Development of Onboard Ship Manoeuvring Simulators and their Application to Onboard Training

Hideo YABUKI[1], Takahiro TAKEMOTO[2], Tsuyoshi ISHIGURO[3] and Hikaru KAMIIRISA[4]

[1] *Tokyo University of Marine Science and Technology, Japan.*
[2] *National Institute for Sea Training, Japan.*
[3] *IHI Marine United Inc, Japan.*
[4] *Akishima Laboratories（Mitsui Zosen）Inc, Japan*

Abstract

The authors developed two types of onboard ship manoeuvring simulators and a new onboard training method utilizing an onboard Ship Manoeuvring Simulator (SMS) that makes practical onboard training for cadets more successful and efficient. This paper describes the outline of the developed simulators and the results of an experiment conducted on a training ship that aimed at assessing the feasibility and the effectiveness of the proposed training method. Based on the results of the experiment, the authors propose an optimal combination of onboard SMS training with real training on a training ship and designed another onboard SMS to overcome the limitation of the first onboard SMS.

Keywords: onboard ship manoeuvring simulator, onboard training, maritime education and training.

1 Introduction

New maritime education and training methods that will improve the quality of onboard training are desired since the supply of able young officers is strongly requested from the maritime community in Japan. Combining classroom simulator training and onboard training was found to be effective by MURATA, et al. [1]. Use of an SMS makes it possible to provide training using the same scenario repeatedly and cadets can master each technical element for ship

handling (elemental techniques [2]) one by one. On the other hand, onboard training offers a unique opportunity for cadets to master integrated ship-handling techniques that take into consideration the effects of such external disturbances as wind and tide, and to develop an ability to make appropriate and quick decisions in ship handling, which is indispensable for deck officers [3]. From this point of view, the authors developed two types of onboard SMS and proposed a practical onboard training method for cadets that combined simulator training with onboard SMS (onboard simulator training) and real training on a training ship (onboard training). The first onboard SMS was a compact type simulator which was installed in a lecture room of the 5,884 G.T. training ship Seiun Maru. For the effective operation of the proposed training method, it is necessary to assess the effectiveness of onboard simulator training for all elemental technique items and determine training items suitable for simulator training. The authors performed an onboard experiment using Seiun Maru to compare the outcome of onboard simulator training and that of real training. The results indicated that the training with the onboard simulator was effective. However, the real training was more effective than the simulator training for certain ship-handling skills apparently because the real equipment was not used for the compact type onboard SMS. To overcome the limitations of the compact type SMS, we designed another onboard SMS utilizing the real equipment on the training bridge of the 6,000 G.T. training ship Ginga Maru, which was launched in June, 2004.

2   Outline of the first onboard SMS

The first onboard SMS was developed for the purpose of supporting a practical onboard training for cadets. The original model of the onboard SMS was the compact-size SMS "IHI-SMS-EC110". The function of the onboard SMS is almost the same as that of a full-size SMS.
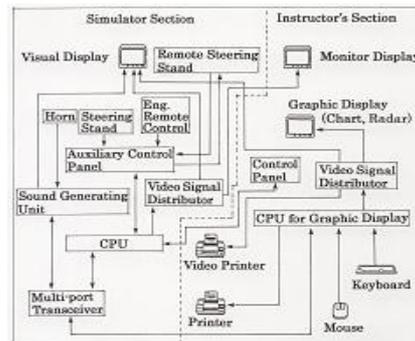

Fig. 1:   System configuration of the first onboard SMS

A precise hydrodynamic mathematical model of Seiun Maru and the sea area database where the ship operates during the onboard training were installed in this simulator. The simulator is composed of the simulator section and the instructor's section shown in Fig.1. This simulator is designed so that all operation for training can be carried out by the auxiliary control panel in the

simulator section. Therefore, cadets can use the simulator by themselves at the time of their demand without the assistance of instructors. The instructor's section is composed of the instructor's monitor, graphic display and control panel. The instructor's section allows users to produce a training scenario, monitor a visual display images, set environmental conditions and record the result of training. The original compact-size simulator is designed for the trainee's individual training. The developed simulator can also be used to the team training by using the portable box type remote wheel stand.

3 Onboard Experiment

3.1 Method

The experiment was performed using the first onboard SMS and Seiun Maru. In the experiment, we chose anchoring practice as the training item for cadets, since it requires integration of various ship-handling techniques. This training is provided in the middle of their 1-year onboard training term. The trainees were 33 cadets of universities of mercantile marine and their previous onboard training experience was approximately 4 months. The cadets' task was to weigh anchor at one anchorage and put the ship to anchor at another pre-designated anchorage. The cadets did the task in a team that consisted of 3 cadets each of whom, in turn, played 3 roles of Captain (Capt.), First officer (1/O) and Third officer (3/O). The cadets were divided into two groups of A and B, and the group A cadets went through the simulator training first and then the real onboard training, and the opposite was the case for the group B cadets. Group A consisted of 17 teams and group B consisted of 16 teams. The procedure of the experiment was as follows:

(1) All of the cadets had 9 hours of explanatory lectures on the outline of the practice, manoeuvrability of the test ship, the procedure of anchoring, planning of ship handling and the bridge teamwork.
(2) The cadets made their ship-handling plans and the instructors (Captain or Senior Professor who has the experience of Captain) checked them and gave appropriate advice.
(3) Group A had the onboard simulator training using the same scenario as in the real practice.
(4) Group A and B had the real anchoring practice using the test ship.
(5) Group B went through the same simulator training as group A.

In the experiment, ship-handling skills of the cadets in the real training were scored by the Captain or Senior Professor according to a check list and the Chief Officer did the same scoring in the onboard simulator training. Each of the evaluation items was related to a small technical element of total ship-handling techniques (items of elemental technique [2]), and the instructors graded each item as "good (3 points)", "fair (2 points)" or "poor (1 point)". The detailed evaluation items on the role of Capt. are shown in Table 1. The obtained scores were converted to ability rank scores given in percentage for each elemental technique using the method proposed by ARAI, et al. [4].

Table1: Details of evaluation (Capt.)

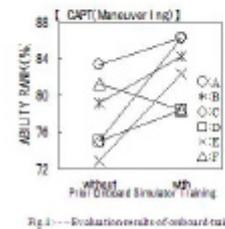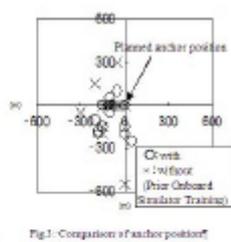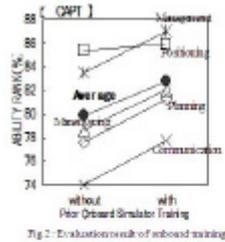| Elemental Technique	Evaluation Item
Planning	Use of marks for ship-handling, Standard of speed control, Proper alteration of maneuvering plan according to external disturbance, Approach to anchorage, etc.
Positioning	Use of heading marks to measure deviation from course line, Use of beam marks to measure distance to anchorage, Estimation of external disturbance, Difference between actual anchor position and planned anchor position.
Maneuvering	Course setting according to ship's speed, ship's position & external disturbance, Speed control for course keeping, Speed control according to ship's position & external disturbance.
Communication	Helm order, Order to mates, Communication to eng. room and bow. (Timing, Clear voice, Correct term)
Management	Prior information to eng. room & bow (Timing of S/B eng., etc.), Actual state information to eng. room & bow (Distance to anchorage, etc.), Manner & self-possession as commanding officer, Ability that get the picture in the bridge, Attitude as commanding

3.2 Results

3.2.1 Effects of the prior onboard simulator training on the real training

We compared the ship-handling technique rank of group A (cadets with prior onboard simulator training) with those of group B (cadets without prior onboard simulator training) for each elemental technique in the real anchoring practice. The comparison results on the role of Capt. are shown in Fig.2. The vertical axes show the mean value of ship-handling technique rank (ability rank scores [4]) of each group. In general, the ability rank scores of group A are higher than those of group B for all elemental techniques. The evaluation results indicate that prior onboard simulator training is useful for cadets to prepare for their real anchoring practice. This result is almost the same as that of classroom simulator training evaluation conducted by KOBAYASHI et al. [5] qualitatively. Fig.3 shows the deviation of the actual anchor positions for both groups from the pre-designated position in the real anchoring practice. The anchor positions of group A are closer to the target position than those of group B on average and the group B anchor positions are more widely scattered around the target than the group A anchor positions. This indicates that prior onboard simulator training is effective in improving the integrated ship-handling technique of the cadets. Therefore, we can conclude that prior onboard simulator training is effective to improve the ship-handling technique of cadets.

With respect to the "positioning" technique, the ability rank scores are almost the same for both groups. This may be because it was difficult for the cadets to estimate the effect of wind and tide accurately by means of bearing observation of a heading mark, and only one practice session with the onboard simulator was not enough to improve the skill. For the mastery of this kind of advanced technique, repeated practice by actual training ship seems to be effective.
The details of the evaluation results on the "manoeuvring" technique are shown in Fig.4. The ability rank scores of group A are higher than those of group B for all the evaluation items except item F. The ability rank score differences are the largest for evaluation items C and E. It seems that the cadets tried to master the techniques for adjusting her course and for controlling her speed according to the

obtained position (C, E) in the prior simulator training since the instructors explained the importance of these techniques for the accurate anchoring in the briefing. On the other hand, no such large group difference is observed with respect to the technique related to adjusting her course according to the external disturbance (F). Perhaps, the reason is that it was difficult for the cadets to master this technique in the prior simulator training, since the wind that existed in the simulator scenario was not strong enough for the novice cadets to realize its effect. This technique will be improved by introducing a strong external disturbance in the simulator training scenario.

Fig.2 : Evaluation result of onboard training

Fig.3 : Comparison of anchor position

Fig.4 : Evaluation results of onboard training (Manoeuvring)

Mark	Evaluation Item (Manoeuvring)
A	Course setting according to ship's speed
B	Speed control for course-keeping
C	Course setting according to ship's position
D	Speed control according to external disturbance
E	Speed control according to ship's position
F	Course setting according to external disturbance
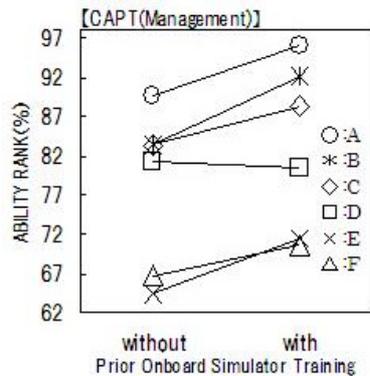
Mark	Evaluation Item (Management)
A	Advance information to engine room & bow. (planned anchor, planned depth of water, timing of S/B engine)
B	Actual state information to engine room & bow. (distance to anchorage)
C	Clear voice order as Commanding officer
D	Self-possession as commanding officer
E	Ability that get the picture in the bridge
F	Attitude as Commanding officer

Fig.5 shows the evaluation results of the "management" technique. The figure indicates that all the items except D (self possession as a commanding officer) improved after onboard simulator training. Obviously beginners always feel stress during their actual ship handling but it is difficult to overcome this pressure in the simulator training simply because it lacks reality. This result indicates that the real onboard training is indispensable for the mastery of integrated ship-handling techniques.

3.2.2 Effectiveness of the real training
We made the same comparison described in 3.2.1 on the onboard simulator training to study the effectiveness of real training. Fig.6 shows the comparison results of the ability rank scores of the two groups. It can be seen from the figure that the ability rank scores of the cadets with real onboard training (group B) are

higher than those of the cadets without real onboard training (group A) for all elemental techniques. The average ability rank score difference between group B and A is14% and this figure is bigger than that of the evaluation results on the real training. Fig.7 shows the details of the evaluation results on the "manoeuvring" technique of the Capt. The ability rank scores of group B are higher than those of group A for all the evaluation items. With respect to the techniques for adjusting her course and for controlling her speed according to the measured position (C, E), the ability rank score differences between the two groups are quite large. These results are almost the same as those of the real training evaluation qualitatively. There is little difference between the two groups on the techniques for controlling her speed and for adjusting her course according to external disturbance (D, F). These results are almost the same as in the case of the real training evaluation. This is probably because these techniques can only be mastered after a considerable amount of ship handling experience. The detailed evaluation results on the "management" technique are shown in Fig.8. The ability rank scores of group B are higher than those of group A for all evaluation items and the differences between the two groups are large compared with those in the real training evaluation results shown in Fig.5.
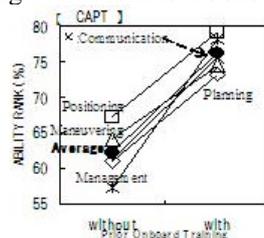

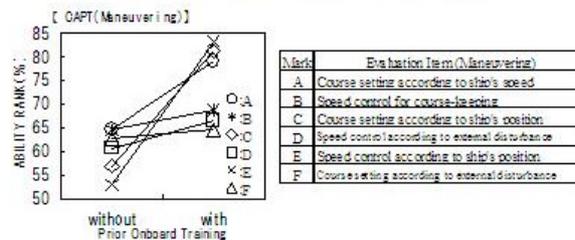Fig.6:   Evaluation results of onboard SMS training

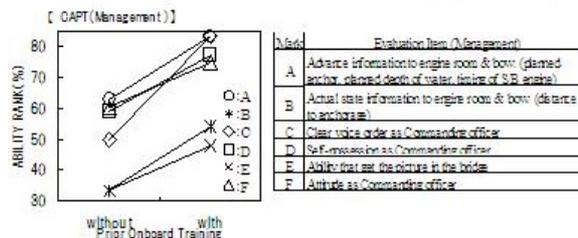Fig.7:   Evaluation results of onboard SMS training (Manoeuvring)

Fig.8:   Evaluation results of onboard SMS training (Management)

For the technique of self-possessed commanding (D), the ability rank difference between the two groups is large. The evaluation results shown in Fig.8 may indicate the advantage of real training over simulator training on the development of the ability of appropriate and brisk commanding in ship handling. We consider that the real training is more effective than the onboard simulator training for cadets to master the integrated ship-handling techniques and onboard training is indispensable to train competent seafarers.

4　Application of onboard simulator training to onboard training

From the results of the experiment described in the previous sections, one can conclude that prior onboard simulator training is effective for the improvement of such techniques as manoeuvring, management and bridge teamwork. Real training, on the other hand, was found to be indispensable for developing integrated ship-handling technique. The authors developed a training procedure shown in Fig.9 for the effective operation of the proposed training method that combined onboard SMS training and real training.

The merits of this training procedure are summarized below.

Fig.9:　Proposed onboard training procedure combined with onboard SMS

(1) Simulator training replicating actual training, given prior to the real ship handling training, is expected to improve cadets' ship-handling techniques.
(2) Since an SMS is installed onboard a training ship, both SMS and real ship training sessions can be given with a little lapse of time between them, making the training scheme highly effective.
(3) The real training can be performed smoothly and efficiently because cadets can confirm their ship-handling techniques and improve them by the prior SMS training.
(4) Instructors can evaluate ship-handling techniques of cadets both in the SMS training and the real training using the same check list and can give proper advice based on the evaluation results, which will help the cadets learn their ship-handling techniques systematically.
(5) The explanation of the suitable training items for SMS training and those for real training by instructors in the briefing will assist the cadets to
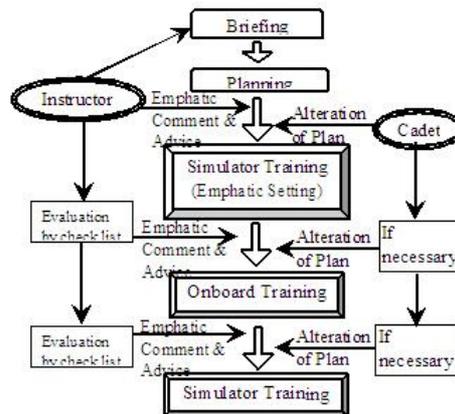
understand the important training items in each training session.

(6) Cadets can confirm their ship-handling plan in the SMS training prior to the real training and can revise it according to the advice of instructors.

(7) Extreme external disturbances such as wind or tide included in the prior SMS training scenario can help cadets learn to take these factors into consideration and to control the ship appropriately.

(8) Any ship-handling techniques of cadets that are not satisfactory can be focused on in further supplemental SMS training sessions.

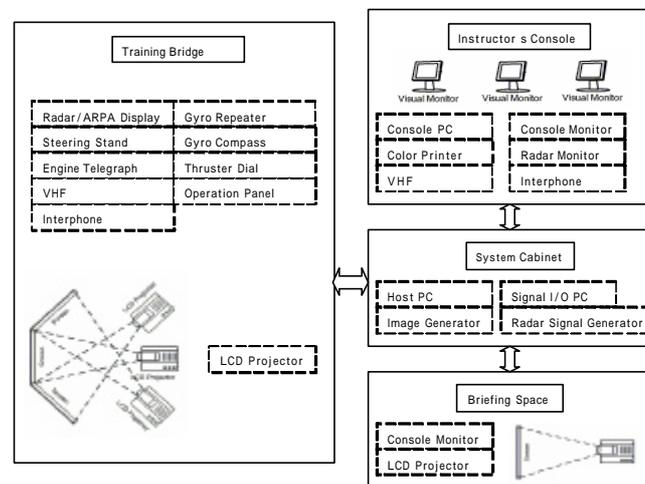## 5　Development of the second onboard SMS

Fig.10:　System configuration of the second

Based on the results of the experiment described in section 3, the authors developed another onboard SMS and installed it on the training ship Ginga Maru. The function of the simulator is as good as that of a full mission SMS. The simulator was designed to utilize the real equipment on the training bridge of Ginga Maru to overcome the limitations of the first onboard SMS of Seiun Maru. The equipment installed in the training bridge of Ginga Maru, which is arranged under the navigation bridge, is almost the same as the equipment in the navigation bridge and cadets can manoeuvre the ship on the training bridge. This makes it possible to practice, using the simulator, such techniques as position fixing and nautical instrument operation, which was difficult with the compact-size SMS of Seiun Maru.

The system configuration of the simulator is shown in Fig.10. The simulator section is installed on the training bridge. The visual system is composed of three sets of liquid crystal projectors and 85-inch wide screen and the range of vision is 135 degrees. The real equipment on the training bridge such as Radar/ARPA,

Steering stand, Bearing compass, Engine telegraph and VHF telephone are used as the equipment of the simulator. The instructor's console is composed of a console PC with LCD monitor, three visual monitors, a Radar/ARPA monitor and training recording devices. A 100-inch wide liquid crystal projector, a console PC with LCD monitor and other devices are installed in the briefing space that is located in the exercise room. In addition to the simulator, a TV camera and microphone system for the simulator training evaluation are installed in the training bridge, instructor's console and briefing space. When briefing or debriefing in the exercise room, simulator screen images and radar images can be displayed on the 100-inch projector by connecting the control PC of the instructor's console with the one in the navigation exercise room.

A unique function of this simulator is the real ship-handling replay function. The manoeuvring data of Ginga Maru such as position, course, speed, rudder angle, engine motion and the target ship's AIS information can be collected using her Local Area Network (LAN) system. The simulator can replay the real ship handling of its own ship and the movement of the target ship in a training area on the screen in the exercise room based on the actual data. This function of the simulator will be effective for the evaluation of the real ship handling of the cadets and will assist them to enhance their ship-handling skills.

We are currently planning to access the effectiveness of onboard training with this new simulator, which uses the actual nautical equipment and has an additional and innovative "replay" function.

6 Conclusions

Results obtained in this study are summarized as follows.
(1) It is confirmed that effective training on a training ship can be achieved by combining onboard SMS training and real training.
(2) Prior onboard SMS training is helpful and effective for cadets to improve their ship-handling techniques. However, onboard training is indispensable for cadets to master the integrated ship-handling technique since simulator training is difficult to provide the "reality" that real ship handling has.
(3) In the briefing, instructors should provide the cadets with the information on the important training items in the SMS training and those in the real training. This will make onboard SMS training and real training more effective.
(4) As for the application of the proposed training procedure described in the section 4, it is important to make a proper training scenario after selecting the suitable training items for the SMS training and those for the real training. Proposed training procedure can be applied to such practices as collision avoiding manoeuvre, route navigation and approaching manoeuvre in addition to the anchoring practice.

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