Inflatable Life Raft Design for Operation – Novel Solutions

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The paper presents the discussion of novel life raft designs. The existing solutions of life rafts available on the market have many drawbacks. In Polish industry, a company having the experience in production of life rafts is Stomil Grudziadz who are now on the way to start new production of modern life rafts. The design for operation has been proposed to introduce complex approach including life raft considered as an element of Search and Rescue System. The conclusions of the paper comprise the main problems which need to be solved in novel design of a life raft - stability in waves, reduction of non-linearity of aero dynamical coefficients, solution of safe and easy entrance to the life raft, increase of thermal protection of survivors, increase of range of detection using novel materials, based on the latest achievements in nanotechnology.

Keywords: life raft, design, operation.

1. INTRODUCTION

Inflatable life rafts are the most widely used survival crafts on board merchant vessels and leisure crafts. The presented study deals with SOLAS life rafts approved with respects to LSA Code (Life Saving Appliances Code). They should meet the requirements of LSA Code mandatory under the International Convention for the Safety of Life at Sea (SOLAS), 1974) [1] comprising the design and operational requirements. These life rafts shall have a carrying capacity of six or more people and no more than fifty people.

The general idea of an inflatable survival craft has not changed for dozens of years. The main design goals were little place necessary to store on board, low cost, use in all possible conditions and automatic launch using hydrostatic release system in case of accident when there was no time to launch any survival craft.

Design for operation or design for safety are the trends in design of vessels and floating units based on the comprehensive approach to design, including the predicted operational characteristics and functions of the designed unit as a part of transportation system [2]. The survival crafts in the case of ship accident are elements of Search and Rescue (SAR) System [3] therefore the preferred method of design shall be based on the performance and risk-based complex approach presented in [4, 5, 6].

The last changes in design of SOLAS life rafts, available on the market, with respect to the desired operational characteristics, are the improvements allowing decreasing weight, giving better thermal protection for the survivors on board, and better life raft stability in wind and waves. Some of the improvements are far beyond the requirements, however they are not common and mainly used for smaller 6- to 12-person life rafts.

In 2013 Iceland presented "A mandatory code for ships operating in polar waters including “Inflatable life rafts designed for polar conditions/operation”, submitted to Sub-Committee on Ship Design and Equipment of International Maritime Organisation [7]. The requirements of this code should increase the chances of survivors in cold waters and heavy weather. They include design and operational characteristics important for all novel designs not only for those operated in polar waters. Some of the requirements are already implemented in advanced commercial applications.

2. OPERATIONAL CHARACTERISTICS OF AN INFLATABLE LIFE RAFT

The main operational characteristics of an inflatable life rafts are related to the possibility of rescuing the survivors:

- access from the water into a life raft – possibility to get into a life raft from water by survivors,
- operation of thermal protection means – insulation and openings influencing the survivors condition during SAR action,
- leeway characteristics – determination of a life raft motion and position during a SAR action,
- life raft stability characteristics in wind and waves,
- operation of means influencing effective reflecting surface of a life raft - passive radar reflectors influencing possibility of life raft detection,
- life raft towing characteristics in waves,
- survivors recoverability from a life raft,
- life raft recoverability from the water.

The design and construction of a life raft canopy, including the use of retro-reflective material, construction of canopy openings with round edges, sleeve type entrances as well as buoyancy chambers, ballast chambers and sea anchor shape and construction – directly influence life raft operations.

2.1. LIFE RAFT ACCESSIBILITY

The access from water into a life raft depends on the possibility to reach a life raft drifting through water, possibility to get into a life raft through the openings in the canopy, using the ladder or boarding ramp. With respect to the LSA Code requirements each entrance shall be clearly indicated and be provided with efficient adjustable closing arrangements, life rafts accommodating more than eight people shall have at least two diametrically opposite entrances, at least one entrance shall be fitted with a semi-rigid boarding ramp, capable of supporting a person weighing 100 kg. The boarding ramp should not cause deflation of a life raft if the ramp is damaged.

The existing solutions, tested in calm water are not user friendly in real sea conditions. The survivors have serious problems in getting into a life raft from water, life rafts drift with a speed higher than speed of a swimmer; they lose stability in wind and waves. The entrances are too high above the water surface and use of ladders or boarding ramps is very difficult for chilled and tired survivors. The kind of lock should be proposed to solve this problem.

2.2. LIFE RAFT INSULATION, THERMAL PROTECTION

The best solution proposed now by the vendors is a double insulated canopy by means of either two layers of material separated by an air gap. Entrances into a life raft should be of round or oval shape with sleeves. Life rafts accommodating more than eight people have two diametrically opposite entrances, double door, double closure - Velcro & ties instead of zippers prone to breaking or jamming [8]. Double insulated floor over the main buoyancy chambers, by means of one or more inflated compartments. No drainage systems are proposed in commercial life rafts.

2.3. LIFE RAFT INSULATION, THERMAL PROTECTION

Leeway is the amount of drift motion to leeward of a life raft drifting in water. It is caused by the component of the wind vector perpendicular to the forward motion of the life raft . The National Search and Rescue Supplement to the International Aeronautical and Maritime Search and Rescue Manual defines leeway as "the movement of a search object through water caused by winds blowing against exposed surfaces". Wave forces may be neglected as the wave effects are small when the length scale of the object is less than one-fifth of the wave length.

Wind forces are dependent on the overwater structure of the object. The National Search and Rescue Manual (USA) shows the maximum angles of the diversion of leeway direction from the wind direction for life rafts as follows:

- life raft with a minimum draft ± 60°.
- life raft with a mean draft ± 45°.
- life raft with symmetrical buoyancy chambers ± 15°.
- the recommended leeway angle to be included in the calculations ± 35°.

Figure 1 presents the maximum leeway angles and the recommended area of possible positions of a life raft . Figure 2 presents the example of deformation of the canopy under wind.

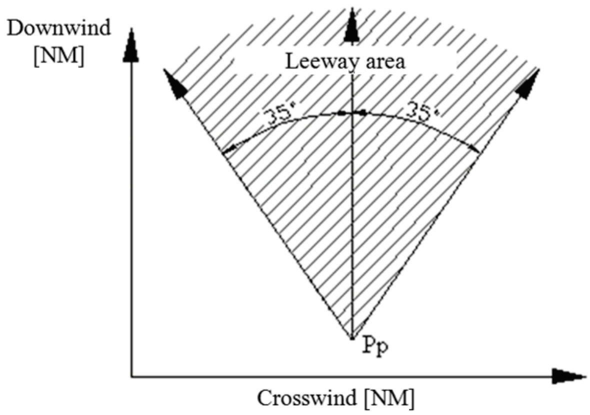

Fig. 1. Maximum leeway angles, area of possible positions of life raft, Pp - initial position of the life raft.

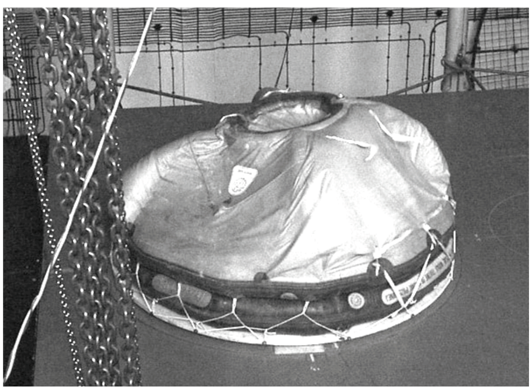

Fig. 2. Deformation of the canopy of a 6 persons life raft - real scale tests in the wind tunnel of Institute of Aviation in Warsaw, Poland [9].

Leeway is dependent on aerodynamic and hydrodynamic characteristics of a life raft. The best solution of a new design shall be obtaining the aerodynamic characteristics as functions independent on wind direction. This can be provided by the axisymmetric shape of the canopy with the vertical symmetry axis and sufficient canopy stiffness. The example of deformation of the canopy under 10 m/s wind speed is presented in figure 2 This deformation was the reason of wind force fluctuations up to 20% [4].

The hydrodynamic characteristics of a life raft are dependent on the geometry of the submerged part of the buoyancy chamber, ballast system and drogue (sea anchor).

The water pockets provide the ballast weight to keep the life raft stable during survivors entry and exit. The life raft drogue performs the function of the sea anchor and strongly influences leeway and stability characteristics. The best solution for not launched life rafts is auto deploying sea anchor [10], as the life raft without it can drift out of reach of survivors. The random limiting safe wind speed for a life raft with water pockets ballast system, determined on the basis of model tests and sea trials has been proposed in [11]. The elements influencing leeway and safety function of a life raft are presented in figure 3.

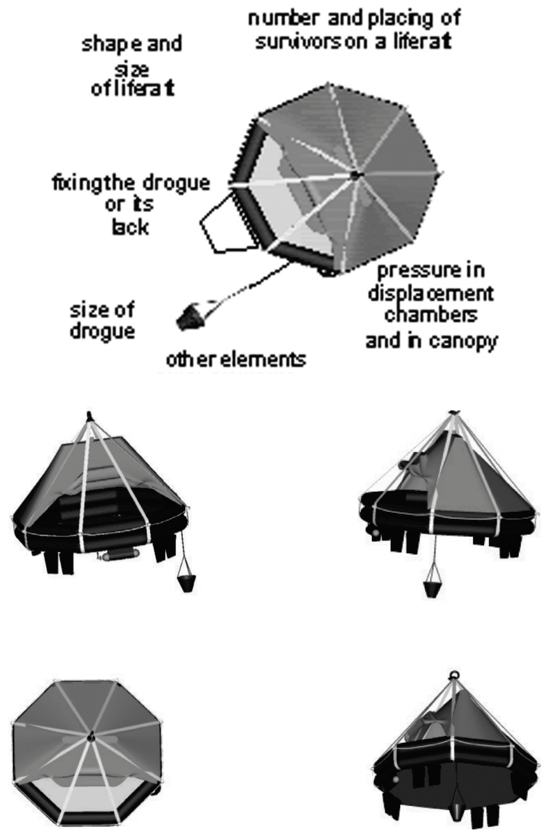

Fig. 3. Elements influencing leeway and safety function of a life raft with water pockets ballast system and drogue [9].

The life raft trim is defined as the list angle measured between the life raft axis in the direction of life raft motion and line perpendicular to the water surface. It is dependent on the speed of life raft motion and increases strongly at speeds over 1.5 m/s. The example of life raft speed - trim characteristic is presented in figure 4.

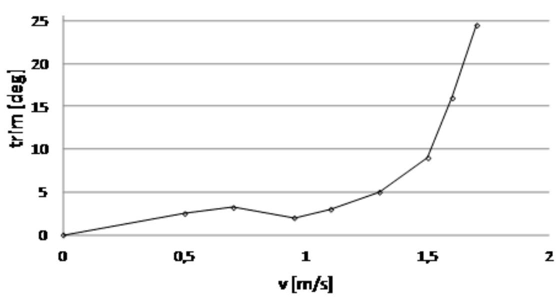

Fig. 4. Trim of 6 persons life raft towed in calm water with 1 person on board [9].

The existing solutions of ballast systems are presented in figure 5. The system of water pockets, presented in figure 5a) is the most popular solution of the water ballast. The more advanced systems is the toroidal stability device in figure 5b), toroidal system of water pockets 5c) [10] and hemispherical ballast bag in figure 5d) [8].

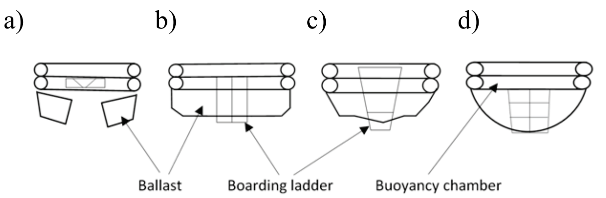

Fig. 5. Ballast systems: a) water pockets, b) toroidal stability device TSD, c) toroidal system of water pockets, d) ballast bag.

The best characteristic with respect to the leeway and stability has the life raft with deformable ballast bag system. The heavy ballasting used in this life raft helps to keep it in place [8] with the mass of about a ton of sea water. The ballast chamber acts as a sea anchor and protects the raft from blowing over or turning over in the roughest weather conditions. The list of the life raft with ballast bag system does not cause decrease of stability like in case of a life raft with water pockets.

2.4. LIFE RAFT TOWING CHARACTERISTICS IN WAVES

Towing dynamics of a life raft in waves is not considered in current regulations of the International Maritime Organization. The "life raft and its fittings shall be so constructed as to enable it to be towed at a speed of 3 knots in calm water when loaded with its full complement of persons and equipment and with one of its sea-anchors streamed" [1].

The two-dimensional problem of the coupled motions of two bodies on a surface wave, representing the fast rescue craft (FRC) and the life raft has been studied in [12] and [13].

The identified important problems are:

- the selection of line length and elasticity for the reduction of snap loadings,
- streaming of the drogue, attached to the life raft .

At lower speeds, the drogue would not be fully streamed, resulting in a lower tow load on the drogue line, life raft yawing and decrease of her stability.

2.5. LIFE RAFT RECOVERABILITY FROM THE WATER

The recoverability of life rafts from the water in extreme seas is still the subject of studies. Following the history of accidents the survivors suffering from the hypothermia were lost during this stage of SAR action. Different systems are proposed to improve recovery performance of a rescue vessel in severe sea states [14].

The principal conclusion coming from the latest investigations is that an inflation pressure of 50 kPa or above is necessary to minimize loss of air during dynamic loads and to retain life raft rigidity during lifting [15].

3. LIFE RAFT DESIGN FOR OPERATION

The main criteria used by ship owners in the selection of lifesaving equipment on board vessels are the low cost, low weight and small place to store on deck. The cheapest life rafts on the market have poor operational characteristics, material and constructional defects.

The novel designs shall have better characteristics with not much higher costs. The design for operation should comprise both life raft performance in real conditions, detectability and recoverability from the water. The process of preliminary design combines general design, static performance and dynamic performance. The general design consists of principle technical specifications and shape design. Floatability and stability in calm water are included in static performance. Dynamic performance comprises stability in waves, leeway, survivability and towing characteristics.

The examples of the algorithms for life raft design: general outlines for stability calculations and life raft detection are presented in figures 6 and 7.

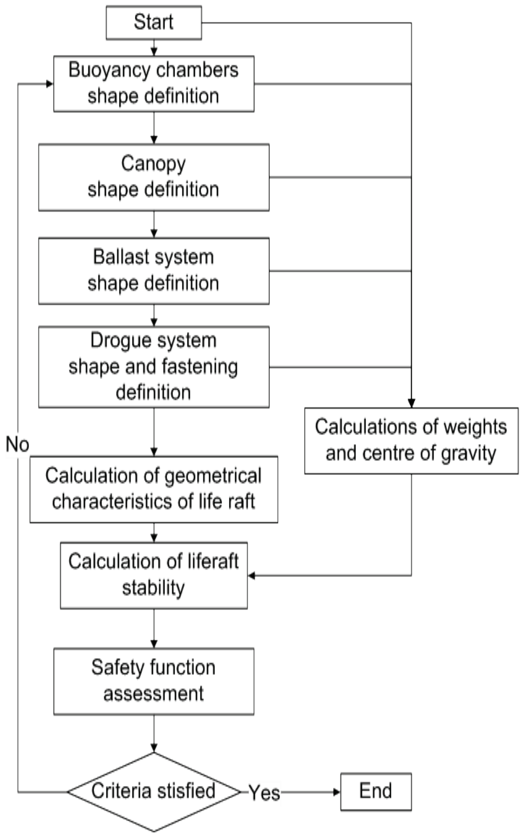

Fig. 6. The general outline of the algorithm for stability calculations.

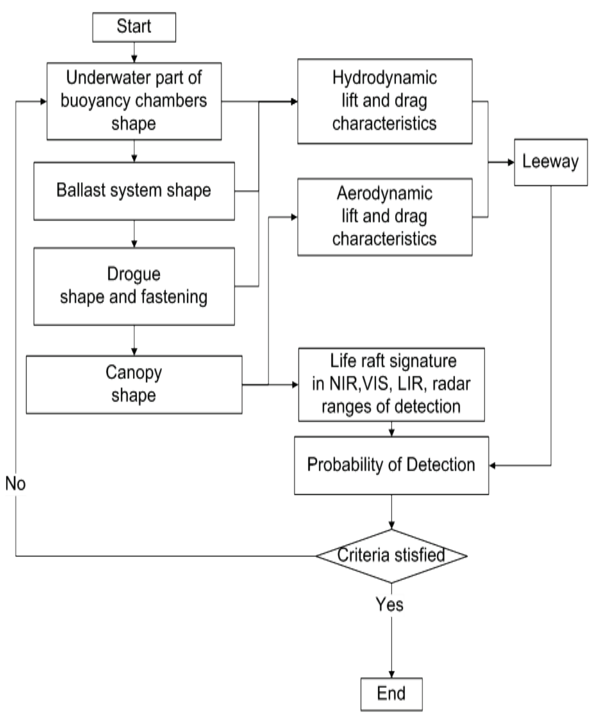

Fig. 7. The general outline of the algorithm for life raft design for detectability.

4. CONCLUSIONS

The most important problems necessary to solve in novel designs are:

- increase of life raft hydrodynamic resistance and stability in waves,
- reduction of non-linearity of aero dynamical coefficients in stream layout influencing the errors of leeway direction,
- new solution of entrance to a life raft - user friendly with increased strength round openings, sleeves and elastic lock,
- increase of thermal protection of survivors – inflatable floor and canopy, drainage system to decrease survivors contact with water,
- increase of range of detection using novel materials based on latest achievements in nanotechnology.
- low pressure in the life raft floor increases the angle of flooding of the life raft.

One of the reasons of deficiencies in life raft design is the vendors not going beyond the minimum requirements. For example life saving crafts should be designed for the assumed weight of a person. The latest amendments in LSA Code introduced the changes of the statistical weight of a person - previously defined as 75 kg should be replaced by 82.5 kg [16]. This amendment will cause changes in life raft design bringing it closer to reality. U.K. Health and Safety Executive (HSE) published a report “Big Persons in Lifeboats”, presenting the mean weights of men and women working in the offshore industry: weight of a man 98 kg and 77 kg of a woman.

The very important element influencing the chances of survivors is life raft operation according to the procedures recommended by the life raft vendor. The operational procedures should meet the results of studies on life raft design followed by tests in real sea conditions.

The investigations of life raft performance with different occupation in wind and waves seem to be of primary importance even they are not obligatory [3]. They allow developing the operational procedures for survivors and reliable information for the rescuers.

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