Study on the Human Error by Unskilled Trainee in Marine Engine Plant Operation*

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This paper, for the purpose of machinery plant operation training by means of Engine Room Simulator (ERS) based on PC, describes the features of human errors by the unskilled trainees in the marine engine plant operation and shows the necessary improvement in the training in order to decrease such errors from the viewpoint of educational technology. Human error data were collected out of the simulator operation record and observation of the trainees in VIMARU (Vietnam Maritime University). The examination of such data has shown that error occurs mainly by omission error and extraneous act. Further analysis was made on such errors by the trainees to find out the characteristics of errors caused in the process of acquiring procedural knowledge for the operation. The analysis has revealed that the human errors occur for the following reasons:

- (1) Lack of knowledge on the over all system and fundamental operation
- (2) Insufficient confirmation to operation
- (3) Incomplete knowledge on the operational sequence

In this paper, the roles of instructor will be described in order to reduce the cause for such human errors and to enhance the educational performance.

1. Introduction

The operational knowledge on the marine engine plant, which is a part of the duty of marine engineer, is procedural knowledge necessary for the smooth operation of the machinery. The unskilled trainee has to acquire such knowledge by actual operating experience on board or by educational training. Since the unskilled trainee are assumed to make a lot of human errors, OJT (On the Job Training) which is the training on the actual operation of the marine engine plant, would be a risky selection. The simulator training is a safe training that never damages machinery and others and, therefore, is effective in learning fundamental knowledge on the machinery operation before starting of the OJT.

Besides, one of the special features of this PC based ERS is that the trainee can use the simulator for themselves according to their own level^[1]. This ERS has been introduced, as effective training equipment to the trainee before going on board, to Marine Technical College and VIMARU, in Vietnam.

In the simulator training, the operational behavior of the trainee, or operational procedure of the trainee until he makes the machinery to a certain state, is recorded as data for an easy review.

Checking such operational procedure from the point of operational error will be helpful for the instructor to know how the machinery should be operated to the trainee, what are the necessary or unnecessary knowledge for operation and whether the instructor's know-how is appropriated or not.

The reason that this paper remarks to the unskilled trainee is because their experience level is low and therefore the effect of simulator training can be found without being affected by actual experienced knowledge.

VIMARU data are used because VIMARU has exactly the same simulator as that of this study and also in order to find the effect of difference of educational syllabus for machinery.

Data for analysis were the operational history of the simulator and the operational procedure of the trainee recorded by a video camera in the simulator training room of VIMARU.

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2. Method of Data Collection

2.1 Purpose of Data Collection

The purpose of simulator training of the marine engine plant is to acquire procedural knowledge that is to know the present situation of the machinery plant and the preparatory operation for the next step^[2]. The data in this case will mainly be the history of operational procedure for the operation.

For example, in the case of transferring of water in the tank to the other, the very necessary thing is to find out whether water is in the tank or not and how condition of tank is (as to condition of outlet valve). If the tank is in the state of ready for water transfer, then the tank for water acceptance has to be checked before the start of transfer pump. The history of the operational procedure thus is consisted of confirmation of condition and operational procedure of machinery. The purpose of the data collection is to look into the operational error to specify the cause of such error from out of such history.

2.2 Method of Data Collection and Its Contents

The data collection in VIMARU was made onto its fourth grade trainee. Operational data were collected from 19 trainees who experienced simulator training for around 10

hours. The contents of data were about 60 operational procedures for the starting of main engine in the marine engine room. The trainee operates machines and valves on the screen graphics simulating an engine room by means of a mouse (as shown in Figure 1).

Main engine remote operation is made on the screen graphics of a control panel (as shown in Figure 2). There is also a screen simulating engine room fuel oil system. 5 screens are used for operation of main engine subsystem such as sea water system etc.

As for the operational history of the trainee, operations of start/stop of pumps are stored in the PC as operational history. Such data were collected by local area network. Data samples are shown in the Table 1 comprising operational hours, contents of operation, machinery equipment and conditions at alarm.

3. Results and Analysis

3.1 Relations Between Achievement Time and Number of Errors

The trainee makes various kinds of errors during their operation before achieving goals. Table 2 shows the number of errors made by the trainee known from the operational history.

Fig. 1 Main Engine Plant

Fig. 2 Main Engine Control Console

The errors show a tendency of 2 polarizations. 5 trainees made only 5 errors and it is assumed that they followed the anticipated operational procedures. Meanwhile, the trainee who made 14 errors or more were assumed to have had difficulties in following the anticipated operational procedures and they were in a mess as to finding the operational procedure and repeated same procedures damaging machinery and equipment seriously

Table 1 Operation record (History data)

Time	Operation Equipment	Condition
13:50:44	No.1 Main L O Pump	Run
13:50:44	Piston Cool Oil Non-Flow	Normal
13:50:44	Main L O Inlet Press	Normal
13:50:44	Piston Cool Oil Inlet Press	Normal
13:50:46	No.2 Cam L O Boost Pump	RUN
13:50:46	Cam Shaft L O Inlet Press	Normal
13:50:50	No.1 Main Cool F W Pump	RUN
13:50:50	Cool F W Inlet Press	Normal
13:51:03	Abnormal Turning	Abnormal
13:51:05	Abnormal Turning	Normal
13:52:04	Turning Gear	Disengage
13:52:32	Indicator Cock	Open
13:52:50	Priming	On
13:53:12	Turning Motor	Run

The assessment to the result of simulator training for the trainee was made based on the achievement time and the

number of errors. Figure 3 shows the actual relations between the achievement time and the number of errors.

Table 2 Number of errors and number of students

Number of errors	Number of students	Number of errors	Number of students
5	5	11	1
6	1	12	0
7	3	13	0
8	2	14	2
9	1	15	2
10	1	17	1

Fig.3 Achievement time and number of errors

The relation in the Figure 3 does not indicate a clear correspondence between the achievement time and the number of errors. Some trainees consumed short time for achievement but made many errors. As for the method of assessment, Nakamura emphasizes the necessity of checking both the achievement time and errors ratio^[3]. The result of this study also indicates the necessity of checking both for the assessment of the training.

3.2 Contents of Operational Errors by Unskilled Trainee

Study was made as to what kind of operational errors occurred during the training by the PC based ERS. The unskilled trainee finds difficulties in making systematical operation and in knowing the intension of the operation, which lead to the operational error eventually. The error of this kind is called behavior error easily distinguishable from outside and is classified as appearing error^[4].

In order to consider the training technique and a method of instruction in the training using the simulator, the contents of errors by the trainee was examined after the practice.

Since it is difficult to build a plan of the operation in case of some of beginners, judging the present state and intention of operation are difficult for them to be able to understand. Therefore, this operational error is classified into the error of the external level so called the error of easily observable behavior^[5]. The kind of the errors and its number are shown on Table 3.

Table 3 Classification of error

Kind of the errors	Number of errors
Omission of operation	63
Extra operation	60
Mistake of operational sequence	24
Forgetting of operation confirmation	11
Repetition of the same operation	9
Others	6
Total	173

The unskilled trainee often makes error of omitting and error of extra operation. In order to clarify the cause of such operational errors, all of such errors were classified according to the specific operational actions. Table4 shows the contents of such various errors.

Specific examples of the errors are described as follows:

(1) Operation of Pumping System

In most of the engine rooms, main pump and stand-by pump are combined in parallel, and therefore the stand-by pump has to “stand-by” when the main pump is running. In some error’s cases, the meaning of “stand-by” was not clear to the trainee and he started the stand-by pump, too. This error occurred in all pumping systems that have main and stand-by pumps.

Some errors occurred by wrong operation of valves. Operational errors occurred sometimes because the pumps are far apart on the screen and their operations were forgotten. All such errors indicate that systematical confirmation after the starting of machinery is forgotten. Many errors on the simulator occurred due to poor handling of mouse.

Table 4 Specific operation error

Details of errors	Number of cases
A preliminary pump is started	40
When the pump is started, a necessary valve is not opened.	22
The operation order of the turning of the main engine is reverse. .	12
Heating of diesel oil	11
A closing failure of the steam valve for heating cooling fresh water.	11

(2) Operation of Main Engine Turning Gear

Most of the errors in the turning operation of main engine occur in the operational procedure, because the mental model of the turning gear is not established. Operation is made only by its arrangement on the CRT screen without paying attention to the procedure.

(3) Operation of Fuel Oil Heating System

Error in the operation of heating system occurs because of the lack of conceptual knowledge of fuel oil heating and of wrong timing of heating. For an appropriate operation of the system, both procedural knowledge and conceptual knowledge are required. Error in forgetting steam valve closing is also observed. This is because attention is not paid to the temperature change of the fuel oil. Such errors indicate the necessity of education on the changing condition of system after the operation of individual equipment. Sufficient explanation and instruction as to the use of the monitor are considered essential. Instructor has to teach checking the condition change of the marine engine plant after operation.

3.3 Reaction to Alarm by Unskilled Trainee

Operation by the unskilled trainee is highlighted at the time of sounding alarm. When the alarm is made by a wrong operational procedure, the unskilled trainee tends to repeat the same procedure from the beginning. For example, when the turning motor is started while the indicator cock is closed, alarm of abnormal turning is made automatically. The unskilled trainee, without trying to find the reason for the operational error, tends to simply repeat the same procedure until he realizes the operational error and corrects it^[6]. This type of human error is the human error in judgment.

Our study on how the unskilled trainee reacts to the alarm shows that the same operation is repeated 2.5 times on average. When the alarm is made, trainee concentrates his attention not to make alarm and stops the turning to escape from the alarm. Knowledge to find the cause of error is considered insufficient. Some kind of support system that helps the unskilled trainee assume the cause of error would be necessary in addition to the simple alarming of the system abnormality^[7]. Moreover, instructor not only teaches procedural knowledge, but has to teach about the acquisition method of the information demanded in order to make the right judgment.

3.4 Behavior of Unskilled Trainee During Operation

In order to characterize the features of the unskilled trainee, their operation was recorded by videotape. Some wrong operations which do not appear in the operational data list are as follows:

- Opening all the valves
- Opening the valves from top to bottom
- Opening the valves in a direction from left to right
- No operation of the indicated equipment
- Making mistake in the timing of valve opening of the starting air system
- Making mistake in the operational sequence of main engine in the control room

3.5 Analysis of Cause of Human Error of Unskilled Trainee

The human error of the unskilled trainee can be caused by not only the insufficient and wrong action plan but also the mental model prepared by the trainee for operation of the marine engine plant. These causes due to shortage of the basic knowledge and the technical information about the marine engine plant. Furthermore, because of his insufficient judgment and conceptual knowledge, the operation corresponding to alarm (not routine action) is not completed in many cases. Therefore, the instructor has to play a major

part in order to solve the above issues that means the unskilled trainee's own weak points.

4. Training with Consideration for Human Error

Human error is said to occur at every step of recognition, judgment and operation. In view of the operational errors and behaviors during the training on the simulator, and of educational technology, following improvements are proposed:

4.1 Acquisition of Fundamental Knowledge Required for Junior Engineer

For acquisition of procedural knowledge through the operation of simulator, fundamental knowledge is essential. It is easy to acquire conceptual knowledge such as structure of machinery etc. in the classroom teaching, but that is not enough for actual operation of the machinery. Junior engineers are required to have more information on the condition of the pumps to run or to stand-by.

Such knowledge, which is usually acquired through the experience in the sea, can also be acquired through self-learning by a simulator. When the knowledge by self-learning is not sufficient, it must be supplemented by the instructor. The acquisition of knowledge by the coordination of self-learning and instructor is most important.

4.2 Acquisition of Knowledge on the System

Junior engineers understand the name and the function of machinery and equipment to be operated, but they often fail to understand the combination of machinery and equipment and its meaning. It may sometimes turn out that the valve near the pump is recognized and operated but the valve far from the pump is forgotten and not operated.

Typical examples of the lack of systematical knowledge are that they open all the valves and/or they open the valves in a direction from right to left on the screen. Since the simulator can put the marine engine plant as an energy flow on the screen, it will be quite necessary to show them the system for their understanding^[8].

4.3 Enhancement of Judgment Skill

When the junior engineers are required to make some decision during the operation of the simulator, they are liable to operate the machinery with wrong judgment or to continue it without any judgment because they are short of knowledge necessary for judgment criteria. When the judgment is required, the criteria for judgment have to be

shown to them. In some cases, they give up the operational failing in satisfying operating conditions. The instructor has to show them the conditions necessary to continue the operation.

4.4 Establishment of Mental Model

Junior engineers often fail in confirming the changing situation of the system being operated. This is because they have no recognition of feedback concept and their knowledge on the system operation is not sufficient. They are indifferent to the condition of the system after they have operated the machinery and/or equipment and don't use the function of the monitor. In order to help them establish the mental model, the instructor has to teach them the system change after the machinery operation in addition to the operational procedure.

4.5 Repetition of Training

The instructor teaches the operational procedure to the junior engineers, but its memory does not last long time and is easily forgotten. In order to change such short-time memory into long-time memory, training has to be made over and over.

5. Conclusion

Throughout this paper, we have described the characteristics of the operational errors by the unskilled trainee during the training by means of PC based ERS for acquisition of operational knowledge. The unskilled trainee are short of both conceptual knowledge and procedural knowledge necessary for the operation; they eventually make a lot of errors. Such errors are produced in the learning process and are inevitable for acquiring knowledge. This learning method is called discovery learning and its effect is approved already^[9]. This learning method, however, has a weak point that takes a long time for acquiring knowledge^[10]. In this case, the support by instructor is essential to enhancement of the learning effect. In order to clarify the items of support by instructor, following methods were taken:

Firstly, we noticed the relations between the time necessary for achieving the goal and the number of errors. As a result, we have found that there is no correspondence between the time for achievement and the number of errors. This means that some trainees may take only a short time for achievement but with many operational errors. Data for the number of errors and for the time for achievement are both

necessary for assessment of the training effect by the simulator.

Classification of the errors by the unskilled trainee from the viewpoint of operational behavior has shown that they are liable to omit some operation and/or make extraneous operations. Such errors are caused by lack of understanding for the total system, lack of knowledge for fundamental operation, insufficient confirmation of the result after the operation and lack of over all knowledge on the total work system.

As a result of the above mentioned, the educational support by instructor will be indispensable for the correction of such insufficiency and the instructor not only teaches the knowledge of fundamental operation procedure, but has to teach the checking criteria for normal operation or abnormal operation.

References

- [1] K. Ikenishi et al., Engine Room Simulator Based on Personal Computer for Effective Self-education, International Maritime Lecturers' Association, Twelfth Conference (2002), p327-336
- [2] Edit of Japan Society for Educational Technology, "Educational technology encyclopedia" (2000), p211, Jikkyou Syuppan
- [3] T. Nakamura, An Assessment Criterion with respect to Training the Marine Engineer as an Operator, 3rd international Conference Engine Room Simulator (1997), p11-20
- [4] James Reason, "Human Error"(1990), p13, Cambridge University Press
- [5] Eric Hollnagel, "Human Reliability Analysis-context and Control-" (1993), p140, Academic Press
- [6] S. Bang and K. Furuta, Operator's Knowledge Model and Ability to Handle Abnormal Situations, Journal of Human Interface Society, Vol.6, No.1, 2004, p113-118
- [7] Takashi Matsuo, The motivation model for prevention of human-errors by external cue, Journal of Human Interface Society, Vol.5, No.1, 2003, p75-83
- [8] T. Nakamura and Y. Arimoto, An Engine Room Simulator for Education, Journal of the Japan Marine Engineering Society, Vol.22 No.6 (1987), p. 379-387
- [9] C. Kogo, An Application of Personalized System of Instruction (PSI) to University, computer & education, Vol.7 (1999), 117-122
- [10] K. Ikenishi et al., Application of Personalized System of Instruction to Education and Training Using ERS based on PC, The Japan Instruction of Marine Engineering, 70th Conference (2003), p81-84