Analysis Of Human Error In Marine Engine Management

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ABSTRACT

In the whole industrial activities, although the people concerned have been making sustained efforts to prevent accidents and casualties, they have not been disappeared. Most of accidents have been caused by human errors. It can be said that human behavior and mind are not perfect and faultless, therefore, it should be recognized that human has to commit faults. The most important matter is making efforts to study existent human error and to prevent actualized danger. In order to decrease actual casualties, it is very important to dissolve unsafe acts or decisions and unsafe conditions hidden behind them, and to analyze and to investigate incidents that indicate a foretaste of actual casualties. However, the systematic accumulation and analysis of the marine incidents are not completed in the maritime industries. There are very few of information on the marine incidents, especially related to the marine engine management because they may include a lot of disadvantage information for mariners or shipping companies.

In this paper, marine accidents are investigated in order to grasp the actual circumstances of human errors in marine engine management. The information of objective marine accidents is collected from the judgments of Japan Marine Accident Inquiry Agency for the last 9 years. According to the IMO resolution A.884 (21), human behaviors are categorized into 3 modes, i.e., skill-, rule- and knowledge-based behaviors. Human errors and violation are classified into 4 modes, i.e., slip, lapse, mistake and violation. The background of error occurrence is assorted into 4 groups correlated with software, hardware, environment or liveware. And the location of the human error can be divided into organization onboard, on shore and both organizations. All of objective marine accidents are analyzed according to the above classification methods. Several deficiencies are revealed through the systematic investigation of actual accidents. The results of this paper realize the importance of marine incident analysis to aim the ultimate goal of marine safety.

1. Introduction

The very valuable morals for the industrial accident prevention were obtained from the industrial accident study conducted by H.W. Heinrich. They are "Prevent the accidents and there can be no injuries." and "Prevent the unsafe practices and unsafe conditions and there can be neither accidents nor injuries." In order to reduce the number of injuries and accidents, it is very important to dissolve the latent situations, which are unsafe practices and unsafe conditions. And it is essential to collect and analyze not only the information of actualized accidents and injuries but also the information of incident that can be considered as a foretaste of actualized one.

The aim of this study is to grasp the actual circumstances of human error in marine engine management. There are very few of information on the marine incidents, especially related to the marine engine management because they may include a lot of disadvantage information for mariners or

shipping companies. In this paper, the marine accidents that are actualized phenomenon are taken as an object of investigation.

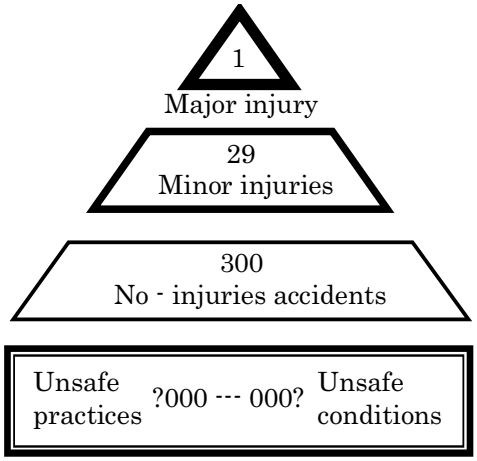

Fig. 1 Foundation of a major injury.
(By H.W.Heinrich)

2. Objective data of marine accidents

The data of objective marine accidents is collected from the court's judgments of Japan Marine Accident Inquiry Agency for 9 years from 1995 to 2003. The marine accidents are classified into 16 categories in the judgments, namely, 1) collision, 2) collision (single), 3) grounding, 4) foundering, 5) flooding, 6) capsize, 7) missing, 8) multiple accident, 9) fire, 10) explosion, 11) machinery failure, 12) equipment damage, 13) facility damage, 14) death and injuries, 15) safety hindrance and 16) navigation hindrance. The marine accidents related to marine engine management are picked out from these all marine accidents. The total number of accident picked out is 887. In addition, the types of vessel involved are focused on merchant ships. In brief, the marine accidents involved with fishing boats or pleasure boats are eliminated. Consequently the number of objective data of marine accidents is finally 173 in this paper.

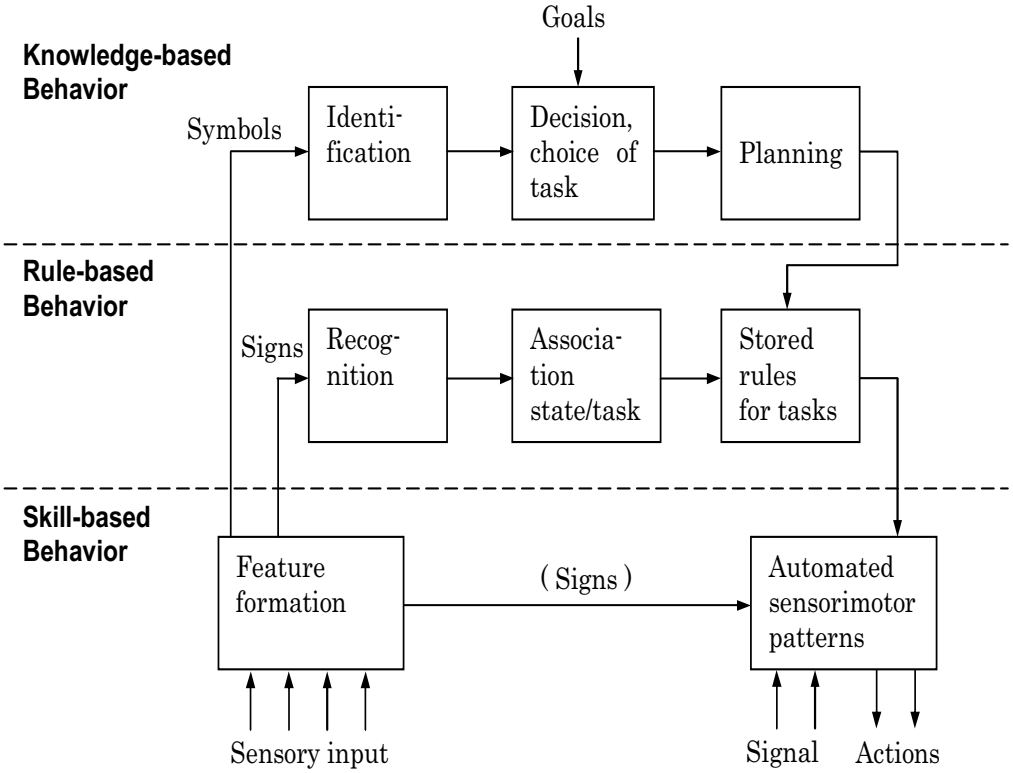

Fig. 2 SRK model : Simplified diagram of the three levels of control of human actions.
(By Jens Rasmussen)

3. Analyzing models for the major factor in accidents

3.1 SRK model

Jens Rasmussen classified categories of human behavior into tree levels of performance : skill-, rule-, and knowledge-based performance. Simplified diagram of the three levels of control of human actions is shown in Fig. 2.

1) Skill-based behavior is automated and highly integrated patterns of behavior without conscious control represented by sensorimotor performance.
2) Rule-based behavior is typically consciously controlled by a stored rule or procedure that may have been derived empirically during previous occasions, communicated from other persons' know-how as an instruction, or it may be prepared on occasion by conscious problem solving and planning.
3) Knowledge-based behavior is controlled physically by trial and error, or conceptually by means of understanding of the functional properties of the environment and prediction of the effect of the plan considered in unfamiliar situations. In this situation, there are no know-how or rules to resolve subjects.

3.2 SLMV model

(GEMS: A Generic Error-Modeling System)

James Reason devised a classification of unsafe acts into four types: slip, lapse, mistake and violation as shown in Fig. 3. The psychological varieties of unsafe acts are classified initially according to whether the act was intended or unintended and then errors are distinguished from violations.

1) **Slip :** A slip is an unintentional action where the failure involves attention.
2) **Lapse :** A lapse is an unintentional action where the failure involves memory.
3) **Mistake :** A mistake is an intentional action, but there is no deliberate decision to act against a rule or plan. There are errors in planning.
4) **Violation :** A violation is a planning failure where a deliberate decision to act against a rule or plan has been made.

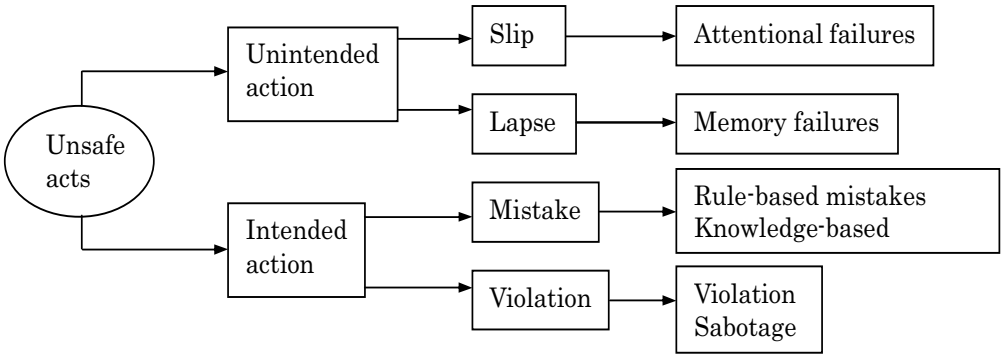

Fig. 3 SLMV model : A summary of the psychological varieties of unsafe acts. (By James Reason)

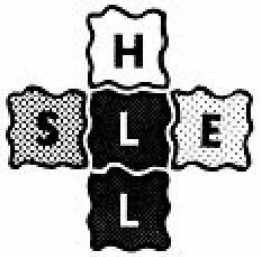

Fig. 4 SHEL model. (By Frank H. Hawkins)

3.3 SHEL model

The SHEL model was initially developed by Elwyn Edwards, with a modified diagram to illustrate the model developed by Frank H. Hawkins. The SHEL model categorize primary component concerned with occurrence of human errors into Software, Hardware, Environment or Liveware. The background of occurrence of human errors can be classified.

1) S - Software : Software is the non-physical part of the system including organizational policies, procedures, manuals, advisories, computer programs, etc.
2) H - Hardware : Hardware refers to the equipments and facilities. It includes the design of displays, controls, function of switch, etc.
3) E - Environment : Environment includes the internal and external climate, temperature and other factors. And, the broad political and economic constrains under which the system operates are sometimes included.
4) L - Liveware (central component) : The most valuable and flexible component in this system is the human element placed at the center of the model. The person under consideration interacts directly with each one of the four other elements.
L - Liveware (peripheral) : The peripheral liveware refers to the system's human-human interactions.

4. Analyzing procedures

4.1 Classification of human behavior and error

The classifications of human behavior by SRK model and human error by SLMV model are integrated as shown in Fig. 5.

An unsafe action is classified into intended or unintended action. The unintended action is classified into slip or lapse according to whether the aim of the action is appropriate or not. An intended action is classified into familiar or unfamiliar action. The familiar action is classified into mistake in rule-based action or violation according to whether the action is followed rules or not. An unsafe action in unfamiliar circumstance is classified into mistake in knowledge-based action. Mistake in rule- and knowledge-based action is represented as "Rule" and "Knowledge" respectively in tables and figures in this paper hereafter.

4.2 Major factor location of occurrences of human error

In the marine accidents concerned with marine engine operation and management, a major factor location of occurrence of human error is categorized into five patterns as followings.

1) Organization onboard
Human factor of only a chief engineer or crewmembers onboard is related to occurrence of marine accident.
2) Support organization on shore
Human factor of a member of shipping company, engine manufacturer or ship repair company, namely support

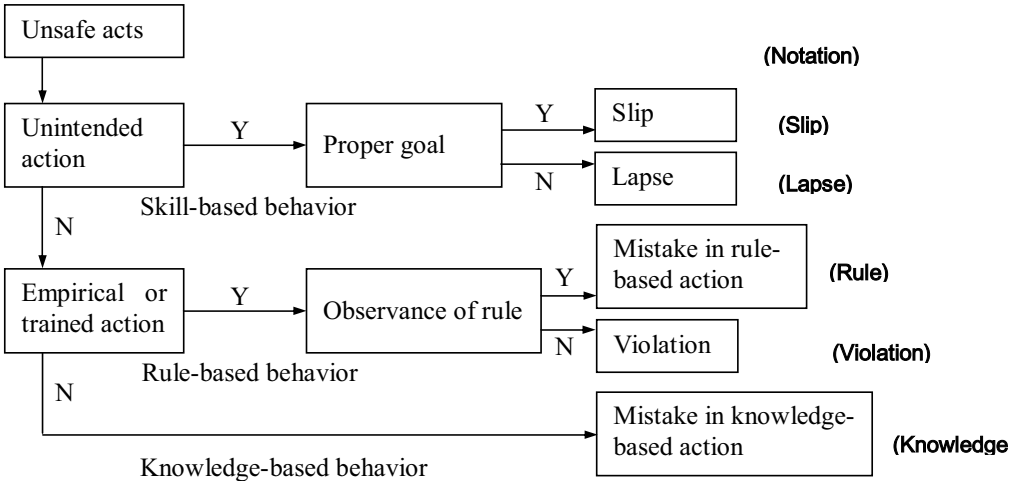

Fig. 5 Classification diagram for human behavior and human error.

organization on shore, is primary related to occurrence of marine accident. There are no human errors in an onboard organization.

3) Both (onboard)
Human factor of both parties onboard and on shore is related to occurrence of marine accident. Human factor of onboard organization affects occurrence of marine accident relatively more heavily than support organization's one.

4) Both (shore)
Human factor of both parties onboard and on shore is related to occurrence of marine accident as well as the above "Both (onboard)". Contrary to the above, human factor of support organization affects occurrence of marine accident relatively more heavy than onboard organization's one.

5) Unidentified
A cause of accident is unidentified, or human factor concerned to accidents is slightness and neglect able.

5. Analyzed results

5.1 Particulars of individual accident

The progresses of typical accident on marine engine management are analyzed and shown below with the categorized human behavior and human error regarding the marine accidents in complicated situation or complex background.

SHIP #1 (Ro-Pax Ferry 9,463gt)

Phenomenon	Action	Background SHEL C/E	Background SHEL 1/E	Behavior SRK	Error SLMV (GEMS)
	Ship management Co. Lack of instruction in emergency situation	Env. Educational env.	Env.	Ship management Co. Knowledge Needs of education	Mistake Decision
	Ship management Co. Nothing equipment of emergency stop by oil mist alarm	Hard. No equipment	Hard.	Ship management Co. Knowledge Effectiveness of equipments	Mistake Decision
Oil mist alarm on same type engine	Engine maker Co. Nothing information of the frequency oil mist alarm	Soft. Nothing report on occurrence	Soft.	Engine maker Co. Knowledge Value of information	Mistake Decision
	Engineer Nothing confirmation on talk of same type engine	–	Soft. Value of information	Engineer Knowledge Value of information	Mistake Decision
Oil mist alarm Nothing slow down and continuation of resolving by oneself	Engineer Nothing appropriate measure	–	Env. Educational env.	Engineer Knowledge Emergency procedure	Mistake Decision
Getting permission of M/E stop Nothing report on oil mist alarm	Engineer Nothing correct report to C/E	Soft. Lack of information	Soft. Value of information	Engineer Knowledge Value of information	Mistake Decision
Disconnection of S/G with normal procedure before M/E stop	Engineer Normal procedure to disconnect S/G	Env. Educational env.	Env.	Engineer Skill Disconnection of S/G	Lapse Work priority
M/E seized					
M/E tripped					

Table 1 Summary of accident, case 1.

1) Case 1
Ship type : Domestic ro-pax ferry, 9463gt.
Accident : Seizure of M/E piston with cylinder liner and break of cylinder liner.

The typical example of that both parties onboard and on shore were responsible for the accident is shown in Table 1.

In this case, after the oil mist alarm occurred, the first engineer on duty did not take appropriate measures such as slowing down of the engine or stopping of the engine in order to detect the source of the trouble and his report to the chief engineer was insufficient. And, when the first engineer tried to stop the main engine at final stage,

the disengagement of the shaft generator connected with the starboard side engine concerned was left after the handling of the port side engine that was under normal running, because he got the normal procedure customary to disengage the shaft generator. The piston and the cylinder liner of the starboard side engine were seized and the cylinder liner was cracked because the stopping work was delayed.

The most important factor in this accident was the watch keeping engineer's error of judgment in knowledge-based behavior when the alarm occurred. But, it was just one penetration of multiple protections. The serious factor related to expansion of the accident can be categorized into "Lapse" in skill-based action of the first engineer when he tried to stop main engines. It can be considered that a composite error caused severe damaged accident. If he stopped the starboard side engine ahead of the port side engine, the severe damage might be avoided. In addition, a background factor was considerably concerned with the occurrence of the accident. The shipping company had not carried out adequate education of operation and management in emergency situation to crewmembers. And, the engine manufacturer had not made the frequency of same type accidents known to users. The background factor based on the support organization on shore had a great influence on the engineer's behavior. And, the unsafe condition was induced.

The judgment of the marine accident inquiry must be considerable because the shipping company and the engine manufacturer didn't even get any punishment such as a recommendation due to taking counter measures to prevent a recurrence after the accident. On the other hand the first engineer got a punishment of reprimand due to his faults.

2) Case 2
Ship type : Ocean going crude oil tanker, 136,688gt.
Accident : Crack of M/E cylinder liner.

The typical example of that only one party on shore was responsible for the accident is shown in Table 2. When the corroded part of M/E cylinder liner was repaired by welding, the removal of residual stress was inadequate. The M/E cylinder liner was cracked at the welded part and some cooling fresh water flowed into the cylinder only one-day service after the repair.

Welding repair was adopted because it would take excessive days to get a new cylinder liner for replacement. After start of the repair works, it was came to light that the condition of cylinder corroded was worse than expectation. In spite of a recommendation from superintendent of shipping company to extend the term of repair, the welding agency rejected the recommendation and forced an original schedule. The main factor of this accident is a decision mistake of knowledge base and a violation of the rule base by the welding agency, which is the support organization on shore.

SHIP #16 (Oil tanker 136,688gt)

Phenomenon	Action	Background SHEL C/ E	Behavior SRK	Error SLMV (GEMS)
Cylinder liner corrosion rapidly progressed				
Tracing survey by maker				
Rejection of repair by welding co. in Singapore	Ship management Co. Taking a lot of time for renewal of cylinder liner	Env. · Hard. Nothing of time margin Order made cylinder liner		
Decision of repair by low-temp. welding				
Planning of repair schedule				
Excessive corrosion	Repair service CO. Rejection of proposal to extend work term. Frocing of original schedule.	Env. First experience	Repair service CO. Knowledge / Mistake Consideration on schedule / Decision	
Lack of peening	Repair service CO. Workers rushed	Env. Impending of termination	Repair service CO. Rule / Violation Low-temp. welding needs long time. / Violation	
Occurrence of crack by residual stress				
M/ E tripped				

Table 2 Summary of accident, case 2.

In this case, no body onboard organization got any punishment. And, the welding agency also did not get any punishment in the judgment of the marine accident inquiry due to taking counter measures to prevent a recurrence after the accident in spite of the court of the marine accident inquiry pointed out that the main cause of this accident was the inadequacy for the work schedule consideration by the welding agency.

5.2 General statistical analysis

The major factors in 173 all examined marine accidents related to the marine engine management are detected from the court's judgments of marine accident inquiry. The result of statistical analysis on the major factor location and the classified categories of human error is shown in Fig. 6.

The largest number of human error related to the marine accident on the marine engine management is the violation of crewmembers onboard and accounts for 45% of the whole. There are extremely a lot of cases that a well-skilled engineer who has abundant experiences relies on the experience and intuition too much and he dose not observes neither a basic procedure, the rule nor the standard. The second largest number is the knowledge-based mistake. The one by crewmembers accounts for 13% and the one by support organizations on shore accounts for 7.5% of the whole respectively. This indicates unquestionably that a person concerned lacks ability to cope an event of the first experience or an unknown trouble. The third largest number is the skill-based lapse. The one by crewmembers accounts for 9%. The many of these cases are following. A person concerned

works carelessly same as usually or mistakes an object equipment to operate, in spite of that an equipment handling procedure at abnormal condition is different from usual. The skill-based slip and rule-based mistake are overall few.

On the major factor location, the organization onboard accounts for 2/3 or more of the whole. It is very important to improve environment in the viewpoint by which the education and training is refined and the unsafe condition is dissolved. The support organization on shore

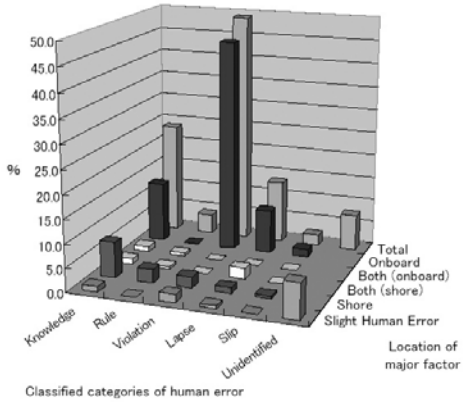

Fig. 6 The major factor location and the classified categories of human error.

accounts significantly for 14.5%. And, it is remarkable that many of prime factors are in support organization on shore when the both parties of onboard and on shore have accident generation factors. There are a lot of knowledge-based mistake accounted for 52% within the support organization on shore. When the repair and maintenance are ordered to the support organization on shore and they execute it, it is important that crewmembers pay attention substantially to the works.

6. Conclusions

As a means to grasp the actual circumstances of human error on marine engine management, the marine accidents on marine engine management are collected from the court's judgments of Japan Marine Accident Inquiry Agency and the analysis is carried out paying attention to the major factor location and the classification of human error.

According to the analyzed results, the following two matters are important in order to dissolve unsafe conditions to cause the occurrence of human errors, and to avoid actualization of accidents.

1) Improvements in environment to carry out education and training for exclusion of overconfidence based on empirical rule and making up for deficiency of knowledge and experience.
2) Improvements in standard for efficient operations and in safety environment conforming reasonably to real state on field.

An interesting result is obtained collaterally.

3) When both parties of the organization onboard and the support organization on shore had the accident factors, although administrative measures such as reprimand or suspension of duty were decided to engineers in many case, any administrative measure was not given to the support organization on shore because the relapse prevention measure was adopted after the occurrence of accident.

Finally, the challenge in the future should be taken is shown below.

4) The results are obtained from actualized marine accidents in this paper. The investigation on latent unsafe practices and unsafe conditions is essential for improvement of maritime safety. The marine incidents not accidents should be collected and analyzed.

5) In most human errors, the mismatch of the correlation with two or more people is one of important factors. The analysis and the improvement of mutual communications between participants in the marine engineering system are essential. That is, it is necessary to introduce the crew resource management also into the field of the marine engine operation and management.

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BIOGRAPHY

Analysis of Human Error in Marine Engine Management

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Dr Makoto Uchida is an associate professor in Faculty of Maritime Sciences, Kobe University. He has been working for marine engineering education for more than 20 years at Kobe University and the predecessor, namely Kobe University of mercantile Marine. He has been a visiting researcher at Australian Maritime College to study Engine Room Simulator for 10 months in 2000. He also worked for Istanbul Technical University, Maritime Faculty as a long-term expert of JICA project for one and half years between 2001 and 2003.

Dr Uchida holds a PhD in engineering from Osaka University and is a graduate from Kobe University of Mercantile Marine.