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The Design and Arrangement of Coastal Ship's Bridge on the Basis of Ergonomic Concept

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Abstract : *In this paper, the ergonomic principle and concept will be established and the conceptual bridge design based on the ergonomic studies pertaining to bridge design undertaken by IMO and ISO will be introduced. In particular, this study has looked into the applicability of ergonomic design concept on coastal ships and proposes new bridge design to make good contribution to the prevention of marine accidents in the coastal sea.*

Key words : *bridge design, ergonomics, human element, bridge configuration, consol layout*

1. Introduction

It is well known fact that the human element makes up more than 80% of causes behind marine accidents. However, there is no objective statistics which clearly shows the proportion of accident caused by the faulty bridge design or mis-arrangement of bridge equipment. Also, even in the marine accident investigations, the focus is often placed on the errors made by the operators and not on the faulty bridge design or mis-arrangement of bridge equipment. Hence, there are little data available on the faulty bridge design or mis-arrangement of bridge equipment.

Although there are no objective statistics available, because the ergonomic factors are often overlooked in the bridge design and equipment arrangement, we can assume that such oversight might be the direct or indirect cause behind many of the accidents. Whilst no quantitative evidence is available to prove this assumption, there is no doubt that the ergonomic bridge design user-friendliness aspect can make substantial contributions to the prevention of marine accidents.

Therefore, in this study, the ergonomic principle and concept will be established and the conceptual bridge design based on the ergonomic studies pertaining to bridge design undertaken by IMO and ISO will be introduced. In particular, this study has looked into the applicability of ergonomic design concept on coastal ships and proposes new bridge design to make good contribution to the prevention of marine accidents in the coastal sea.

2. Definition of bridge

In some dictionaries, a bridge is simply defined as the navigation center of ship(Branch, 1995), or more complexly as a platform on the upper deck of motor ship installed athwartship direction where captain and watch officer perform navigation duty and where all activities of the ship is controlled and monitored(Kemp, 1994).

In ISO, the bridge is defined as the area from which the navigation and control of the ship is exercised, including the wheelhouse and bridge wings. The wheel house is enclosed part of the bridge and bridge wings are those part of the bridge on both sides of wheelhouse which, in general, extend to the ship's side(ISO 1990).

In the past, the bridge of sailing ship simply meant the upper deck area of ship covered with canvas equipped only with a wheel and magnetic compass. It wasn't until the late 1940s that a radar was first installed on board ships. In 1950s and 1960s, as various navigational equipment were starting to be installed in the bridge, enclosed space was needed to protect the various equipment onboard.

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Along with the invention and development of navigational equipment, the bridge design was also beginning to be affected . With the enclosure of bridge, more instruments and equipment were installed in the bridge. As a result, the function of bridge changed from a place for only steering to the total control center with the installation of echo sounder, speed log, navigational equipment and radar, etc.

3. Ergonomics and bridge design

Simply stated, ergonomics can be summarized as "the design process for the use of human". The focus of ergonomics is on the consideration of human aspects in the design of material, tools or environment which are used in various aspects of life.

The goal of ergonomics in design stages of material, tools and environment is to heighten practical efficiency for the better use by the operator and, through this process, maintain or enhance living standards. Ultimately, the end result of ergonomics is the betterment of human welfare.

The ergonomics approach is the systematic application of information pertaining to human characteristic and behavior in the design of material, tools or environment. If we can explain ergonomics as the process of designing equipment or system for more convenient and efficient use by operator, the introduction of ergonomic concept in the arrangement and design of bridge will allow the master, navigator and others to use the bridge in more efficient and convenient manner. In order for this to happen, the following 6 areas of ergonomic concept need to be applied in design of bridge(Maccormick, 1976):

3.1 Physical aspects of the human/machine interface

The physical aspects of human/machine interface examines the size, shape, colour, texture and method of control operation and displays.

3.2 Cognitive aspects of the human/machine interface

The cognitive aspects of the human/machine interface considers the standing of information displayed and instructions. It is important that there is no information overload while operating the bridge system. The ways of simplifying the displayed information as well as the way in which it is displayed on a monitor should be tested.

3.3 Work place design and work place layout

The workplace design and workplace layout considers the layout of the ship's bridge and the relationship between the different pieces of equipment. Also, the relationship between other furniture on the bridge and different equipment components needs to be considered.

3.4 Physical environment

The physical environment considers the effects of noise, vibration, motion and illumination on performance.

3.5 Psychological environment

The optimum performance of operator, in terms of reliability and efficiency, is most evident when the operator actually pursues his own satisfaction without any form of deep frustration or too much physical and psychological stress. In this respect, the psychological environment aspect examines the organizational structure and how it may affect the task satisfaction and productivity as well as examining any other contributory social factors.

3.6 Job design, selection and training

The job design, selection and training examines the effects of shift work etc. on performance as well as considering the design of instructions, job aids and training schemes. The selection of personnel against criteria of aptitude and personality is also examined

The job design in bridge system is the process of checking whether the operation of bridge is done in a safe and efficient manner and whether the operator is acting at optimum performance level. In other words, it is a process of finding out whether the operator knows what he is doing, what he can do, whether it is worth doing and making improvements in a logical fashion. The operator may work at an optimum level during a relatively short period, but he may become disenchanted with the job over time. In such cases, to get optimum performance out of the operator, it is necessary for the operator to obtain a certain amount of job satisfaction. To this end, it is important to comprehend what kind of work the operator does and what kind of effect the changes to work environment has on the work being performed.

Up to now, the changes to the work environment have been the reduction in manning and the remodelling of the workplace design and workplace layout. As the reduction in manning and unmanned machinery space means that the watchkeeper may be the only person at night who is awake, the effect of shift work, i.e, various watches, on board ship needs to be looked into for further study.

There are two main types of training - a basic training of the merchant officer and a training for specific equipment. It appears that the type of training that would be most desirable for a modern integrated bridge system should encompass a certain amount of knowledge of all the system that are being monitored.

4. Ergonomics approach in the design of bridge

In addition to software approach in the ergonomics, IMO has recognized the importance of hardware aspect in the ergonomics. To this end, IMO has made the application of ergonomic principles in the design and arrangement of bridge mandatory in the Chapter V of SOLAS as follows:

1) bridge design, design and arrangement of navigational systems and equipment on the bridge and bridge procedures in the Reg. 15; and
2) requirements pertaining to navigational bridge visibility in the Reg. 22 of SOLAS Chapter V, in addition to ISO 8468.

The International Association of Classification Societies (IACS) are comprised of 10 member societies and these societies collectively class approximately 95% of cargo carrying ships. Since the early 1990s, each IACS member societies has established and has been applying rules concerning bridge equipment and arrangement. At the beginning, these rules were developed with one man bridge watch in mind, but ever since the MSC of IMO has adopted the resolution to ban the one man bridge watch at night, IACS member societies have been endeavoring to develop rules incorporating the ergonomics in the design and arrangement of bridge to ensure the safety of ships and to prevent marine accidents in accordance with the requirements of Regulation 15, Chapter V of SOLAS.

ISO, on the other hand, has established the requisites and instructions pertaining to arrangement of bridge and related equipment as ISO 8468 in 1987 and made amendments thereto in 1990. In 1999, to strengthen the ISO 8468, ISO established ISO 14612. Although ISO 8468 does not mention the ergonomics directly, the standards were mostly developed under the principle of ergonomics. It is safe therefore to assume that the most of documents pertaining to design and arrangement of bridge available today were influenced by the ISO 8468. The composition of ISO 8468 are as follows(ISO, 1990):

(1) Bridge Configuration, (2) Bridge Arrangement, (3) Bridge Equipment, (4) Bridge Working Environment, (5) Safety of Personnel[5].

5. Status of coastal ships

The coastal ships referred in this study are ships of all types which are less than 5,000 GT navigating the coastal waters of Korea, China, Japan and East Asia. Among the registered vessels, the number of subject vessel in the range of 500~5,000 GT were 435.

5.1 Size of bridge

Presently, there is no formula or method for determining the area of bridge. Instead, the area is determined by the number and size of equipment installed inside the bridge. Although the type of equipment for bridge is usually determined prior to the commencement of design of ship, the size of equipment differs from a manufacturer to a manufacturer which cause adjustment problems. In large ships, the bridge area is quite large in comparison with the size of equipment to be installed, so no real problems exists.

In examining the length and width of subject ships' bridge by using the available drawings, the widths of bridge on ships of 500 GT, 1,000 GT, 3,000 GT and 5,000 GT were measured as 5.02m, 6.08m, 7.12m and 8.20m respectively. When the width of a ship is compared with the width of bridge, it was determined that the width of bridge is approximately half the width of a ship. As a result, in order to expand the width of bridge, it is desirable to enclose the bridge wing, including the wheel house as bridge space.

5.2 Study of equipment in the bridge

The results obtained from a survey and field study carried out to study the arrangement of bridge and equipment and environment has revealed that the required statutory equipment according to tonnage were properly installed onboard all subject ships. However, almost no ships had ECDIS or electronic chart onboard as navigational equipment other than the statutory equipment. Instead, the ships were equipped with GPS Plotter, especially the smaller ships.

The instruments installed onboard the coastal ships are not much different than the ones installed onboard the large ships. The study has found that most of coastal ships were equipped with basic instruments. For most ships, the gauge board was located in the upper part of front window with the exception of few ships which had the instruments installed on the console. As for the installation of GMDSS as radio equipment, all the subject ships were equipped with required statutory equipment, although equipped

GMDSS were slightly different from ships to ships according to the area of navigation.

Turning to the engine control equipment, all subject ships, even the ones which were not unmanned machinery space ship, were equipped with the monitoring system to check the running status of engine and generator.

As auxiliary equipment, equipment other than for navigation such as life jackets, signals, shapes to be used for not-under command or restricted draft situations, various nautical publications, drawers for binoculars, reference publications, etc. must be installed and provided onboard.

5.3 Opinions on the bridge arrangement

Among those who had replied to the survey, more than half of respondents pointed out the lengthy distance to cover within the bridge as a problem. As for the location of gauge board, the majority of respondents had no problems or had little problems. We can therefore safely assume that the gauge boards are placed on correct location. Concerning the problems with the field of vision, 1/3 of respondents indicated that they had experienced some problems in the past. So, there is a need to look into this problematic continually in the future. Even though more than half of respondents indicated the lengthy distance to cover within the bridge as a problem, more than half of the respondents indicated that the area of bridge is quite cramp. Because this observation is an indication that there is a problem with the equipment arrangement in the bridge, a comprehensive review and actions for improvements need to be carried out.

6. Scheme for ergonomics design of bridge on coastal ships

As one can assess from above, the bridges of Korean costal ships generally have a common problem of lengthy distance to cover within bridge and are inconvenient and ineffective to use. These problems can be attributed to the dimension of bridge, the arrangement of equipment within the bridge, design lacking workstation concept, non-ergonomic design of consoles, etc.

When one considers the reduction of watches in the bridge nowadays, these problems will likely be further aggravated and cause accidents by increased fatigue, reduction of time spent on lookout to accomodate insufficiency of automated navigational equipment, etc.

Therefore, as a scheme to resolve theses problematic areas, the equipment to be installed in the bridge of coastal ships needs to be reorganized into an integrated console and arranged appropriately into the bridge according to the dimension of bridge. To do this, the bridge configuration and arrangement of console are coordinated while taking into account of advantages and disadvantages of such system advised by the experts to propose the ideal bridge configuration and arrangement which are appropriate for the coastal ships.

6.1 Design of console

A console refers to the cabinet housing the instrument, controls or displays which are used to carry out specific duties of the bridge. The console which integrates all of these consoles required in the bridge is called the integrated console. Consoles are categorized according to the navigational instrument they house.

As navigational instruments housed in the radar console, ARPA console and ECDIS console are big enough, they can constitute a single console on their own. However, like the navigational information console, several gauges or displays can be integrated into a single console.

6.2 Number and arrangement of console

The number of console to be installed onboard should include the number of statutory requirement according to ship size as well as other equipment as necessary. According to the result of survey carried out for this study, the typical number of console for ships in the 500-3,000 GT range was 7 and for ships above 3,000 GT, 8.

However, for ships of 500 GT and above, it was found that the width of ship (5.02m) was not enough room to install all consoles required (5.08m). Even for ships 5,000 GT, it was found that there is only 1.6m of free space is available from the width of bridge to allow sufficient space for movement. Therefore, in order to accomodate consoles as integrated console for coastal ships in bridge, it is necessary to adopt totally enclosed bridge layout which would enclose right up to the bridge wing.

6.3 Standard design of bridge

On an assumption that coastal ships adopt totally enclosed bridge layout to employ the integrated console, the following three standards are suggested in this study. The scope this study is limited to how to arrange the equipment and the size of integrated console. Therefore, the review on

the ergonomic arrangement of equipment and control gauge board housed in the console are not carried.

The shape of standard bridge is arranged so that the fore windows are projected forward. Considering that the average length of coastal ship is 5.0m, the windows in the bridge projected forward to increase the dimension of bridge. Although not clearly apparent in the drawing, the height and inclination of window were made to be in compliance with the international standards.

1) Type A bridge

As shown in Fig.1, the short length of bridge was overcome by arranging the integrated console at the projected part of bridge. This will likely benefit the ships 500GT and above the most. In this case, however, because the length of a console is 880mm and the seated or on the feet position of watchkeeper is 150mm away from console, there is a problem of performing lookout at a distance of 1,030mm away from the window. Moreover, there is a difficulty in installing the gyro repeater which enables the watchkeeper to observe 360° around the ship.

The advantages of type A bridge configuration, in the way of shortened distance to be covered within bridge, are the swift equipment control and continual lookout, convenience of performing lookout and gauge watching at same time and performance of all the duties while on the one man watch keeping duty. Additionally, the extra space provided by this configuration will simplify activities within the confines of bridge.

The disadvantages of type A configuration are the inability to keep lookout while moving freely from the front window area to either side, the obstruction to field of vision caused by the lights emitted by the instruments and the difficulty of observing deck activities.

2) Type B bridge

The type B involves arranging the integrated console in the middle part of the bridge. This type is only possible when the length of bridge is quite adequate. Because the integrated console is arranged 1m from the front window, the approach to front window is much easier than in the case of Type A. However, the field of vision may be obstructed by the people trespassing in the front of console. Also, there is an inconvenience of going around the large console for the control of steering instruments, the checking of ship's location, etc.

The advantages of type B bridge configuration are the easy lookout due to acquisition of space in the front of console, no obstruction to field of vision caused by emitting

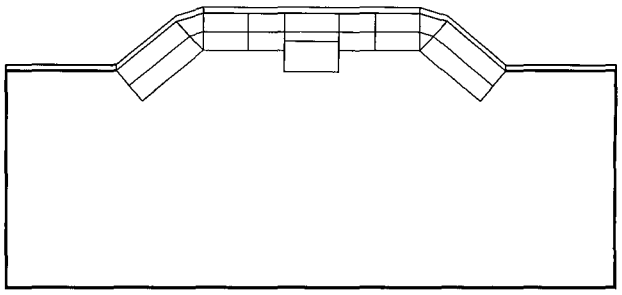

Fig. 1 Bridge configuration and console layout type A

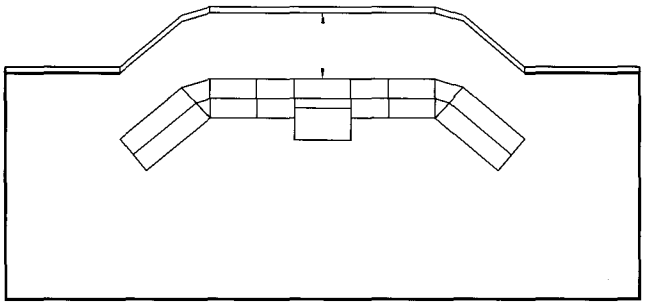

Fig. 2 Bridge configuration and console layout type B

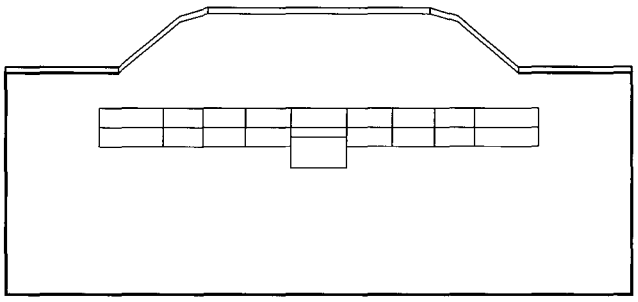

Fig. 3 Bridge configuration and console layout type C

lights of instruments and easy monitoring of deck activities. Overall, this type allows for clearer field of vision than the type A.

The disadvantage of this configuration is the inability to perform one man watch keeping duties (lookout and control of instruments at the same time not possible) during emergency, inconvenience of moving from one place to another to check the navigational instruments and inconvenience of going around the large console for lookout while controlling instruments.

3) Type C bridge

As in [Fig. 3], the length of bridge permitting, the integrated console configuration of B may be straighten. Because this configuration extends the length of console, the bridge width longer than type B is required.

The advantages of this type are as same as the type B. As for the disadvantages, they are as same as the type B, except it takes longer to move in and around the console area.

7. Standard bridge design for ship engaged in coastal voyages

7.1 Verification of feasibility

By using the results obtained from the review of drawings, the field examination and the questionnaires, three different standard bridge design schemes were proposed. As a measure to verify the feasibility of proposed schemes, the questionnaire methodology and the expert opinion methodology were adopted in the study.

First, the present situation and problems associated with the bridge design of today were identified through ship officers engaged in navigation. Then, the comprehensive data inclusive of data collected during the field examination, problems revealed in the questionnaires and potential problems given by the experts and solutions thereto were studied to propose 3 different standard design, including the protruding window configuration. Finally, 3 different designs, including the protruding window configuration were reviewed to extract advantages and disadvantages associated with each design.

The opinion hearing of ship officers, field examination and interviews were done through the questionnaire methodology. The collection process of advantages and disadvantages associated with proposed three standard designs and solutions thereto were derived by using the expert opinion methodology.

7.2 Configuration and layout of standard bridge

1) Compared to large ships, the bridge in small ships are lower in height. As a result, to consider the damage from the operation of on shore and onboard cargo gears, the smooth curved line was adopted as the shape for the front part of bridge without the protruding part exceeding beyond the house marine.

2) In adopting the integrated type console within the bridge, taking the length of required console and the width of bridge, the study has revealed that the ships of 500 GT to 3,000 GT should acquire the necessary bridge space by enclosing the bridge wing. Because ships of above 3,000 GT have relatively sufficient bridge size to accommodate the console, it is not necessary to enclose the bridge wing.

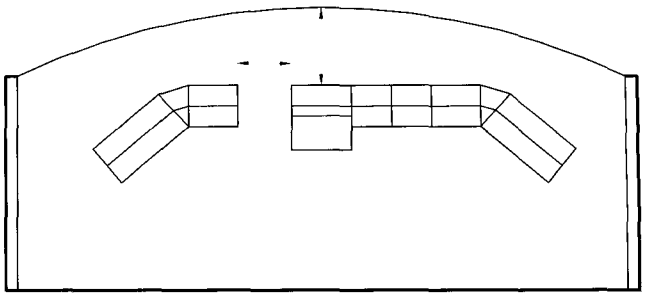

Fig. 4 Bridge Configuration and Console layout

3) It was concluded that the arrangement of console 1 m away from the fore end wall of bridge is better option for Korean coastal ships. This is because the study has revealed that Korean navigators tend to think that the lookout from the close proximity of bridge fore window is more reliable method. Additionally, to acquire swifter information from the navigational instruments at the lookout position, it is better to make a passageway in the middle of bridge by installing the two parts integrated console type rather than the totally integrated type.

4) It was determined that the length of bridge does not pose much of problems even on costal ships. Therefore, the shape of bridge on coastal ships should take on the flat contour shape instead of the protruding type. The dimension of bridge should be at least 8m in width and 4.5m in length. In this design type, the console should be arranged 1 m from the fore end of bridge wall and it is most desirable to have a passageway of 80 cm in width by passing the middle of the console arrangement, instead of one consolidated console[Fig. 4].

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