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Capabilities of Ship Handling Simulators to Simulate Shallow Water, Bank and Canal Effects

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ABSTRACT: Safe operation of ships in restricted areas, in particular in canals and waterways of restricted width and depth, often with presence of current. depends on operator skill. One way to influence operator skill and hence to increase safety against collisions and groundings is proper training of operators in realistic environment. Training could be accomplished on board ships, which takes, however, long time but also on simulators. There are two types of simulators: full mission bridge simulators (FMBS) working in real time and physical simulators using large manned models in purposeful prepared training areas (MMS). Capabilities of both type simulators are discussed in detail. Capability of FMBS depends on computer codes governing them. Few examples of capability of FMBS to reproduce correctly ship handling situations are shown. There are few MMS in the world, one of which is Ilawa Ship Handling Research and Training Centre. In the centre models of several types of ships are available and training areas are developed representing different naviga-tional situations. The main purpose of the training exercises is to show the trainees how to handle the ship in many close proximity situations, in the presence of current, in very restricted water areas etc.

1 INTRODUCTION

Collisions, rammings and groundings, so called CRG casualties, constitute large part of all casualties at sea (approximately around 60 per cent) (Samuelides & Friese 1984). Therefore reducing risk of CRG casualties contributes largely to the reduction of overall risk of sea voyage.

Risk of CRG casualty depends on several factors, one of which is human factor, i.e. operators skill. Published analyses associated with commercial shipping during recent years indicated that human errors that occurred during handling operations were responsible for approximately 62 per cent of the major claims figure (Payer 1994). Other sources show, that about 80 % of all CRG casualties are results of human failure. Therefore attention is focused recently to the role of human factor in safety. (US Coast Guard 1995).

As about two thirds of all CRG casualties are caused by human error it is necessary to analyse factors which contribute to the efficiency of the operator. The author discussed this subject in the paper presented to Nav 2009 (Kobylinski 2009) showing that one of the most important factors contributing to this is training.

2 SIMULATOR TRAINING

There are several factors contributing to the reduction of the number of CRG accidents, and experience is one of them. Experience is gained over years of practice. Specialized training on simulators accelerates gaining experience, in particular gaining experience in handling dangerous situations that may be rarely met during operation of real ships. Therefore specialized training in ship handling is required by the International Maritime Organisation. Seafarers' Training, Certification and Watchkeeping (STCW) Code, Part A, includes mandatory standards regarding provisions of the Annex to the STCW Convention. Apart training onboard ships, approved simulator training or training on manned reduced scale ship models is mentioned there, as a method of demonstrating competence in ship manoeuvring and handling for officers in charge of navigational watch and ship masters.

Also ship owners companies and pilots organizations attach recently great importance to training on simulators and some pilots organizations require repetition of such training every 5 years.

Obviously the best way to train ship officers and pilots in shiphandling and manoeuvring is to perform training onboard real ships. Any use of simulators should be in addition to training onboard ships. However, gaining skill "on job" watching experienced practitioner working is a long and tedious process. Moreover certain handling situations including some critical ones may never occur during the training period onboard ships and no experience how to deal with such situations could be gained this way. When serving on ships engaged in regular service there is little or no possibility to learn about handling in critical situations because such situations must be avoided as far possible.

Simulator training is expensive, therefore the simulator courses must utilize time available in the most effective way. In order to achieve positive results simulators must be properly arranged and the programme of simulator exercised should be properly planned in order to achieve prescribed goals.

In general, simulators may be either equipment or situations. A simulator is defined as any system used as a representation of real working conditions to enable trainees to acquire and practice skills, knowledge and attitudes. A simulator is thus characterised by the following:

- imitation of a real situation and/or equipment which, however, may permit, for training purposes, the deliberate omission of some aspects of the equipment in operation being simulated, and
- user capability to control aspects of the operation being simulated.

The effectiveness of a simulator in training mariners depends on the simulator capabilities to simulate the reality. Sorensen (2006) stressed the point that simulators must be realistic and accurate in simulating the reality. Therefore simulators should, apart from simulating properly the main manoeuvring characteristics of a given ship, i.e.

- Turning characteristics
- Yaw control characteristics
- Course keeping characteristics and
- Stopping characteristics

be capable to simulate different factors influencing ship behaviour, e.g: at least:

- Shallow water effect
- Bank effect
- Effect of proximity of quay or pier
- Effect of limitation of dimensions of harbour basin
- Surface and submerged channel effect
- Ship-to-ship interaction
- Effect of current
- Effect of special rudder installations, including thrusters
- Effect of soft bottom and mud
- Ship-tug cooperation in harbour (low speed towing) and.
- Escorting operations using tugs
- Anchoring operations.

3 FULL MISSION BRIDGE AND MANNED MODELS SIMULATORS

Simulators used in training in ship handling and manoeuvring are basically of two types : Full Mission Bridge Simulators (FMBS) and Manned Models Simulators (MMS).

FMBS computer controlled simulators are widely used for training of ship officers, pilots and students of marine schools and also for studying various manoeuvring problems, first of all problems associated with the design of ports and harbours.

There is at present a considerable number of such simulators of different types operating throughout the world, starting from desk simulators to sophisticated FMBS where the trainee is placed inside a bridge mock-up with actual bridge equipment, realistic visual scene of the environment, and sometimes rolling and pitching motions and engine noise.

FBMS are working in the real time and are controlled by computers programmed to simulate ship motion controlled by rudder and engine (and thrusters or tugs) in different environmental conditions

MMS use large models for training purposes in specially arranged water areas, ponds or lakes. Models are sufficiently large in order to accommodate 2-4 people (students and instructors) and are constructed according to laws of similitude. Models are controlled by the helmsman and are manoeuvring in the areas where mock-up of ports and harbours, locks, canals, bridges piers and quays, shallow water areas and other facilities are constructed and where also routes marked by leading marks or lights (for night exercises) are laid out all in the same reduced scale as the models. Also in certain areas current is generated. As a rule, monitoring system allowing to monitor track of the model is available.

Important feature of manned model exercises is that all manoeuvres are performed not in real time, but in model time which is accelerated by the factor λ^{-1}. This may pose some difficulties for trainees at the beginning who must adjust to the accelerated time scale.

Currently there are only few training centres using manned models in the world, however, according to the recent information, few others are planned or even in the development stage.

4 CAPABILITIES OF FBM SIMULATORS

In FMBS because there is a mathematical model of ship motion on which computer codes are based it is important that this mathematical model represents properly behaviour of the real ship. In spite of great progress in the development of the theoretical basis of ship manoeuvrability not only in unrestricted water areas (turning, course-keeping and stopping characteristics), but also in the proximity of other objects (bank, shallow water effects and the effect of other ships), the last effects are still investigated not sufficiently enough. Sophisticated computer programmes that include calculations of hydrodynamic coefficients using advanced methods requiring powerful computers and extreme large memory. simulating the close proximity effects cannot be used in FBMS because they must work "on line" therefore rather simplified methods must be developed for this purpose.

Practically all modern FMBS are capable to simulate manoeuvring and ship handling characteristics in open water properly. Usually they are also capable to simulate the close proximity effects based on simplified theory. But in many cases even simple manoeuvres such as turning circle manoeuvre or zigzag manoeuvre are often simulated not accurately enough. Gofman & Manin (1999, 2000) showed several cases where results of simulation on Norcontrol SH simulator differed considerably from results obtained during tests of full-scale ships. One may however argue that results shown by Gofman were obtained in nineties of the last century and modern simulators are much more effective.

There is little information available on the validation of the effectiveness of FBMS. Some data on comparison of simulated and measured at full scale trials of few ships were collated by Ankudinov (2010) and one example of simulation of turning circle test on TRANSAS simulator is shown in Table 1.

Fig 1 shows results of comparison of simulated and measured characteristics of stopping manoeuvre of the ship ARKONA. Simulator in this case was ANS 5000 developed by Rheinmetall Defence Electronics GmbH (de Mello Petey 2008). In both cases it is seen that the simulation is quite reliable.

Results of simulation of manoeuvring capabilities of POD driven ships on this simulator are also available (de Mello Petey 2008) and by Heinke(2004). The code used in this simulator 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.

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

	Manoeuvre to port		Manoeuvre to starboard	
	Simu-lated	Actual	Simu-lated	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 [knots]	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

The high level of accuracy achieved by the simulation module 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 (de Mello Petey 2008).

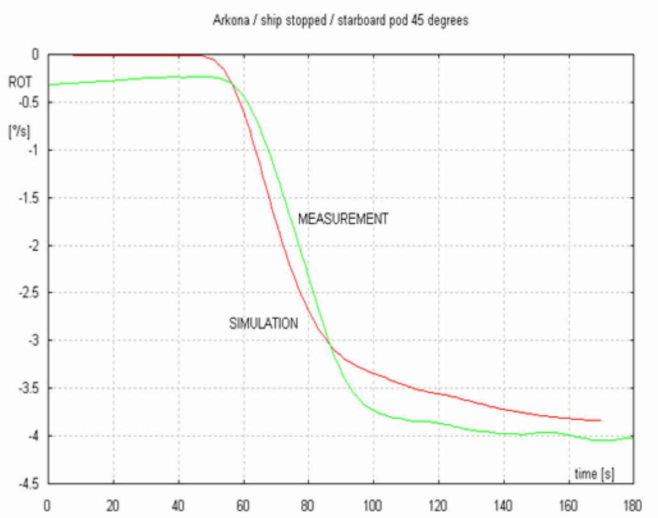

Figure 1. Comparison of simulated and measured characteristics of stopping manoeuvre ARKONA ship (Ref. 27)

The technique used by TRANSAS in simulating manoeuvring characteristics of ships in shallow water and the bank effect is based on the generalized flow pressure functional describing motion effects and variable pressure field of maneuvering ship in the restricted channel of variable bottom and banks in the presence of other stationary or moving ships. The developed technique is fairly complex and best suited for solid unmovable objects in the channel (walls, moored ships). The modeling of proximity of other maneuvering ships of various types moving with various heading angles and velocities needs however further refinement (Ankudinov 2010).

Gronarz (2010) reported results of the simulation of shallow water and bank effect in four most modern FBMS, marked A,B,C,D. The results of simulation of speed loss in shallow water and increase of turning diameter are shown in figs. 3 and 4.

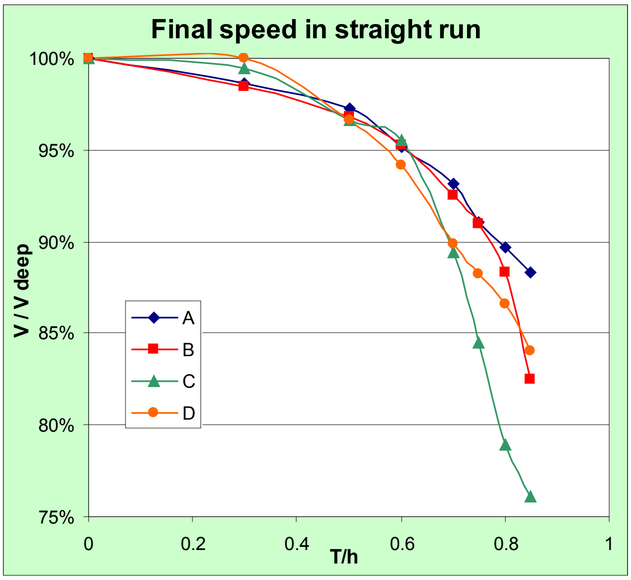

Figure 2. Speed loss with reduced UKC

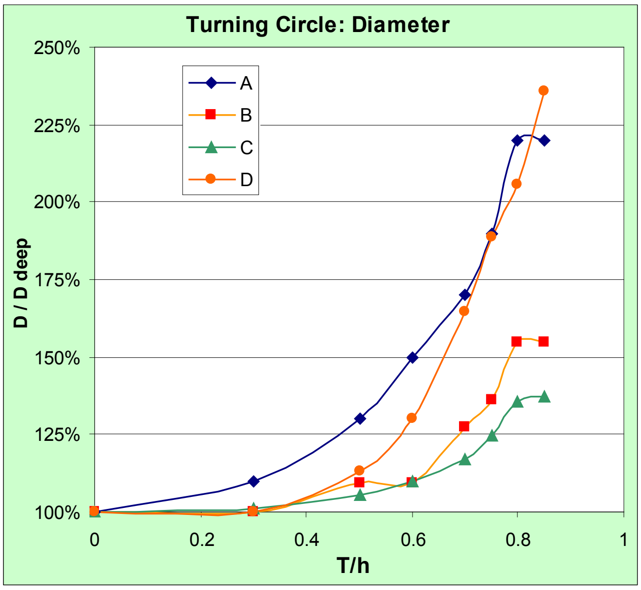

Fig 3 Increase of turning circle diameter with reduced UKC

In deep water a ship can reach the highest velocity using constant revolutions of the propeller. With reduced UKC, i.e. increased T/h the speed loss will increase. In general all simulators show loss of speed with decreasing depth of the water as it can be seen in fig. 2. However, for T/h=0.3 i.e. the case where UKC is more than twice the draught of the ships gap the speed loss should only be marginal. This is represented correct for simulators C and D, but simulators A and B show significant loss of speed which is not correct. On the other hand at very shallow water (T/H~0.8) the speed loss shown by simulators A and B is not great enough as it should be.

The simulated turning circle diameters in shallow water are larger, as expected (Fig.3).

However simulator A shows increase of turning diameter in rather deep water (T/H=0.3) which is not correct. As it is seen from fig.3 the increase in diameter in shallow water is significantly different. The range of 35% (C) to 135% (D) increase seems unusual. Also for simulators A, B and C the turning diameters are nearly constant for T/h=0.80 and 0.85 which contradicts the theory. This means that simulation of shallow water effects are not represented by all simulators correctly and the computer codes used have to be improved.

5 CAPABILITIES OF MMS SIMULATORS

In the case of manned models the governing law of similitude is Froude's law and all quantities for models are calculated according to the requirements of this law. However, as it is well known, the requirements of second law of similitude which is relevant to ship motion, Reynolds law, cannot be met. This means that the flow around the ship hull and appendages and in particular separation phenomena might be not reproduced correctly in the model scale. Fortunately those effects are important when the models are small. With models 8 to 15 m long the Reynolds number is sufficiently high to avoid the majority of such effects.

One important difficulty with manned models is impossibility to reproduce wind effect. Wind is a natural phenomenon and according to laws of similitude wind force should be reduced by factor λ^3 (λ - model scale). Wind force is proportional to the windage area and to the wind velocity squared. Windage area is reduced automatically by factor λ^2 but wind velocity apparently cannot be reduced. However, actually windage area in models is usually reduced more than by factor λ^2, and wind velocity. due to sheltered training area and low position of the windage area in the model in comparison with the full-scale ship is considerably reduced. Still usually wind force is larger than it should be.

Capability of manned models to simulate shallow water, bank, submerged and surface canal effects, effect of current, close proximity of other stationary or moving objects is automatically assured and is practically unlimited, restricted only by local conditions in the training area.

As there are only few manned model centres operating in the world, facilities arranged in the Iława Ship Handling Research and Training centre are shown below as an example.

As safe handling of ships is much more difficult in restricted areas and in presence of the current, in Iława Ship Handling Centre there are artificially prepared training areas that, apart of the standard model routes marked by leading marks, leading lights (at night) and buoys, comprise also routes particularly suitable for training ship handling in canals and shallow and restricted areas. They include:

- restricted cross-section surface canal of the length 140m (corresponding to 3.3 km in reality), called Pilot's Canal. In this canal exercises comprising passing the canal feeling bank and restricted cross section effects, stopping ships in restricted width of the fairway, meeting and overtaking with two or three ships feeling interaction effects are performed,
- wide (corresponding to about 360m width in reality) shallow water canal of the length corresponding to about 1.5 km, where current could be generated from both sides, called Chief's Canal. Passing the shoal, feeling slowing down and squat, berthing in shallow water, turning the ship in shallow water and in current and similar exercises are performed.
- long (corresponding to about 2.5 km in reality), narrow deep water waterway comprising several bends, marked by buoys, simulating some routes in fiords and similar areas called Captain's Canal,
- narrow fairway restricted from one side by the shore, called Bank Effect Route where ships are supposed to feel bank effect,
- narrow passages, including narrow passage under the bridge feeling the close proximity effect,
- river estuary area where several current generators installed create current. Several mooring places are provided in the estuary, including sheltered dock. Current pattern and velocities could be adjusted by activating particular current generators, the maximum current velocity correspond to 4 knots in full scale.(fig.4). There is possibility to arrange several exercises where ships make manoeuvres in current.
- locks, deep and shallow water docks for docking ships in different situations, harbour basins of different dimensions and configuration of the entrance
- mock-up harbour basins, locks, bridges, fairways and other arrangements existing in different parts of the world as the need arises.

6 CONCLUSIONS

It appears that simulator training in ship handling becomes more and more popular and some pilots organizations require now refreshing such courses every five years.

From the experience with FBMS and MMS simulators it is now clear that they do not supersede but rather they supplement each other, because the purpose of training on each of them is different.

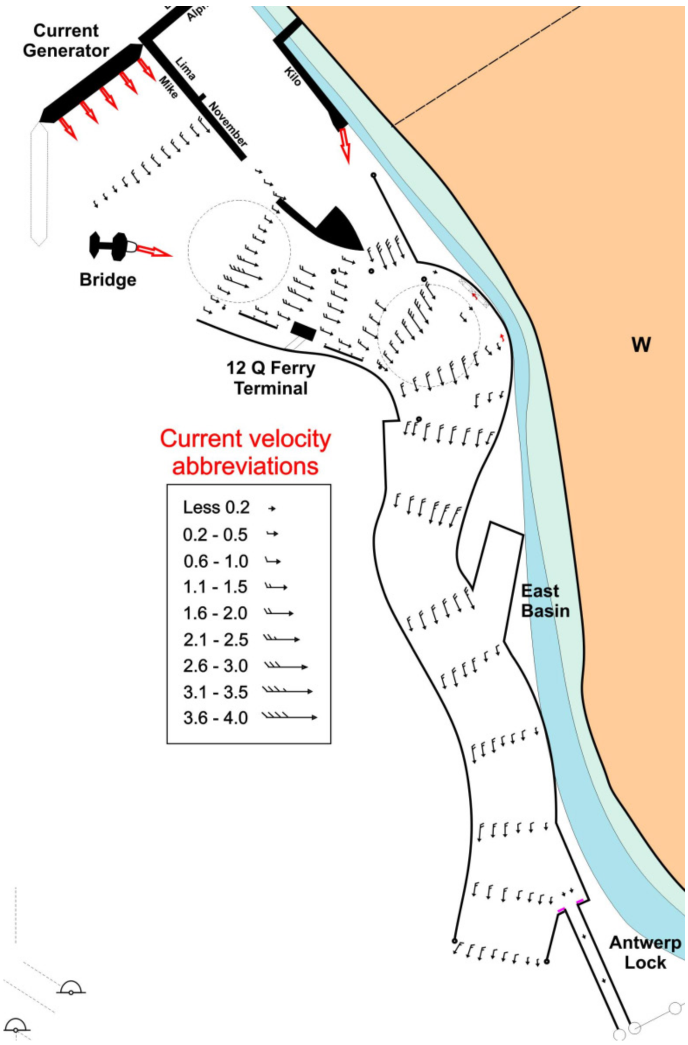

Figure 4. Arangement of the river estuary at Ilawa centre

Capability of FBMS depends on the reliability of computer codes governing them, that are still far from perfection, and the quality of visualization of the situation around the ship simulated. They are particularly suitable to simulate situations in some ports, canals, approaches etc, and master and pilots may learn how to maneuver in this particular situation. FBMS may be used also as a tool for harbour design.

The capability of MMS depends on the possibility of making different arrangements such as described above in the training area available. From this point of view Ilawa training centre in comparison to the other centres (Port Revel and Warsash) has the advantage of having to its disposal large water area (Silm lake),where different arrangements could be installed.

The purpose of training on manned models is mainly to make the trainees aware of different hydrodynamic effects, in particular close proximity interactions, which may be easily arranged. High realism and automatically hydrodynamic correct representation of close proximity situations is the main advantage of MMS.

Tugs action, escort and anchoring and ship-to-ship operations, simulation of which is attempted also in FBMS are particularly realistic when using manned models.

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