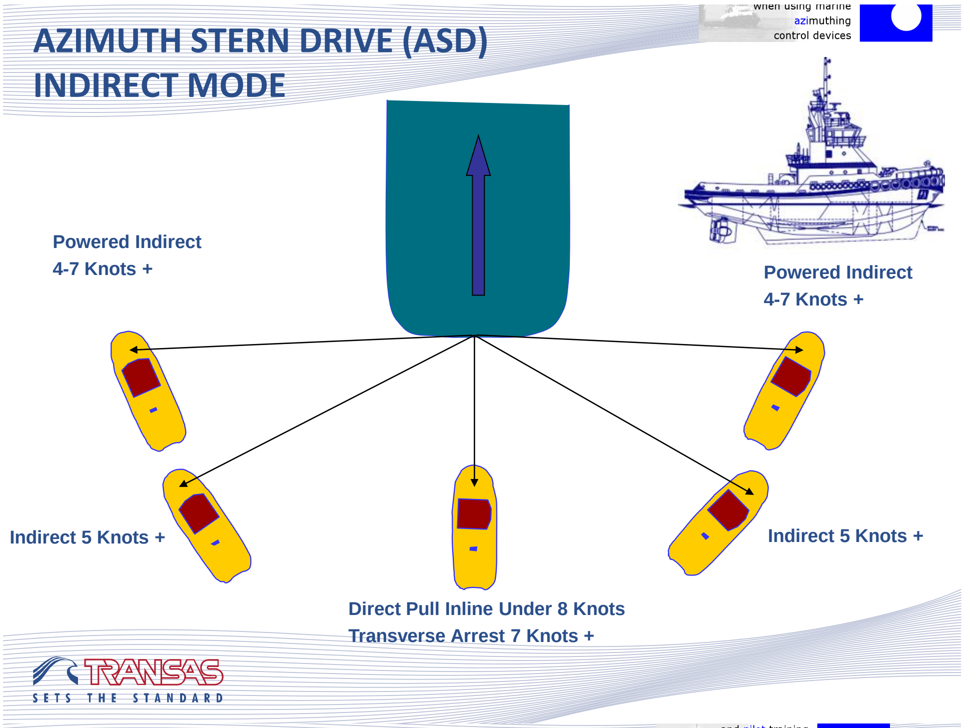
TRANSAS SETS THE STANDARD

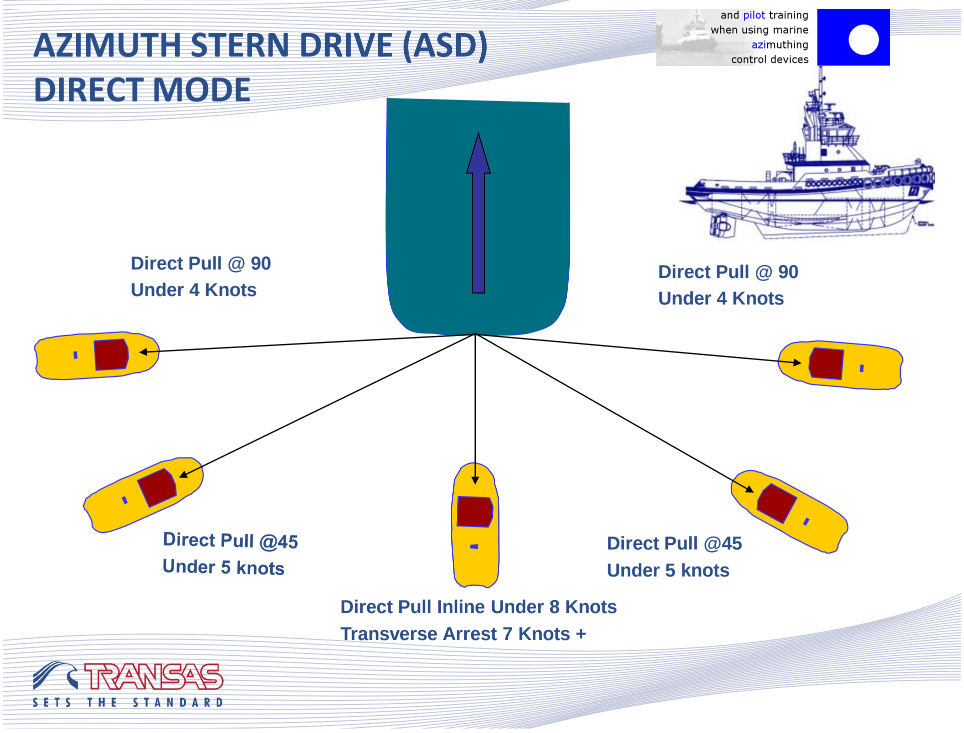

TRACTOR TUGS
when using marine
azimuthing
control devices
Z-Drives forward
Twin Azimuth
Drives forward
Excellent turning lever
TRANSAS
SETS THE STANDARD


AZIMUTH STERN DRIVE (ASD)
and pilot training
when using marine
azimuthing
control devices
Multi Directional Propellers
Rotate through 3600 in the vertical axis
No rudders
Two towing points
One forward
One near amidships
TRANSAS
SETS THE STANDARD


WORKING AN ASD TUG FORWARD
and pilot training
when using marine
azimuthing
control devices
1
2
3
TRANSAS
SETS THE STANDARD


WORKIING AN ASD TUG AFT
Intuitive operation
and pilot training
when using marine
azimuthing
control devices
AZIPILOT
1
2
3
TRANSAS
SETS THE STANDARD


AZIMUTH STERN DRIVE (ASD)
INDIRECT MODE
when using marine
azimuthing
control devices
Powered Indirect
4-7 Knots +
Powered Indirect
4-7 Knots +
Indirect 5 Knots +
Indirect 5 Knots +
Direct Pull Inline Under 8 Knots
Transverse Arrest 7 Knots +
TRANSAS
SETS THE STANDARD


AZIMUTH STERN DRIVE (ASD)
DIRECT MODE
and pilot training
when using marine
azimuthing
control devices
Direct Pull @ 90
Under 4 Knots
Direct Pull @ 90
Under 4 Knots
Direct Pull @45
Under 5 knots
Direct Pull @45
Under 5 knots
Direct Pull Inline Under 8 Knots
Transverse Arrest 7 Knots +
TRANSAS
SETS THE STANDARD

SIMULATION CAPABILITIES ABLE REALISTICALLY SIMULATE PERFORMANCE OF VESSELS EQUIPPED WITH AZIMUTH DEVICES

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

a) Simulation realism requires adequate modelling capability verified with full scale data and pilot handling validation

b) Three alternatives to evaluate hydrodynamic forces on vessels equipped with Azimuth Devices:

- Directly from model tests
- Indirectly from various semi-empirical approaches as synthesis of experimental, statistical and analytical methods
- Indirectly from full-scale trials by applying System Identification (SI) techniques

c) Transas maneuvering simulation model describes motion of the vessels equipped with Azimuth Devices in Six Degree of Motion:

- Various formulations are integrated into simulation model development tool called 'Virtual Ship Yard' (VSY)
- Model Wizard package creates 3D visual image of vessels and navigational data base (along with VSY)

TRANSAS SETS THE STANDARD

VALIDATION OF SIMULATION & HYDRODYNAMIC MODELS OF VESSELS EQUIPPED WITH AZIMUTH DEVICES.

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

a) Full scale trials:

Full scale trials of the (3 x 5) 15 barge and two (2 x 3) and (3 x 2) 6 barge tows with 'M/V Benyard', 4300 HP Tow Tug in Lake Pontchartrain in New Orleans. Average water depth = 5.18 m

- Rake end barges, L x B x T = 59.4 x 10.7 x 2.7 (m)
- Combined LBT: 349.4 m x 32 x 2.7 (m) – 15 Barge Tow
  230 x 21.4 x 2.7 (m) – (2 x 3) 6 Barge Tow
- Instrumentation recorded position, velocities, RPM, rudder angles, and wind every 4 seconds

TRANSAS SETS THE STANDARD

VALIDATION OF SIMULATION & HYDRODYNAMIC MODELS

b) Model Tests

PMM at Hydronautics Model Basin

- 15 Barge Tow, 1/30 scale ratio, L=11.5 m
- 6 Barge Tow, 1/17.5 scale, L=11.62 m
- Deep water and 2 shallow water conditions (H/T = 1.5 and 1.17)
- Measurements of resistance, propulsion and maneuvering forces in Ahead and Astern motions

TABLE 3 EQUATIONS OF MOTION FOR SURFACE SHIP MANEUVERING SIMULATION

AXIAL FORCE

$$
\begin{aligned}
& m\cdot(\dot{u}-v\cdot r-x_g\cdot r^2)= \\
& +\frac{\rho}{2}L^4(X'_{rr}\cdot r^2) \\
& +\frac{\rho}{2}L^3(X'_{\dot{u}}\cdot\dot{u}+X'_{vr}\cdot v\cdot r) \\
& +\frac{\rho}{2}L^2(X'_{vv}\cdot v^2) \\
& +\frac{\rho}{2}L^2\cdot u^2(a_i\cdot+b_i\cdot\eta+c_i\cdot\eta^2) \\
& +\frac{\rho}{2}L^2\cdot u_R^2(X'_{\delta R\delta R}\cdot\delta R^2)+\frac{\rho}{2}L^2(X'_{vv\eta}\cdot v^2)\cdot(\eta-1)
\end{aligned}
$$

LATERAL FORCE

$$
\begin{aligned}
& m\cdot(\dot{v}-u\cdot r-x_g\cdot\dot{r})= \\
& +\frac{\rho}{2}L^4(Y'_{\dot{r}}\cdot\dot{r}+Y'_{r|r|}\cdot r\cdot|r|) \\
& +\frac{\rho}{2}L^3(Y'_{\dot{v}}\cdot\dot{v}) \\
& +\frac{\rho}{2}L^3(Y'_r\cdot u\cdot r+Y'_{vrr}\cdot v\cdot r\cdot r'+Y'_{r|v|}\cdot r\cdot|v|) \\
& +\frac{\rho}{2}L^2(Y'_*\cdot u_*{}^2+Y'_v\cdot u\cdot v+Y'_{v|v|}\cdot v\cdot|v|) \\
& +\frac{\rho}{2}L^2\cdot u_R^2(Y'_{\delta R}\cdot\delta R) \\
& +\frac{\rho}{2}L^3\cdot Y'_{r\eta}\cdot u\cdot r\cdot(\eta-1)+\frac{\rho}{2}L^2\cdot Y'_{v\eta}\cdot u\cdot v\cdot(\eta-1)
\end{aligned}
$$

YAWING MOMENT

$$
\begin{aligned}
& I_z\cdot\dot{r}+m\cdot x_g(\dot{v}+u\cdot r)= \\
& +\frac{\rho}{2}L^3(N'_{\dot{r}}\cdot\dot{r}+N'_{r|r|}\cdot r\cdot|r|) \\
& +\frac{\rho}{2}L^4(N'_{\dot{v}}\cdot\dot{v}) \\
& +\frac{\rho}{2}L^4(N'_r\cdot u\cdot r+N'_{vrr}\cdot v\cdot r\cdot r'+N'_{r|v|}\cdot r\cdot|v|) \\
& +\frac{\rho}{2}L^3\cdot u_R^2(N'_{\delta R}\cdot u_R^2\cdot\delta R) \\
& +\frac{\rho}{2}L^4\cdot(N'_{r\eta}\cdot u\cdot r\cdot(\eta-1)+\frac{\rho}{2}L^4\cdot N'_{v\eta}\cdot u\cdot v\cdot(\eta-1)
\end{aligned}
$$

Where: $u_R^2=e\cdot u^2+funD_p+g\cdot n^2\cdot D_p{}^2$ = flow velocity on rudder,

$u_*^2=d_*\cdot u^2+e_*\cdot funD_p+f_*\cdot n^2\cdot D_p{}^2$ = asymmetry velocity on propeller,

D_p = propeller diameter,

n = propeller rotational speed, RPS.

3. VALIDATION OF HYDRODYNAMIC MODELS

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control devices

Coefficient	15 Barge River Tow				6 Barge River Tow			
	Trial Measurements		PMM Model Tests		Trial Measurements		PMM Model Tests	
	Ahead	Astern	Ahead	Astern	Ahead	Astern	Ahead	Astern
X_{Udot}	-0.000059	-0.000062	-0.000051	-0.000051	-0.000271	-0.000281	-0.000253	-0.000251
X_{vv}	-0.003269	-0.002122	-0.001901	-0.001740	-0.001042	0.000893	-0.001248	0.000793
X_{rr}	0.000027	0.000042	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
X_{vr}	0.000603	0.000585	0.000543	0.000494	0.002363	0.002363	0.002172	0.002212
X_{dd}	-0.000325	0.000192	-0.000245	0.000193	-0.000368	0.000355	-0.000357	0.000372
Y_{*}	0.000008	-0.000008	0.000008	-0.000008	0.000010	-0.000010	0.000010	-0.000010
Y_{v}	-0.003990	0.004258	-0.002409	0.005103	-0.006690	0.009530	-0.006892	0.010605
Y_{r}	0.000593	-0.000288	0.000477	-0.000139	0.000359	-0.000507	0.000293	-0.000830
Y_{vdot}	-0.000723	-0.000651	-0.000820	-0.000775	-0.002080	-0.001971	-0.002502	-0.002585
Y_{rdot}	-0.000076	-0.000086	-0.000076	-0.000063	0.000169	0.000957	-0.000165	0.000410
$Y_{v\|v\|}$	-0.004377	-0.003950	-0.013455	-0.004662	-0.014410	-0.005800	-0.016518	-0.007460
$Y_{r\|v\|}$	-0.000530	-0.000450	-0.000195	-0.000185	-0.000181	-0.000104	-0.000341	-0.000411
$Y_{r\|r\|}$	-0.000280	-0.000310	-0.000136	-0.000131	-0.000333	-0.000581	-0.000037	-0.000021
Y_{vrr}	-0.002066	-0.002145	-0.002782	-0.002230	-0.004880	-0.002450	-0.004048	-0.003130
Y_{d}	0.000329	-0.000220	0.000336	-0.000225	0.000660	-0.000516	0.000613	-0.000681
Y_{vn}	-0.000319	0.000459	-0.000536	0.000503	-0.000480	0.001570	-0.000443	0.001729
Y_{rn}	0.000200	-0.000280	0.000242	-0.000268	0.000196	-0.000443	0.000278	-0.000589
N_{*}	-0.000004	0.000004	-0.000004	0.000004	-0.000005	0.000005	-0.000005	0.000005
N_{v}	-0.000979	-0.001350	-0.000616	-0.001349	-0.001355	-0.003413	-0.001606	-0.003735
N_{r}	-0.000375	0.000409	-0.000339	0.000385	-0.000686	0.000752	-0.000689	0.000760
N_{rdot}	-0.000043	-0.000031	-0.000049	-0.000040	-0.000115	-0.000110	-0.000138	-0.000138
N_{vdot}	-0.000260	-0.000250	0.000071	-0.000060	0.000272	0.000629	0.000135	0.000055
$N_{v\|v\|}$	0.000571	0.000465	0.000692	0.000239	0.000557	0.000820	0.000493	0.001345
$N_{r\|v\|}$	-0.000482	-0.000552	-0.000622	-0.000559	-0.000331	-0.000315	-0.000438	-0.000425
$N_{r\|r\|}$	-0.000180	-0.000192	-0.000156	-0.000211	-0.000344	-0.000301	-0.000345	-0.000417
N_{vrr}	0.000050	0.000120	0.000057	0.000081	0.000661	0.000658	0.000340	0.000265
N_{d}	-0.000171	0.000117	-0.000171	0.000117	-0.000331	0.000267	-0.000301	0.000337
N_{vn}	0.000151	-0.000215	0.000239	-0.000221	0.000243	-0.000801	0.000242	-0.000955
N_{rn}	-0.000082	0.000125	-0.000105	0.000120	-0.000099	0.000223	-0.000149	0.000315
a	-0.000150	0.000550	-0.000326	0.000657	-0.000510	0.000376	-0.000509	0.000346
b	-0.000450	0.000700	-0.000251	0.000414	-0.000610	0.001081	-0.000645	0.001916
c	0.000600	-0.001250	0.000577	-0.001071	0.001110	-0.001457	0.001154	-0.002262
e	0.185000	0.245000	0.147507	0.288542	0.115000	0.165000	0.123212	0.129407
f	0.045000	0.085000	0.109274	0.098623	0.104500	0.148000	0.136592	0.120063
g	0.112900	0.084920	0.152169	0.082881	0.220000	0.085900	0.203606	0.069596

Table 4 Non-Dimensional Hydrodynamic Coefficients (Identified From Trial Measurements and Model Testing)

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3. VALIDATION OF HYDRODYNAMIC MODELS

Intuitive operation
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azimuthing
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c) System Identification (SI)

- Could serve as a validation base for model tests and computer predictions because it provides proper modelling of viscous damping forces
- Adopted SI technique was partially based on methodology to extract aerodynamic coefficients from flight data
- Parametric differentiation process is based on generalization of the concept of small perturbation around a known solution
- Table 2 provides a final set of maneuvering coefficients: differences are in the range 10 – 20%

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COMPARISON OF THE PREDICTION AND TRIAL MANEUVERING PARAMETERS

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Turning Parameters	Trials	System Identification	Model Testing	Transas Simulation
Advance, Ft	2015.	2004.3	1980.5	2095.4
Transfer, Ft	1155.	1132.7	1074.0	1187.5
Tactical Diameter, Ft	2730.	2711.4	2625.7	2788.9

15 Barge Tow

Turning Parameters	Trials	System Identification	Model Testing	Transas Simulation
Advance, Ft	1635.	1617.5	1619.0	1654.1
Transfer, Ft	824.	812.3	838.4	865.7
Tactical Diameter, Ft	-	1873.2	1919.7	1991.4

6 Barge Tow

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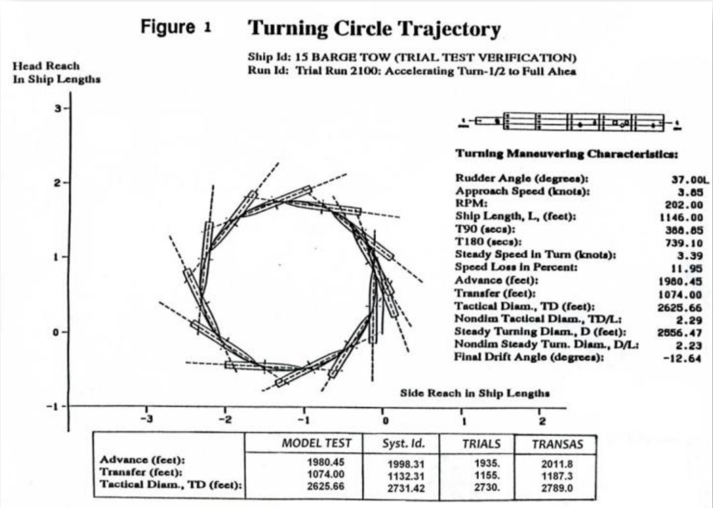
Intuitive operation and pilot training when using marine azimuthing control devices

AZIPILOT



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control devices

AZIPILOT

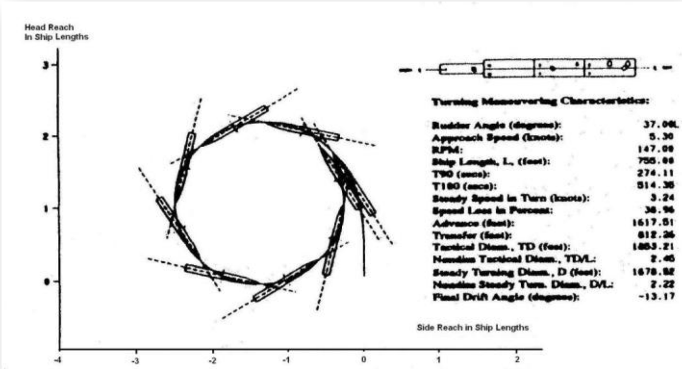

Fig. 2 Turning Circle Trajectory
(Ship Id: 6 BARGE TOW
(TRIAL TESTS CONDITIONS)
Run Id: Trial Run L2011: Hard Turn at Full Ahead)

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when using marine
azimuthing
control devices

AZIPILOT

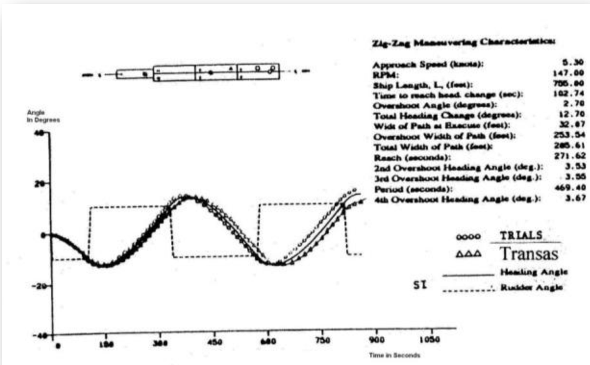

Fig. 3 Left 10-10 Zig-Zag Maneuver
(Ship Id: 6 BARGE TOW
(TRIAL TESTS CONDITIONS)
Run Id: Trial Run L3011: 10/10 Overshoot Maneuver. Full Ahead)

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a) Towing In the notch

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

b) Towing On the Hip

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c) Towing Inland Towboat

d) Towing Barge make up

BRIEF SUMMARY OF SIMULATION CAPABILITIES FOR VESSELS EQUIPPED WITH VARIOUS AZIMUTH DEVICES

- Azimuth devices for TUGS are still developing technology and subject to restrictions until the limitations are addressed
- Azimuth Devices for TUGS offer great advantages in ship handling and significant advantages in technical and hydrodynamic terms
- The modern simulators realistically simulate most of the TUG typical operations including coastal passage, assisting in berthing and anchoring operations and require accurate visual image
- Simulation Improvements should include more accurate modeling of ship-TUG interaction effects and low speed maneuvers with large pods angles
- In application of the TUG podded propulsion in DP systems and in joystick systems, the simulation software has to perform within the latest guidelines and restrictions

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Thank You