Analysis of risk to passengers and evaluation of the possibility of evacuation on high speed crafts

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Abstract

The short specificity of high -speed passenger craft (HSC) and analysis of factors affecting the safety of such units is presented at the article. Normative documents relating to the HSC evacuation is also described. The purpose of this article is to analyze and evaluate the possibility of evacuation of passengers in emergency situations on HSC. This analysis was done on the example of a catamaran in accordance with regulation MSC/Circ.1166 given by IMO.

Introduction

The efficiency of the ship and reliability of the equipment at the stage of designing, building and operation are the ability of a vessel to sail.

In addition, qualified staff and adequate supply state condition allow for making certain operation tasks at the appropriate level of security. Gradually increasing ship traffic entails the risk of accidents. Compared to other modes of transport effects of accidents and disasters at the sea are much bigger dimension.

It is, therefore important to ensure an adequate level of security, since the consequences of such events can be considerable, both for human life and the environment. Events that occur during the operation of the vessel in both the port and the inland it is difficult to predict. Their course is always unique, and the effects are different dimension and character. It is known that elimination of the hazards and risks of accidents at the sea is impossible, so it is important to conduct all entities responsible for the operation of the ship. Specific measures and actions contribute to the fact that it is possible to prevent and / or minimize the possible impact.

According to the statistics of accidents involved passenger vessels in cases of total amounts to about 26%, and the human factor is usually the main cause of the event.

Introduced still new EU regulations concerning the safety of passenger ships, are the most stringent in the world.

This is the result of a process for continuous improvement, pro-active and preventive measures to raise standards in the field of maritime safety.

On the seas surrounding Europe increasingly can be seen high-speed crafts (HSC), which allow for reduction of travel time. These units are characterized by high operating speed above 38 knots and a maximum travel time specified by the regulations to four hours.

The design and safety of high-speed craft is regulated by the High Speed Craft Codes of 1994 and 2000, adopted by the Maritime Safety Committee of the International Maritime Organization (IMO).

The purpose of this article is to analyze and evaluate the possibility of evacuation of passengers in emergency situations on HSC. This analysis was done on the example of a catamaran in accordance with regulation MSC/Circ.1166.

The specificity of high speed passenger craft

Today, many routes are serviced by a single or double-hulled high-speed passenger craft which are called in short HSC – "fast ships", "fast ferries" or incorrectly "fast catamarans".

High-speed craft is a special category of sea-going vessels that includes hovercraft, catamarans and hydrofoils. The construction and operation of commercial high-speed craft is generally subject to similar legislation to that controlling other merchant shipping. However, due to the specific issues created by their speed of travel, there are both additional and substitute regulations that take account of the operation of these craft, whether used for cargo or passengers [1].

High-speed craft can be classed in two broad categories, Air-Supported and Displacement type. Air supported craft include Air Cushion Vehicles (ACV), Surface-Effect Ships (SES) and Foil Supported craft, such as hydrofoils and jetfoils. Displacement type vessels include conventional mono-hull, catamaran, trimaran, small waterplane-area twin-hull (SWATH), and air lubricated hulls. While each type of vessel has its own unique characteristics, they all suffer from the common problem of limited payload and a sensitivity to wind and sea state [2].

The classification societies considered in this study have two different definitions of a high speed craft, the one used by ABS and the other defined by IMO and the other class societies. Figure 1 compares the two versions. As can be seen, while it is not possible to directly compare the definitions as the IMO criteria is displacement vs. speed and the ABS criteria is length vs. speed it is nonetheless useful to show two criteria together and to compare a specific vessel. Consider a corvette sized vessel that is classed as a HSC under the DNV Rules. It is 61 m long with a full load displacement of 950 tonnes. Under the IMO criteria a 950 tonnes vessel must have a design speed of at least 22.5 knots to be considered a high speed vessel. The same vessel 61 m long can have a design speed of only 18.4 knots under the ABS Rules and still be considered a high speed craft [3].

These types of vessels have specific needs in terms of infrastructure and maintenance, so they can not be compared to conventional vessels and should be considered as a new form of transportation. HSC have difficulty in approaching the port, carrying out manoeuvres as well as problems during loading and unloading. Such complications can cause costly delays due to longer time to prepare the ship for the next trip which restricts using of these units [4].

IMO's High-Speed Craft Code applies only to vessels engaged in international trade service. Domestically, HSC passenger carrying vessels are required to be US Coast Guard inspected; however, the Coast Guard does not differentiate HSC from other passenger vessels. Consequently, HSC passenger vessels would typically fall under the regulatory standards for subchapters T or K. This is an example of regulations not keeping pace with technology. Not the least of the concerns is the lack of any specific requirements for crew training relative to the operation of HSC [2].
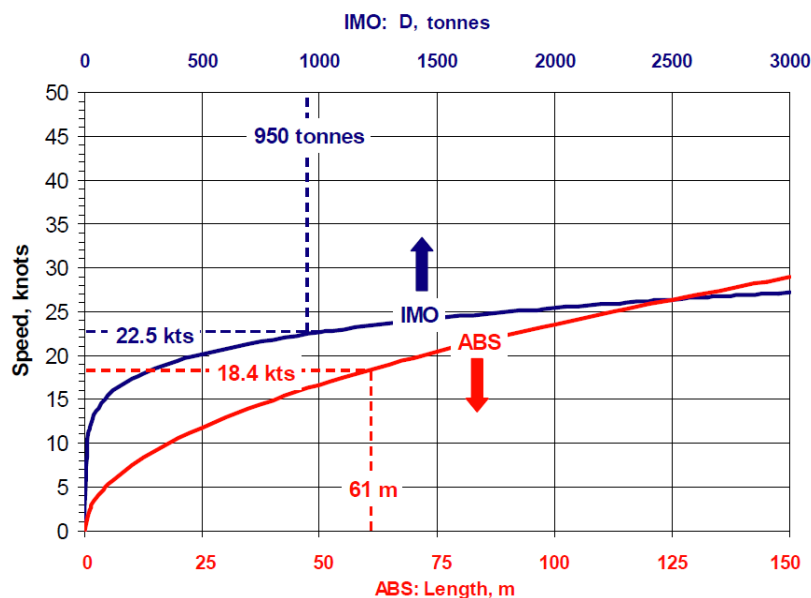

Fig. 1. IMO and ABS Definitions of High Speed Craft [3]

HSCs are becoming increasingly popular among shipowners engaged in ferry shipping in the Baltic Sea. Such units for the Polish central coast ports, can provide an excellent alternative to conventional the larger vessels, especially that European shipyards offer also HSC ferries having a steel hull. This solution affects strongly on significant prolongation of service life.

Unfortunately, these vessels have several important drawbacks: significant fuel consumption, short range and an aluminum hull structure limiting the period of shipping only for months, in which there is no ice cover [5].

Analysis of factors affecting the safety of HSC

Safety of each vessel depends on many factors, among others, technical-operational, navigational, meteorological and human factors. External and environmental interaction are the hydro meteorological conditions and the state of sea, which directly affect the possibility of shipping. Storms, strong winds, precipitation greatly hinder the movement of the ship, and emerging obstacles like ice, shallow, other floating objects threaten the safety of the ship.

For the safety of navigation are affected: taking into consideration the dangerous areas like the shallows, hydro meteorogical conditions, constant availability to current and reliable information and quality of navigational observation and control of ship [6].

During the operation the ship is all the time subjected to impacts of two environments – water and air-provoking waves, the ship drift, trim and flooding. Environment adversely affect the quality of the technical indicators of the ship. This can lead to accidents [6].

Technical and operational factors are dependent on the reliability of the work of all mechanisms which are situated on the ship as well as the efficiency of equipment and appliances assure the ship's propulsion and manoeuvreability [7].

Guarantee the safety of the ship is to fulfill all the required norms and standards relating to his condition, which is defined as the ability to counteract the ship difficult external environment conditions such as storm, strong wind, waves, ice, etc. For this condition affects the hull strength, stability equipment for lifesaving and fire protection measures, navigation systems and traffic management [7].

Technological progress has meant that technical, operational and navigation factors are increasingly smaller share of failures and accidents of the ships.

In previously conducted studies and observations indicate that the main factor in initiating various types of events is the man. Errors committed by him leads directly up to 80% of failures and accidents. In other cases, we may notice an indirect human impact on the occurrence of dangerous situations. We can not ignore the human factor, as a man on the basis of technical equipment makes the final decisions. It is known that failure, accidents or disasters of the ships can not be completely eliminated. However, we can increase the safety of ships by making changes in their design, construction and operation. Visible in all areas of optimization of the operating costs of vessels does not increase the level of safety. The introduction of new, innovative solutions makes that the technique rarely is unreliable, and formulated procedures are getting better and better. Almost every disaster that took place at the sea, induced a number of measures to improve the level of safety of passengers, crew, cargo, and the ship itself. It is connected with the rules and procedures for the design, construction and operation of vessels used to impose specific technical solutions or methods and safety management systems under certain conditions. Strenght and stable ship's structure, appropriate emergency and fire protection equipment, number and qualifications of the crew, the proper management of security gives a better chance of survival and reduces or eliminates the effects of hazardous events. Over the years, construction of passenger ships has changed a lot. It forced the huge investment to redevelop existing ship or additional equipment and purchase new units. Further changes are planned in regulations, e.g. in the area of stability, navigation or the rescue systems. Disaster of "Costa Concordia" showed irregularity of existing regulations, because of the wrong time of instructing passengers how to deal with unforeseen events.

In recent years increasing interest in high-speed crafts, moving on a relatively short-distance shipping. This interest is due to the much shorter travel time than for conventional vessels. Evacuation of this type of unit is much easier than in case the large passenger ships, because HSC units carry much less people and have less corridors and decks. The passengers do not travel in the cabins but they have seats which simplifies the evacuation process. However, the shipping routes are quite short is definitely easier to get emergency help. However, the safety of passengers of HSC depends on many factors and unfortunately to this day we can not eliminate all risks associated with the traveling of such as units. The following are examples of high-speed craft accidents (Table 1).

Table 1. Examples of high-speed craft accidents [8]

No.	Vessel	Date	Type	Craft type
1	Hai Yang and Man Boo	April 1997	Collision	Catamaran / Conventional ferry
2	Superferry 2	October 1997	Multiple collision	Monohull
3	Flores	May 1998	Mechanical failure	Jetfoil
4	Laura	June 1998	Grounding	Hydrofoil
5	Sunnhord-land / Kingtor	June 1998	Collision	Catamarans

The main reasons forcing the evacuation of passengers and crew, we can certainly include fire and collision. Most accidents are caused by human error. The evacuation of HSC most often takes place in unfavorable hydro meteorological conditions, at night and in a hurry.

The picture (Fig. 2) shows an example of a damage catamaran after a collision with another ship.

Fig. 2. The damage of passenger compartment on the starboard side of the HSC *The Cotai Strip Expo* [9]

The summary of HSC incident category statistics is presented in MCA Research Project 504 (Table 2).

An analysis of 40 ocean-going vessel accidents was compared with the study of a similar HSC's at the paper [11]. From the analysis one could see that the HSC accidents and incidents are mainly related to bridge personnel and operations where the human factor is the most responsible element. Also weather conditions (lack of visibility, waves, wind) is one of the main factor in collisions especially on busy routes.

Normative documents relating to the HSC evacuation

Requirements for the design, equipment and construction of high-speed craft and requirements for the operation and maintenance determines the resolution MSC.97 (73). From the ship designing viewpoint, regulations on evacuation analyses at the design phase are crucial. According to requirements of High Speed Craft Code (HSC Code) (Ch. 4.8.2) HSC have to undergo evacuation-related analysis at the design stage, taking into account counterflows (crew moving in opposite direction) and blockage of some routes. The following documents have been prepared as guidelines for evacuation analysis:

– *Interim Guidelines for a simplified evacuation analysis of high-speed passenger craft* (Msc/ Circ.1001);
– *Guidelines for a simplified evacuation analysis of high-speed passenger craft,* (Msc/Circ. 1166).

Maritime Safety Committee (MSC) at 74th session (30 may – 8 June 2001), after findings of 45th session of Fire Protection Sub-Committee (FP) (8–12 January 2001), approved circular MSC/Circ. 1001 for a simplified evacuation analysis of high-speed passenger craft.

Table 2. HSC incident category statistics [10]

No.	Accident category	Number of incidents	Percent of total incidents	Fatalities	Major injuries	Minor injuries	Equiv. fatalities	Equiv. fatalities per incident	Fatalities per incident
1	Accident to personnel	10	1.47	0	4	7	0.47	0.05	0
2	Collision	162	23.86	41	177	631	65.01	0.4	0.25
3	Contact	143	21.06	10	90	221	21.21	0.15	0.07
4	Explosion	6	0.88	0	21	14	2.24	0.37	0
5	Fire	46	6.77	14	6	51	15.11	0.33	0.3
6	Flooding or leakage	8	1.18	0	0	0	0	0	0
7	Grounding or stranding	84	12.37	18	186	364	40.24	0.48	0.21
8	Loss of hull integrity	20	2.95	0	32	27	3.47	0.17	0
9	Machinery failure	117	17.23	0	0	0	0	0	0
10	Other	83	12.22	16	42	29	20.49	0.25	0.19
11	Total	679	100	99	558	1344	168.24		

MSC at 81'st session (11–20 May 2005), after examining the application from 49th session of FP (24–28 January 2005) determined on the experience gained in the application of the above-mentioned interim guidelines approved circular MSC/Circ. 1166. This circular supersedes document MSC/Circ.1001.

The example of evacuation time calculation based on MSC/Circ.1166

The object of the analysis of evacuation is catamaran (Fig. 2) with main dimensions:

- lenght over all 45 m;
- breadth 12.3 m;
- draught 3.7 m.

Typical example of HSC is used to the analysis. The catamaran is equipped with one main staircase which passengers in the event of an emergency evacuation, follow the assembly stations and embarkation. The catamaran consists of two decks, in which there are 444 persons (therefore this craft is classified in category A according to the HSC Code). Passengers should be assumed to be distributed in a normal voyage configuration. At the start of the evacuation the passengers and crew will evacuate via the primary escape route to the lower deck to the marine evacuation system (MES): 144 passengers marshaled by 1 crew member move from the upper deck through stair down to the lower deck and join with 128 passengers and 1 crew member and 168 passengers marshaled by 2 crew members. They are separated into two streams which move through the door 1 and 2 and along the corridors 1 and 2 to MES 1 and 2 respectively.
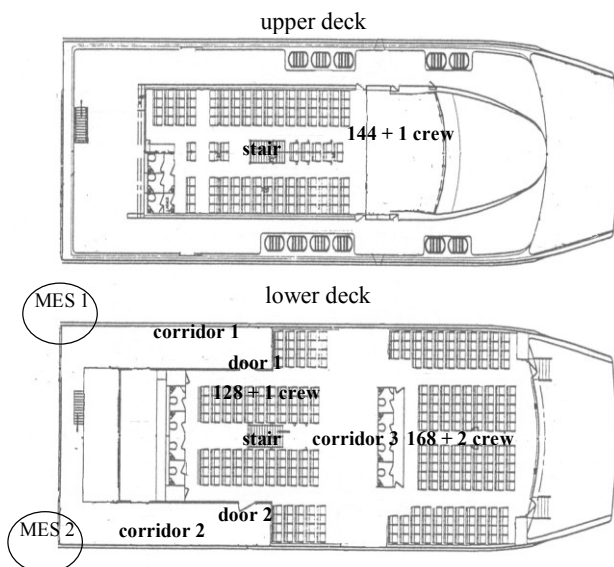

Fig. 3. Catamaran decks plan [own study based on http://www.ag-ems.de]

The escape routes from assembly station to embarkation station are represented as a hydraulic network where the pipes are the corridors and stairways, the valves are the doors and restriction in general (Fig. 3).
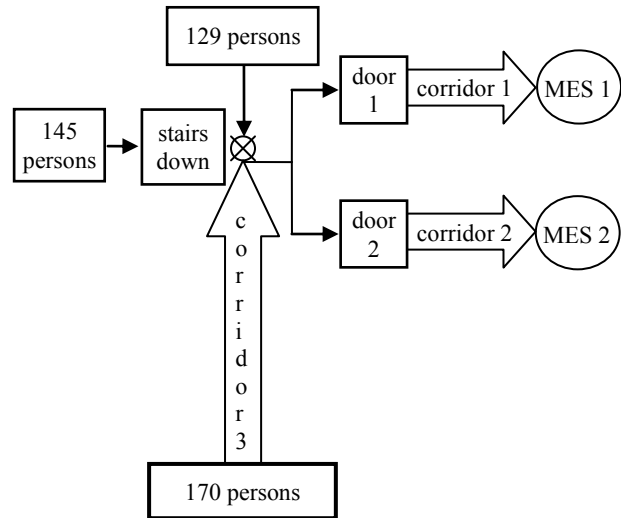

Fig. 4. Sketch of evacuation path and its schematization [own study]

The characteristic of the escape path's elements are as follows (Table 3).

Table 3. Escape path's elements characteristic [own study]

Element	L [m]	W_c [m]	F_s [person/(m/s)]	S [m/s]	F_c [person/s]	N [person]
door 1	NA	1.4	1.3	NA	1.82	222
door2	NA	1.4	1.3	NA	1.82	222
stair	4.7	3	1.1	0.55	3.3	145
corridor 1	15	4	1.3	0.67	5.2	222
corridor 2	15	4	1.3	0.67	5.2	222
corridor 3	6	4.5	1.3	0.67	5.2	170

Where:
L – length [m];
W_c – clear width [m];
S – speed of persons [m/s];
F_c – calculated flow of persons is the predicted number of persons passing a particular point in escape rout per unit time [person/s];
F_s – specific flow of persons is the number of evacuating persons past a point in escape rout per unit time per unit of clear width [person/(m/s)].

Value of F_s and S are taken from table 4. Value of F_c is obtained by formula:

$$F_c = F_s \cdot W_c \qquad (1)$$

Table 4. Value of S [12]

No.	Type of facility	Speed of persons S [m/s]	Specific flow F_s [p/(m/s)]
1	Stairs (down)	0.55	1.1
2	Stairs (up)	0.44	0.88
3	Corridors, doorways	0.67	1.3

The total number of persons on board is broken down into one or more groups of people. It should be assumed that all persons in a group carry out the evacuation at the same time.

We define:

t_F – flow time is total time needed for a group of N persons to move past a point in the egress system [s];

t_w – walking time is the total time needed for a person to cover the distance between the assembly station and embarkation station [s].

The walking time is calculated by using the speed of persons specified in table 4 and the distance between the pertinent assembly and embarkation stations. The flow time of each portion of escape route is calculated using the F_s and appropriate W_c of that portion of escape route (formula 2). The total flow time is the largest value obtained.

$$t_F = N / F_c \qquad (2)$$

The travel time is obtained as a sum of walking time and a total flow time. Calculation should be repeated for each foreseen group of people. The highest resulting travel time is then taken as the ideal travel time t_I needed for the slowest group of people to reach the embarkation point.

The results of walking time and flow time are as follows (Table 5).

Table 5. The results of walking time and flow time [own study]

No.	Element	L [m]	W_c [m]	N [person]	t_w [s]	t_F [s]
1	door 1	NA	1.4	222	NA	122
2	door2	NA	1.4	222	NA	122
3	stair	4.7	3	145	9	44
4	corridor 1	15	4	222	22	43
5	corridor 2	15	4	222	22	43
6	corridor 3	6	4.5	170	9	33

The resulting total walking time is the sum of the walking element in escape path and totals 31 s. The flow time corresponds to 122 s. Accordingly the ideal travel time is 153 s.

The allowable evacuation time t_A is:

$$t_A = \frac{SFP - 7}{3} \ [\text{min}] \qquad (3)$$

where:

SFP – structural fire protection time is the protection time for areas of major fire risk.

The following two performance standards should be complied with for calculating the overall evacuation time (according to HSC Code).

$$t_M + t_E \leq t_A \qquad (4)$$

$$t_I + t_E \leq t_A \qquad (5)$$

where:

t_M – ideal deployment time is the time needed for the preparation and launching of the marine evacuation system and the first survival craft in calm water;

t_E – ideal embarkation time is the time needed for all passengers and crew to board the survival craft from the starting situation.

The values of t_M and t_E should be calculated separately based on approval trials for any inflatable liferafts and MES'es and fullscale shipboard trials.

The above calculations of the ideal travel time t_I on the selected unit of HSC gave the result 153 seconds. Analyzed unit has two decks where there are over 400 people, the time about 3 minutes is, therefore, a relatively short time. Also note that this is the time of the largest group of people. This group has to overcome about 20 meters, including a staircase leading down to the lower deck. For the analysis of evacuation a simplified method was used then real evacuation process could by longer. This simplified method also has its advantages, which is undoubtedly the simplicity and speed of performance analysis.

Conclusions

During the operation of each ship there are phenomena and processes which can deviate from the accepted and recognized standards. They can cause risks which arise as a result of emergency situations and events, such as collision, accident, disaster, etc. The occurrence of such events may be independent of the actions and the will of man but also can be the cause of human errors of crew, passengers or port service. Their consequences include financial expenses, operating losses but above all the loss of lives of passengers or crew members.

Ensuring adequate level of security and effective implementation of the transport and handling processes largely depends on the crew of the vessel – its composition, qualifications and experience. This is not an easy task, due to the emergence of new threats at different scales, such as terrorist attacks.

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