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Human Factors and ergonomic considerations for super-fast boat design

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ABSTRACT

This paper describes background information and improvements of an integrated Human Factors (HF) for Super-Fast Boat (SFB) design process. A short overview about SFB technology is explained in more detail. This project also includes some evaluations and discussions of the SFB design in the following pages. Some important considerations such as SFB motion, sound, sight, environment, health & safety, man-machine interface, habitability and maintainabilityare described within the appropriate sections.

KEYWORDS

Super-Fast Boat;
Boats;
Human factors in engineering;
Boat design process;
Product design.

INTRODUCTION

In recent years, developments of technology especially in power and propulsion systems have cause the speed of SFB increase. That increase leads to much more SFB accidents which cause the mechanical damage, injury or death (see Figure 1). As a result of this, the importance of Command and Control (CC) and Situational Awareness (SA) have increased in the littoral environment.

By the increase speed potential of SFB, crew and passengers are exposed to Whole Body Vibration (WBV) and Repeated Shocks (RS), with the following impacts;

- Chronic injuries and acute (damaged vertebra, see Figure 2)[28,35].
- Reduced Situational Awareness
- Motion Induced Fatigue (MIF), reduced per-

Figure 1 : Some serious high speed boat crashes, (super-fast boat crash, 2011, http://mybreak ingnews.cp24. com/medi ade tail/3067723?offset=1&collection=528&siteT; http://mybroadband.co.za/photos/showfull. php?photo= 4657')

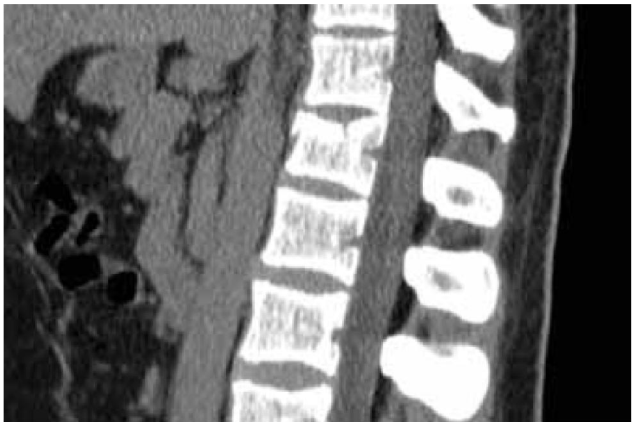

Figure 2 : A wedge fracture of the vertabre during a RIB transit

formance[16].

As it is presented, capabilities of human have not kept pace of this increase in speed of potential in SFB. Thus, design of a SFB requires focusing on protection and comfort of the crew and passengers. Briefly, the focus of this report is also assistance to address a number of HF problems and their improvements which are associated to the design and operation of SFB; for instance,

- Increased SFB performance and safety
- Increased operational capability and readiness
- Reducing the SFB through-life costs such as reducing the risk of injury
- Reducing the WBV and noise exposure.

In general, several boat types are chosen due to the position of crew/passenger related to their seating/ standing conditions during transits, particularly in poor sea conditions. The types of boats include;

- Rigid Inflatable Boat (RIB) 3-12 m or 10-40ý (Figure 3-a)[26],
- Hovercraft (Figure 3-b)[21].
- High Speed Craft (Figure 3-c)[11].

SFB - HF RESEARCH

In this part, the magnitude of fatigue and the capability of seating in order to reduce fatigue have been presented with some example, using the US navy trials. Some of trials, which were operated using 28ý RIBs are shortly explained below;

First of all, energy expenditure was measured (via oxygen uptake) for two different seat types, fixed and

Figure 3a : Example of a RIB

Figure 3b : Example of a hover craft

Figure 3c : Example of a high speed craft

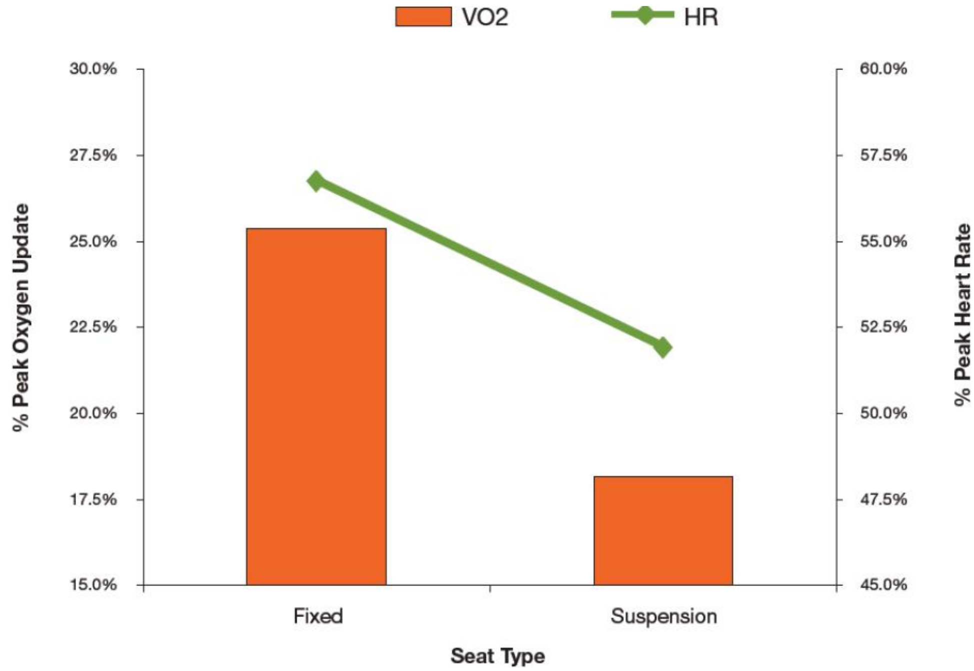

Figure 4 : The effects of fixed and suspension seat on RIB passengers' physiological responses[22]

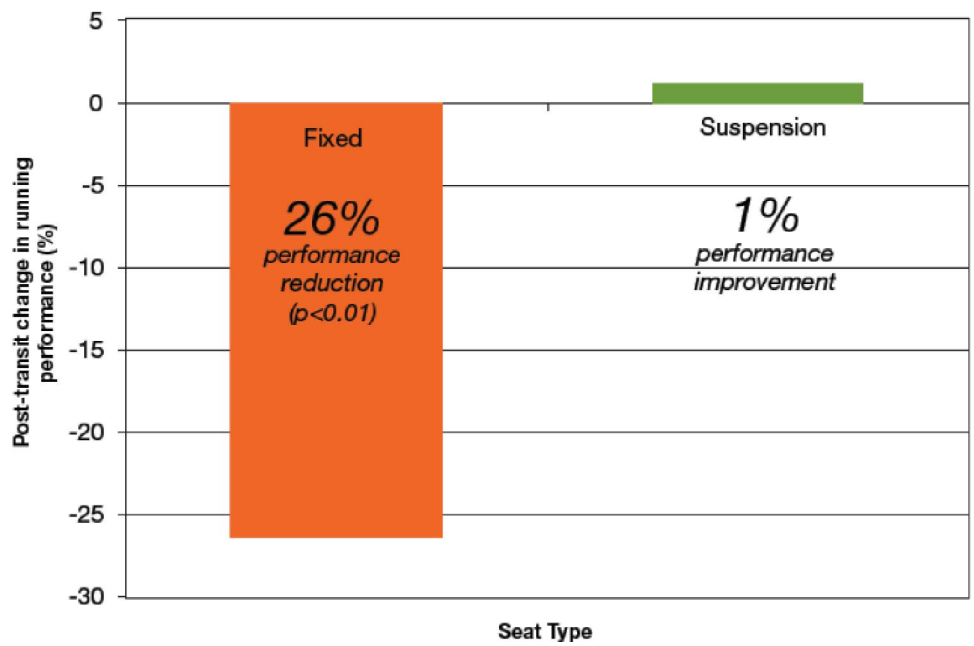

Figure 5 : The changes running performance during3 hour transit on 28ý RIB[22]

suspension, during poor and moderate travelling conditions. As a result of this, although passenger in a RIB does not need to aerobic activity such as running, this measurement shows that energy expenditure affects the performance of passengers during a long transit[16]. In comparison with the fixed seat, suspension seat provide reducing energy consumption particularly in rough sea conditions. Figure 4 compares the effects of fixed and suspension seat on RIB passengers' physiological responses. Furthermore, MIF can be reduced with using suspension seat. On the one hand, large performance reductions were reported for passengers in fixed seats during same rough conditions (see Figure 5).

Standards

As it is mentioned previously, car and aircraft industries have employed HF to increase the performance and safety of their vehicles. SFB design is also include same concepts for crew workstation; for example, pilot, captain or driver requires static position to conduct the vehicle. Hence, some SFB design standards can be taken from air and land vehicles. Some of them are;

Air and associated HF standards include,

- FAA Human Factors Design Standards (HFD-STD- 001)
- NASA-STD-3000, Man- Systems Integration Standard
- NATO STANAG 3994: Application of Human Engineering to Advanced Aircrew Systems
- ASCC AIR STD 61/116/13, the application of Human Engineering to Aircrew Systems, (Aircrew Systems, 2011, www.airstandards.com).

Land vehicles and related HF standards,

- US Federal Motion Vehicle Safety Standards Part 571:
- Standard No: 207- Seating Systems
- Standard No: 101- Controls and Displays

All of these standards are used to reduce the risk of injury or death during the accidents and crashes. Figure 6 demonstrates a helicopter cockpit design with utilizing these standards[10].

SUPER FAST BOAT - HUMAN FACTORS

Nine HF subjects have been determined to support the integration of HF within the SFB design process. The detail about these nine HF areas is presented on TABLE 1.

SFB motions

In the SFB design process, motions have to be considered because of their potential to degrade performance. Also, shock and vibration must also be minimised to prevent risk of acute and chronic injury. The SFB can be exposure two types of motions;

- SFB may be exposure repeated shock or transient vibrations due to the wave impacts. The motion can be any duration
- Occasional shocks and transient vibrations can impact the boat on any duration[5].

The environment characterisations, RS and WBV, reduce the operational effectiveness and readiness of crew and passengers. The effect results are given in

Figure 6 : Sussex police helicopter H900 cockpit

two areas;

- The performance of crew/passengers (MIF)
- Acute or chronic injury

Human performance is affected by SFB motions in three factors. (Figure A-2)

Balance: The motion causes the increase task time, due to the individuals losing of crew/passenger's balance. This problem is known as Motion Induced Fatigue (MII)

Fatigue: The motion lead to fatigue that affects working performance negatively.

Motion Sickness: Under this problem, people cannot operate effectively. This is known as Motion Sickness Induce. (MSI)

Chronic injury usually occurs on spinal, knee, arm or neck injury which can be from high energy event[7]. For instance, in comparison with general military members, many military crewmen was observed higher back and knee injuries because military crewmen always exposure the SFB operational environment,(Ensign 2000). European Union by the Physical Agents Directive supports to reduce risk of chronic injuries and limit exposure to WBV[6], (Minimum health and safety requirements, 2002).

For the purpose of reducing the S&V effects during control of the SFB by the crewmembers, some improvements can be employed on the following variables;

- Coxswain craft-control skill
- SFB speed
- Deck
- Seat
- Hull geometry

TABLE 1 : Human factor areas to support the SFB design process

HF Area	Area Descriptions
A-HSC Motions	Motion effects • Fatigue (MIF) • Balance (MII) • Motion-sickness (MSI) Accelerations Motion measurement and analysis Shock and vibration mitigation Seat support issues
B-Sight	External and internal line-of-sight (instruments)
C-Sound	Noise exposure Communication
D-Environment	Weather protection • Clothing • Helmets Atmosphere (ventilation, claustrophobia) Temperature Humidity
E-Health and safety	Mechanical Safety Electrical safety Fire Safety Physical Safety
F-Man-machine interface	Design crewmember workstation Crew & passenger size (Anthropometry) Controls
G-Habitability	Local comfort • Crew & passenger size (Anthropometry) • Bunks • Access
H-Maintainability	Maintenance
I-Design review	Formalised design review and acceptance procedures • CAD Drawings

TABLE 2 : Changes of human responses to motions during increasing efficiency, (Mansfield 2004)

Frequency (Hz)	Effect
0.05 – 2	Motion sickness, peak incidence occurs at about 0.17 Hz
1 – 3	Side-to-side and fore-and-aft bending resonances of the unsupported spine
2.5 – 5	Strong vertical resonance in the vertebra of the neck and lower lumbar spine, (Hedge 2007).
4 – 6	Resonances in the trunk, (Hedge 2007).
20 – 30	Resonances between head and shoulders, (Hedge 2007).
Up to 80 Hz	Localised resonances of tissues and smaller bones

- Control of human shock absorption and posture such as legs and torso.

For example; coxswain or any operators' posture is an important issue during design process to reduce effects of S&V. Human spine becomes misaligned, so this structure can cause the injuries directly. As a result, operators have to be strong posture that can absorb remarkable amount of impact and force, otherwise working performance can reduce as much as 30%[2].

(a) Human response to vibration motions

The most important human responses to vibration motions, in the range between 0.05 Hz to 80 Hz, are illustrated on TABLE A-1. However, some factors such

Figure 7 : Different types of suspension seats[32]

as old equipment, posture and headrest may affect these responses.

(b) Motion measurement and analysis

(A) Rotation

In addition to vibration, SFB is also impacted by high level of rotational motion. Measurement of absolute angle of the SFB related to gravity is technically different due to the rough environment conditions, during being rotation. Thus, critical angular acceleration and velocities crew can be measured for human response. Probably, longitudinal and lateral accelerations may cause the difficult working conditions for operators, so at this point, operators need to high level muscular work to provide postural stability.

(B) Analysis of WBV

Currently, various WBV analysis ways are possible. These include;

- Route Mean Square (r.m.s) (ISO 2631 Pt 1), (Evaluation of Human Exposure to Whole-body Vibration, 1997)
- Vibration Dose Value (VDV)

The most important SFB biodynamic problems are the repeated shocks and musculoskeletal injury[8]. Presently, studies have been attempted to mitigate these biodynamic issues with some analysis during designing safe boat and seats at sea. Hence, one of them is ISO 2631 Pt analysis method that provides some predictions about the risk of injury especially on lumbar spine. In general, ISO 2631 is used as two different models on SFB design;

- Model of the seated lumbar spine that estimates lumbar spine movements via seatpan accelerations.
- Fatigue-based injury model, via laboratory test on cadaver.

(c) Shock mitigation

The amount of shock mitigation can be changed associated with the different types of purpose/mission. For instance, while a boat that must maintain a high level of speed in all sea conditions, can have larger mitigation requirement than another craft that needs high speed in moderate sea conditions. Also, shock mitigation is also dependent on desired of design SFB; for example, once SFB is used on pleasure activities, aesthetic and hull shape design more important than other mitigation techniques. However, once the purpose of use for military applications, hull form is the most emphasized mitigating technique in all other techniques. For these different types of design, some solutions are given below;

- Hull (mono vs. multi hull)
- Ride control
- Suspended deck
- Suspension seats (see Figure 6)

(d) SFB seats and workstations

The following several seat support problems are considered for SFB design;

(A) Lateral stability

Probably, having lateral support might provide feeling in security for crews on SFB. This support leads to reduce risk of injury especially to the neck. Figure 7 illustrates how the vertebrae bends related to a lateral acceleration when supported around upper torso and hips. In torso lateral support design, upper torso remains stable during putting stress on the spine. Hence, neck exposes the sharply stress and serious injuries can be occurred. Unlike torso lateral support, in only hip

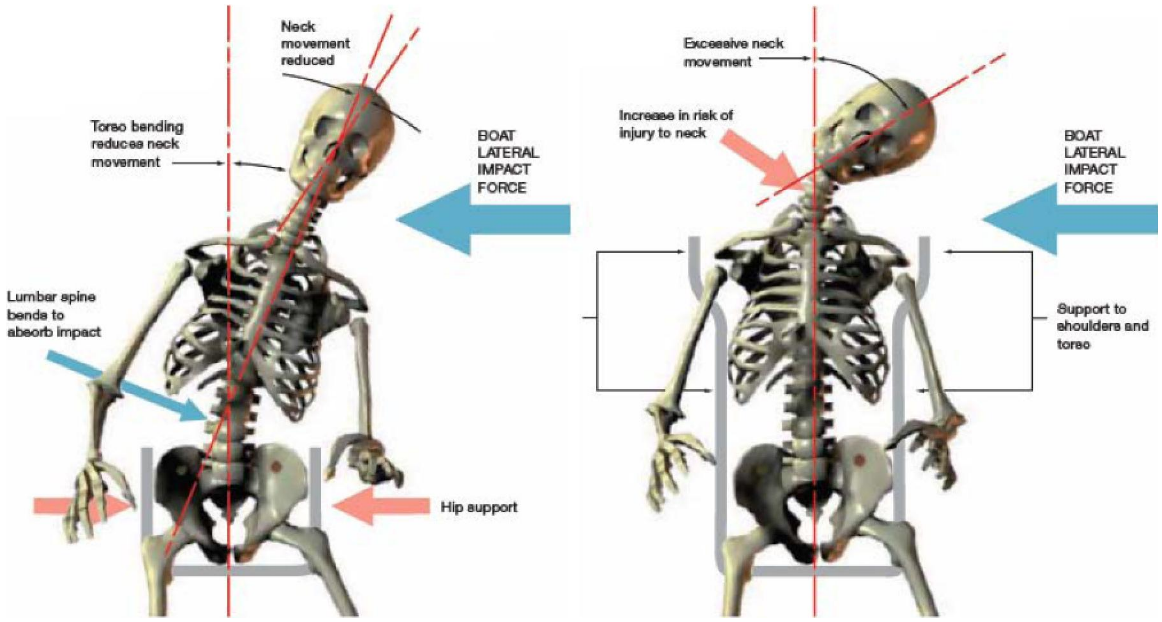

Figure 8 : An example of the impact of SFB seat lateral support on spine deflection[15]

lateral support design, stress can be distributed for whole upper torso. Therefore the neck position can be kept in normal alignment.

(B) Seat cushion

Another important factor for SFB seat design is type of seat cushion; for instance, by the several shock and vibration, soft comfortable seat cushions can rapidly compress. Then, compressing cushion foam matrix collapses aside of seat. As a result of this, seat structure changes as a rigid surface and eventually protection of crew/passengers reduce from the seat.

(C) Foot straps

The foot straps also provide feeling of security for operators on SFB, due to the reducing being displaced events from the seat or boat. However, the main difficulty associates to the suitable position of foot straps. Foot straps should be comfortable for both tall and short occupants. Additionally, design of foot straps must be considered for sitting, leaning and standing positions.

(D) Restraint systems

Movement of operators can be limited by restraint systems in order to prevent operators falling from the seat during the emergency situation such as boat capsizes.

(e) SFB workstation design

Figure 9 : Suspension seats with restraint harness and lap strap[31]

Some following points are considered during design of a SFB workstation;

(A) In the workstation, many dimensional factors can affect crewmember performance directly. Some of them are;

- the correct eye position with respect to sight and display.
- correct postural support that can be provide adjustable seat height, backrest depth and backrest angles.
- control of operator's hand and foot reach requirements.

Figure 10 : Differences in coxswains view while sitting and standing position[15]

(B) Restraints and harnesses

- In the SFB seat design, lap-belt is more widely preferable than shoulder harnesses which is prevents upper torso movements, resulting in a serious worse injury during impact of a sharply stress. Figure 9 demonstrates suspension seat with restraint harness and lap strap.
- Restraints are established adjustable for different operators (tall/short and small/large) and their dresses.
- Occupants can sometimes wear gloves, so mechanism of restraints should be quick for release. In addition to this, the mechanism of restraint must be suitably designed for poor sea conditions. For instance, the seat belt material should not be affected corrosion under the sea.

Sight

Visibility is the significant section for both crewmembers and passengers. While designing of a crewmember work position, different crewmembers and their requirements such as eye heights are considered in order to provide optimum operating performance. Figure 10 illustrates differences in coxswains view while sitting and standing positions.

Another point of visibility is internal lighting (lighten stairways and some internal areas) that is necessary in a SFB to provide safety of crew and passenger. Additionally, in the coxswain and navigator, crewmembers

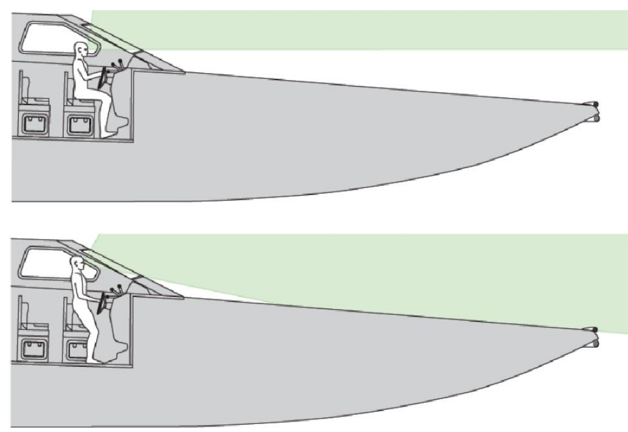

Figure 11 : Differences of line of sight for a sitting and standing coxswain in a closed SFB[15]

require clear and maintain external visibility for task-driven (see Figure 11). Also, passengers, who may see outside and horizon in a closed SFB, will feel in safe and comfortable.

(a) Field-of-view

In general, in this design, the most significant information must be located in the centre of the crew' visual field as within central 30 degrees of viewers' vertical line of sight and also 30 degrees of viewers' horizontal line of sight from eye of height. The less important information can be positioned within the central 60-70 degrees of the viewers' horizontal line of sight and also 40 degrees below and 30 degrees above from the viewers' vertical eye height[13].

In the work station, seating position for the field-

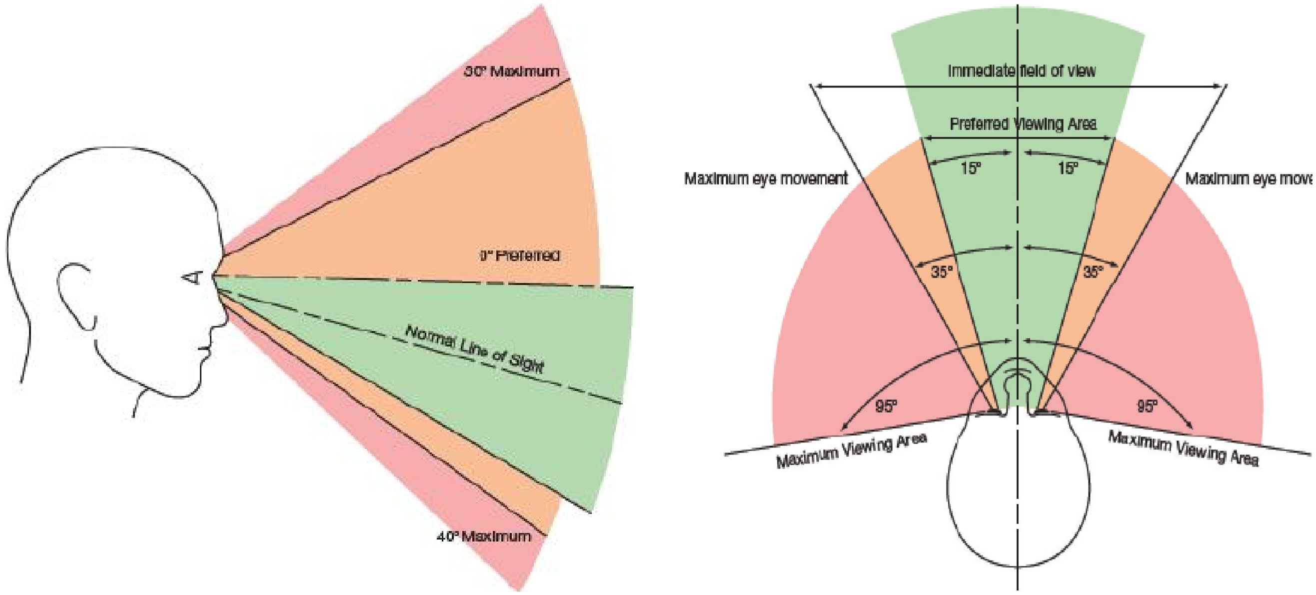

Figure 12 : Example of the optimal vertical and horizontal field of view[13]

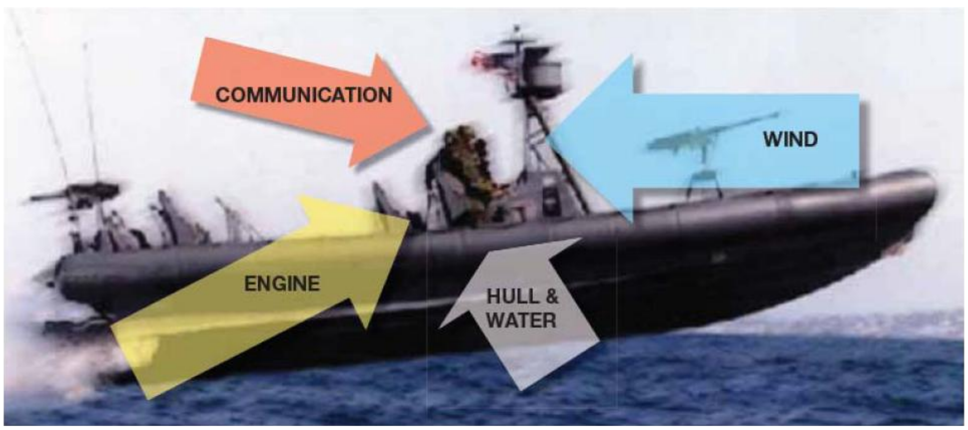

Figure 13 : Sources of sound in a open SFB, (US Navy)

of-view of SFB can be determined with considering following subjects;

- to observe the sea surface at a distance of a boat
- to view the bow of the boat
- to sea leading marks

Figure 12. shows graphical interpretation of the field of view.

Sound

Sound for SFB can be classified in two main heading, noise and crew communications. Figure 12 demonstrates the sources of the sound. These are engine and drive system, wind, hull interaction and communications. High level of noise in the SFB can lead to risk of health hazard and reduce the quality of crew communications. Furthermore, excessive noise affects crew working performance negatively.

According to the European Union Physical Agents (Noise) Directive and UK DSTAN, crewmembers can expose maximum 8 hour Leq (equivalent continues sound level) at the occupant's ear of 80 dB (A) within per 24 hour period. For example, noise level on a RIB was measured in the range between 85 dB (A) in 12 minutes to 90 dB (A) in 36 minutes during travelling at approximately 30 Kts,(Holmes 2001).

Moreover, while in normal office conditions, speech levels for conversation is around 65 dB at a distance of one metre, in background high level noise in a boat can be reach about 85 dB at a distance of one metre.

Therefore, during design of the SFB, the noise reduction can be provided with using through soundproofing sources. Nonetheless, this method is expensive and

Figure 14 : Example of a boat opetion in freezing conditions

not preferable for limited space of SFB. Thus, hearing protection and microphone can be used for noise mitigation in the boat. Particularly, noise-cancelling microphones may be optimised as very close the mouth and also these microphones can exceed 100 dB without raising vocal effort.

Environment

Extreme environmental conditions may affect crew activities directly such as harsh weather clothing interfering with mobility in an open SFB. Moreover, occupants' discomfort can cause the reducing attention and motivation. Low temperatures (cold) and high wind velocity weather conditions, especially travelling with open SFB over 75 km/h, is a serious risk for human health (Figure 13)[1,9]. Nonetheless, protection from adverse weather conditions is possible; for instance wearing cold weather clothing (including gloves) can lead to increase performance of an activity of crews and passengers.

On the one hand, the risk of heat stress and heat illness can become under bright sunshine conditions. As a result of this, in order to provide comfortable and high performance of crew and passengers in a SFB, the comfortable range of temperatures, which are 21 to 27 fC in a warm climate and 18 to 24fC in a colder climate, are considered and then appropriate clothes should be chosen for these different seasons.

(a) Personal protective equipment in a SFB:

In a SFB design process, protective equipment of crew and passengers are listed below;

- Life jacket
- Gloves
- Helmet
- Clothing- waterproof outer layer and insulative under layer
- Shoes
- Eye protection
- Additional equipment such as flare and radio.

Example about cold weather conditions and results are presented as cold stress below;

One of the most crucial risks related with cold stress are frost-bite and hypothermia. TABLE 3- illustrates probability of frost-bite (from olive green low probability of frost-bite to brown for extreme probability)

For instance, in an open RIB, air temperature is about -5 fC and travelling conditions at 40 Kts/ 75 km/h that which cause the -17 fC wind-chill. Once operator is wet in foul sea condition, the risk of cold injury will probably increase.

Additionally, mechanical ventilation and air-conditioning system can be settled up to maintain standard room temperature and humidity in the closed SFB. The air velocity for ventilation system is preferred around 0.3 m/s. Nevertheless, these installations are impossible to establish for open SFB.

Health&Safety

Health & Safety is a statutory requirement; hence following issues have to be considered during design process.

- Mechanical safety: Crew and passengers have to be protected from injury against machines, moving parts, sharp edges and corners and also fire hazards.
- The risk of electrocution have to be minimised.

Furthermore, following risksare associated with crews of SFB[25];

a) capsize of boat (Figure 14)
b) falling overboard
c) striking a solid part of the boat
d) head injury from object falling due to the severe moving of the boat
e) entrapment risk for finger when kook on and release.

Some solutions are possible to reduce hazards for counter these risks. There are;

TABLE 3 : Wind chill chart[36]

Wind Speed		Air Temp(°C)					
Knots	(km/h)	5	0	-5	-10	-15	-20
2.7	5	4	-2	-7	-13	-19	-24
5.4	10	3	-3	-9	-15	-21	-27
8.1	15	2	-4	-11	-17	-23	-29
10.8	20	1	-5	-12	-18	-24	-30
13.5	25	1	-6	-12	-19	-25	-32
16.2	30	0	-6	-13	-20	-26	-33
18.9	35	0	-7	-14	-20	-27	-33
21.6	40	-1	-7	-14	-21	-27	-34
24.3	45	-1	-8	-15	-21	-28	-35
27.0	50	-1	-8	-15	-22	-29	-35
29.7	55	-2	-8	-15	-22	-29	-36
32.4	60	-2	-9	-16	-23	-30	-36
35.1	65	-2	-9	-16	-23	-30	-37
37.8	70	-2	-9	-16	-23	-30	-37
40.5	75	-3	-10	-17	-24	-31	-38
43.2	80	-3	-10	-17	-24	-31	-38

Figure 15 : Example of capsize of a boat

a) waterproof clothing
b) helmet
c) warning system and appropriate escape and evacuation place have to be designed for emergency situation such as a fire in SFB
d) lifting apparatus design to minimize entrapment risks

Figure 16 : An exampleequipment- That is designed for the recovery of man-overboard victims[19]

Additionally, one of the most important issues is manual handling that associated about 25 to 20% of all work-related accidents which are particularly about back complaints. A man can be carried a weight of up to approximately 25 kg with minimal injuring risk. The risks can be reduced with optimum carrying position

Figure 17 : Example of SFB man-machine interface design solutions. (from RNLI)

Figure 18 : Example of the difficulty operating SFB displays when using gloves[15]

where close to waist between elbow and knuckle height[34]. Figure 15 also show an example of equipment utilized to improve manual handling.

Man-MachineInterface

Man-Machine Interface (MMI) is related the fitting workspace for operators to improve their working effectiveness. Figure16 shows an example of SFB MMI design solutions where engine throttles are conducted with finger-tip controls, microphone, radio and cup-holder.

Before design workspace, the following areas require to be considered;

- console layouts; control and instrument layouts should be clear
- seating; as it is mentioned previously, the seating should be designed for operator size (anthropometry).
- task lighting.
- emergency lighting- this one is designed for emergency event such as capsize and fire.
- controls using gloves; briefly, gloves can affect operator's ability and sensitivity directly. Thus, control buttons are designed as larger for using gloves, because large buttons can be used very quickly during extreme SFB S&V motion (see Figure 17 for difficulty operation).

Moreover, the crewmember workspaces have to be designed compatible with the size of operators (anthropometric dimensions) in order to use equipments practically. Also, equipmentsshould be located within reach limits of both large and small operators (Figure 18).

Furthermore, displays should be with respect to operator's normal line of sight (section B for more detail). Figure 12, which was given before in section B, illustrates preferred viewing areas and also, Figure 19 shows acceptable design in coxswain workstation.

(a) Controls

Controls should be easy to operate because of the violent S&V environment. Control principles are dem-

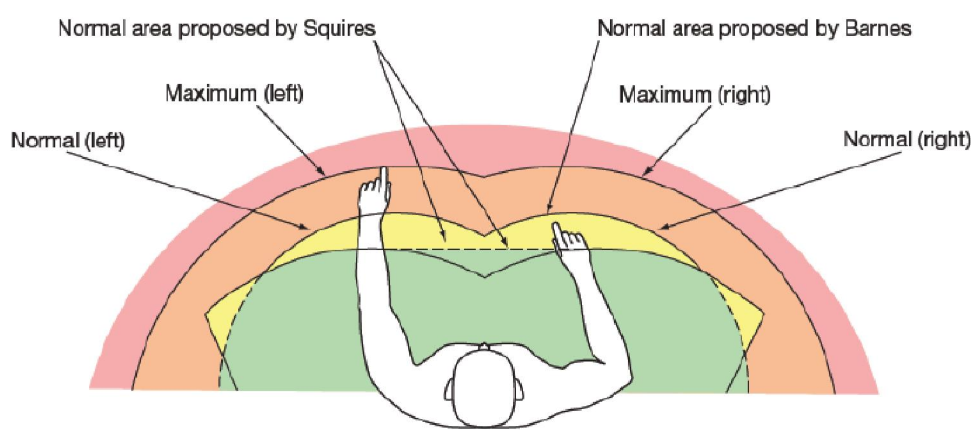

Figure 19 : Effective reach parameters[4]

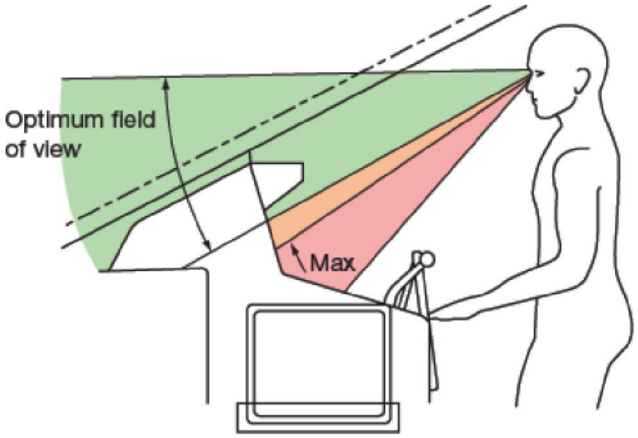

Figure 20 : Example of optimal field of view of workstation and coxswain, (Small craft, engine-driven,200)

Habitability

Habitability includes human requirements, some of which were mentioned in previous sections deeply, in a SFB. Consideration of the following habitability issues are;

Task duration such as 2 hours to 72 hours (WC facilities)

- Furnishing
- Sleeping accommodation (see Figure 21)[15]
- Motion (section A)
- Vibration (section A)
- Noise (section C)
- Atmosphere- temperature (section D)

TABLE 4: Compatibility principles in designing controls and displays[27]

Principle	Description
Principle of location compatibility	Controls should be located to the corresponding display, and their spatial arrangement should allow users to tell easily which control is used for a particular display.
Principle of movement compatibility	The indicator of a display should move in the same direction as its control.
Principle of conceptual compatibility	The layout and the operational methods of controls should be consistent with expectations of the intended user population.
Principle of compatibility of display orientation	For analogue displays, the orientation and ordering of the display should be consistent with those of the mental representation.
Principle of compatibility of display movement	The direction of movement of the moving part of a display should be consistent with user expectation.

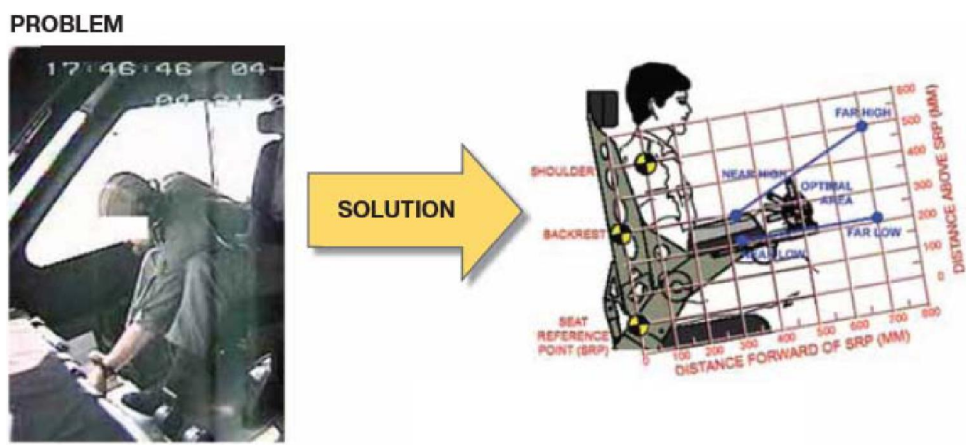

Figure 21 : Solution integration of the suspension seat with the controls. (from US Navy)

onstrated on TABLE 4.

Control panels, which are the most important and frequently used, are designed as easy of accessing of operator's normal working position. Figure 20 demonstrates the effect of integration suspension seat on reach of control panels during coxswain activities.

- Visibility (section B)
- Clothing (section D)

In addition to this, some equipment such as crew's personal equipment are stored awayso as not to prevent operation of SFB. Typical storage system of SFB is shown on Figure 22.

Figure 22 : Example of boat bunk accommodation

Figure 23 : Example of roof storage method on a SFB[15]

Maintainability

Design of a maintenance access details affect maintenance time and operational readiness. For example;

The engine design may be complex for maximum engine power; this can often result in their becoming minimal area around the engines to allow maintenance

Figure 24 : Poor access to engine tools

(see Figure 23)[12].

Although good maintenance access for engine cannot seem to be directly associated to the operational effectiveness of a SFB, poor maintenance access may affect operational readiness during repairing conditions.

DESIGN REVIEW

A design review is an integral part of the SFB design process to ensure that are no surprises when the design is finished. Recently, there are many review tools to check design process step by step. One of them is Computer Aided Design (CAD) drawing that is the first step in the SFB design process. Initially, the absolute design of a SFB is drawn as 2- dimensional to understand whole structure of the product. However, this is not better for comprehension of the design, so 3-dimensional images are used to comprehend all project in detail (see Figure 24). Furthermore, presently, animation of a design is possible within CAD environment, particularly where the crewmembers can be positioned interacting with the SFB systems. Recent example with such animation model is shown in Figure 25.

Moreover, drawing process is carried out some considerations such as passenger activities, lighting measurements and maintenance operations, which are explained in other sections, must be integrated in CAD drawings.

Practitioner summary

According to the Formal Systems Engineering design procedures, Human Factors (HF) and Human Factors Engineering (HFE) is a significant part of the design process. Many sectors such as automotive and aerospace have been utilized the HF and HFE within

Figure 25 : 3D CAD images to design a SFB[15]

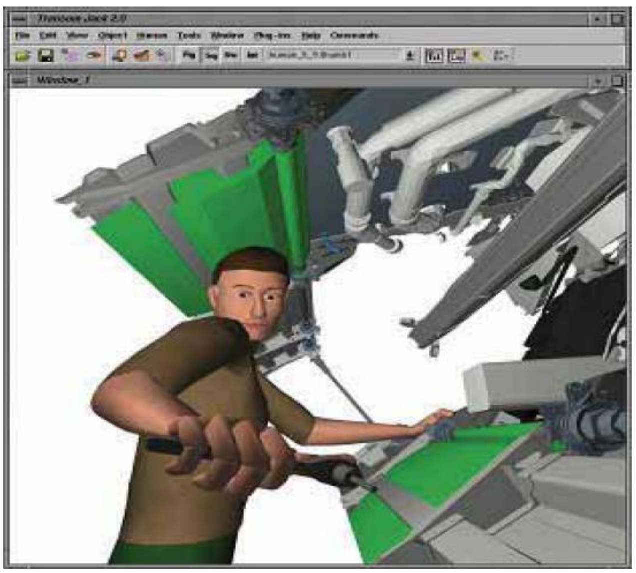

Figure 26 : CAD modelling for access components of SFB[15]

lots of successful design operation. This paper will investigate maritime sector with using Human Factor (Ergonomics of Human System Interaction,2011).

EVALUATION &CONCLUSION

The performance of the SFB system is assessed to support production of SFB. The prototype SFB is tested with respect to HF under various critical conditions which are defined to show risk of crew and passengers[24].

- Night/dark conditions
- Rough/poor sea conditions
- Cold and hot environments

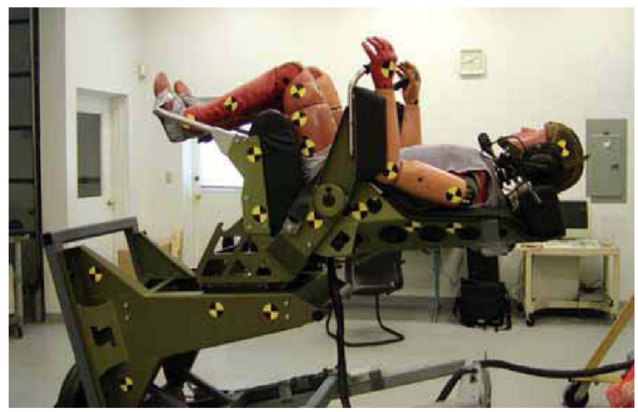

Figure 27 : Laboratory basedantropometric crash test on suspension test[15]

Figure 28 : Suspension set testing in a real sea conditions[15]

- Emergency conditions.

(a) Shock mitigation seat assessment

In the University of Virginia Center for Applied Biomechanics Crash Test Facility, a single high acceleration impact was replicated to measure ability of seat in different variations (see Figure 26). Additionally, laboratory based anthropometric crash tests were applied to evaluate of the loadings and stress with the body.

For instance, the RNLI undertook development of new suspension seat for the Tamar Class Lifeboat[3]. Firstly, the prototype suspension seat is tested in the laboratory. After that, the suspension seats exposure serious of sea trials on a RIB. This testing is presented in Figure 27.

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