The disturbances of the life raft leeway induced by the fluctuations of wind direction in the life raft coordinate system

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Abstract

The paper presents the results of investigations on the life raft leeway induced by the fluctuations of wind direction. The surface current is one of the main factors determining the life raft leeway, but the recently conducted research confirmed that there are also other elements influencing the perturbations of leeway direction. The field experiments showed diversion of the life raft leeway from the downwind direction. This diversion can be explained by the existing cross wind component. The wind tunnel tests allowed to determine the aerodynamic coefficients in the fluid-state control system. On the basis of the test results the expression for the wind pressure force has been formulated. The mean deviation and median of probability distribution of the leeway diversions from the downwind direction has been determined on the basis of investigations conducted at sea. The models for the life raft velocity dependent on wind velocity, developed for the life raft with drogue and without drogue, are presented in the paper.

Keywords: *Search and Rescue, life raft aerodynamic coefficients, sea investigations of life raft leeway, model of life raft leeway*

INTRODUCTION

The most important element of SAR (Search and Rescue) action at sea is the proper determination of search area. Search area is the part of sea which contains the Datum/Datums. The probability of search object containment in this area is the hightest. There are several factors influencing the Datum and search area dimensions. The most important is the search object leeway. The velocity and direction of the leeway can be expressed by the leeway vector. This vector determines the position of search area. The divergence of search object leeway from the downwind directon has the influence on the search area fuzziness – figure 5.

Definitions of the Search Object Leeway

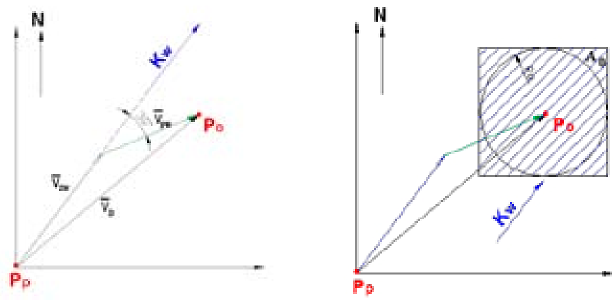
There are severeal definitions used to define the leeway of surface objects published in scientific works and research reports. The leeway definitions that are widely used for the search objects and considered in the paper are as follows:

- Leeway is the movement of a craft through the water, caused by the wind acting on the exposed surface of the craft [4],
- Leeway is the motion of the search object on the water surface induced by wind and waves [7],
- The more general definition is formulated by the author: leeway is the motion of the search object on the water surface, induced by the wind, waves and self object's motions dependent on the operational conditions of the object.

The search area and the method of search area determination recommended by IAMSAR until 2002 is presented in figure 1.

Investigations of life raft leeway in real Sea conditions

The research conducted at sea conditions showed the search objects leeway diversion from the downwind direction [1,2,5,6]. Figure 2 presents the progressive vector diagrams of trajectories relative to the downwind direction for twenty experimental drift runs of 4-6-person life rafts, with deep-ballast system and canopy, in light loading condition. The twenty-degree divergence angles for this leeway category specified by Allen and Plourde (1999) [6] are shown as dashed lines.



Where:
Pp – Initial Position
V_{ZW} – Leeway Vector,
V_{PW} – Wind Current Vector,
V_D – Drift Vector,
P_o – Datum,
A_o – Determination Search Area,
Kw – Wind Direction (Downwind)

Fig. 1 *determination of search area recommended by IAMSAR before 2002*

One of the factors causing the diversion of life raft leeway from the downwind direction is the surface current, however the laboratory tests and sea investigations confirm that there are additional factors influencing the disturbances of the leeway direction. The most important factor is the cross wind component. Crosswind component of leeway versus wind speed for different operational conditions of life rafts is presented in figure 3. The leeway diversion from the downwind direction of the 10-person life raft is presented in figure 4.

Table 1 presents the observed real position of the 10-person life raft after 8 hours since it was observed at the initial position.

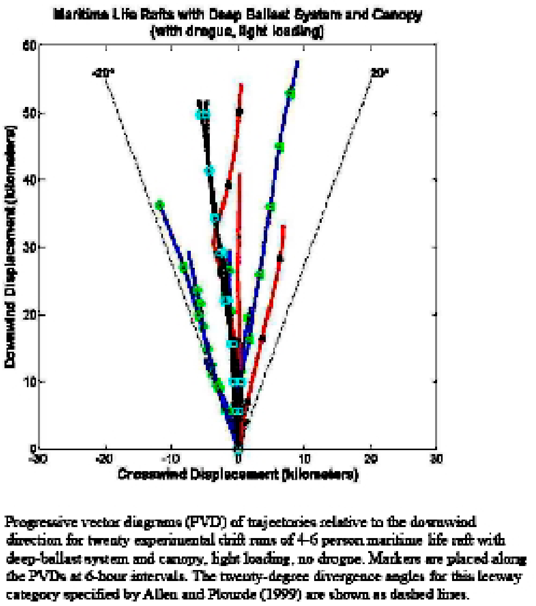


Fig. 2 *Progressive vector diagrams of life rafts trajectories relative to the downwind direction for twenty experimental drift runs [6].*

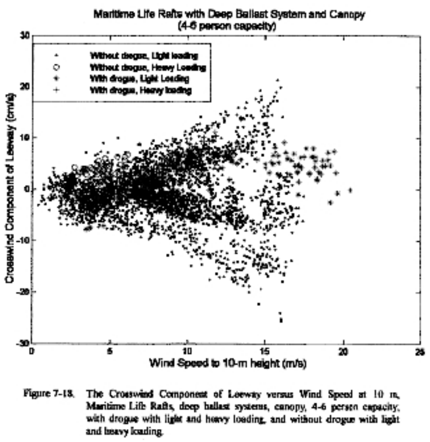


Fig. 3 *Crosswind component of leeway versus wind speed for different operational conditions of life rafts [6].*

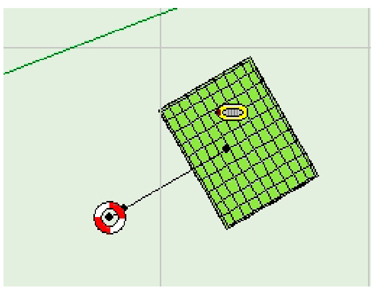


Fig. 4 *The real position of the 10-person life raft diverged from the downwind direction.*

Search area determination

The new method of search area determination, which considered the observed leeway diversions to the right and left side from the downwind direction, follows from the results of

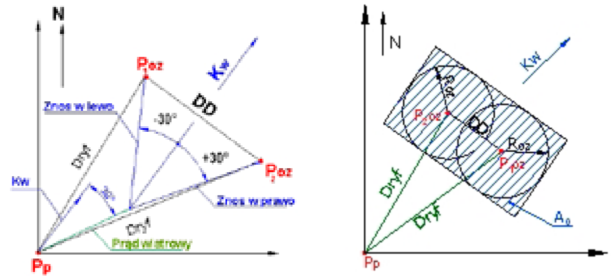


Fig. 5 *Search area recommended by IAMSAR after 2002.*

research conducted since 2002 [1,2,5,6]. The search area recommended by IAMSAR after 2002 is presented in figure 5.

Apart from sea investigations on the life rafts leeway there were several laboratory experiments conducted for the real 10-person life raft. The results of the laboratory test were used to determine the forces acting on the life raft. Measurements

Fig. 6 *Investigations of wind pressure force of the life raft conducted at Aerodynamic Laboratory of the Air force Institute in Warsaw.*

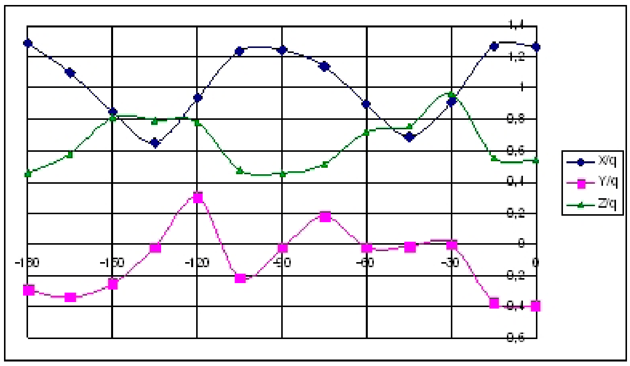


Fig. 7 *Linear aerodynamic coefficients in the fluid-state control system for the 6-person life raft and wind speed of 10 m/s .*

collected during wind tunnel tests allowed to determine the functions of air pressure force coefficiens in relation to the wind direction in the life raft coordinate system. The investigations were conducted at the Low Speeds Aerodynamic Laboratory of

TABLE 1. *The real position of the 10-person life raft observed after 8 hours at the wind speed of 24 knots.*

Search Object	Initial position P_p		Real observed position		Time of drifting [hours]	Downwind direction [°]	v_w [knots]
10-person life raft	φ = 55°20,7'N	λ=017°12,7'E	φ =55°26,5'N	λ=017°24,3'E	8	240	24

the Airforce Institute in Warsaw [1,2,8]. The results illustrating the dependence of the aerodynamic coefficients on the direction of life raft axes in the fluid-state control system are presented in the diagram of the aerodynamic coefficients in figure 7.

The changes of wind pressure force of the life raft, expressed by the linear coefficients in the fluid-state control system, are one of the reasons of the life raft leeway diversion from the downwind direction. Due to this reason the determined search area must be broadened. The broadening is the efect of the uncertainty of determination of wind direction in the coordinate system of the life raft axes.

To make the allowance for the wind direction changes influence (in the coordination system related to the life raft axes) in the expression of the wind force $F_N(v)$ it is necessary to use conditional probability:
where:

$$F_N(v) = P(A_1)F(v \mid A_1) + P(A_2)F(v \mid A_2) + ... + P(A_n)F(v \mid A_n) \quad (1)$$

$P(A_i)$ – probability of the wind direction
$F(v/A_i)$ – wind force function dependent on wind velocity for the i-th wind direction

$$F(v \mid A_i) = C_i \cdot F(v)$$
$$F(v) = a_0 + a_1 \cdot v + a_2 \cdot v_2 \quad (2)$$

where:
coefficients a_0, a_1, a_2 are presented in table 2,
v- wind velocity.

The model parameters for the different life raft types and different life raft loadings for the life raft with drogue are presented in table 2.

TABLE 2 *Coefficients of the wind force for the 10-person life raft*

Life raft type	a_0	a_1	a_2
10 persons	-18,4608	3,55045	0,814599

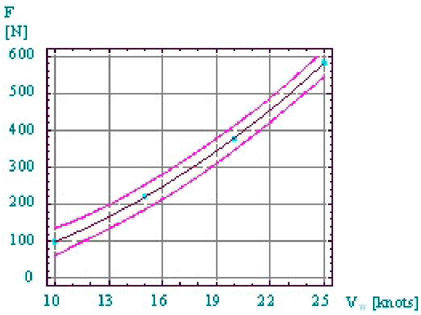


Fig. 7 *Wind pressure force for the 10-person life raft*

The 10-person life raft during the tests conducted in the real sea conditions is presented in figure 8. The investigations of the life raft leeway at sea has proved that the life raft motion induced by wind is diverged from the downwind direction [1,2]. The mean diversion of life raft leeway from wind direction is 8,6° and the median is 11°.

Fig. 8 *10-person life raft during the tests conducted in real sea conditions.*

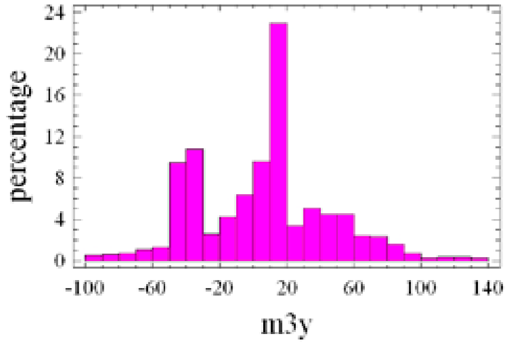


Fig. 9 *Histogram of the life raft leeway diversion from the downwind direction in the coordinate system of the life raft axes.*

For the force F(v) the expression for the life raft leway velocity can be formulated. The model describing the influence of wind velocity on the life raft velocity v_{tr}, for the life raft without drogue, can be expressed by the following polynomial (3):

$$V_{tr}(V_w) = a_4 V_w^4 + a_3 V_w^3 + a_2 V_w^2 + a_1 V_w + a_0 \quad (3)$$

The coefficients of the model for the different life raft types and life raft loadings, with or without the drouge are presented in table 3.

The model describing the influence of wind velocity on the life raft velocity v_{tr}, for the life raft with drogue, can be expressed by the following polynomial (4):

$$V_{tr6}(V_w) = a_8 V_w^8 + a_7 V_w^7 + a_6 V_w^6 + a_5 V_w^5 + a_4 V_w^4 + a_3 V_w^3 + a_2 V_w^2 + a_1 V_w + a_0 \quad (4)$$

The minimum and maximum life raft loadindg should be considered due to the lack of information regarding the number of survivors inside the life raft during SAR action. Therefore the models for the full loading and minimum loading should be assumed as the upper and lower limits of the leeway velocity changes.

The position of life raft drogue fastening induces the drag force and moment (5) being the additional reason of the

TABLE 3 *Coefficients of leeway velocity for the life raft without drogue*

Life raft type and loading	a_4	a_3	a_2	a_1	a_0
10 persons without drogue 10% loading	-2,7912E-07	3,315E-06	1,6907E-03	-1,0098E-03	0,2221
10 persons without drogue 10% loading	-2,3051E-07	-2,7377E-06	-1,5519E-03	-9,2637E-07	0,26348

TABLE 4 *Coefficients of leeway velocity for the life raft with drogue*

Life raft type and loading	a_8	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0
10 persons without drogue 10% loading	-3,77E-15	8,95E-14	4,51E-11	-8,15E-10	-3,06E-07	3,68E-06	1,03E-03	6,19E-03	13,971E-02
10 persons without drogue 10% loading	-2,57E-15	6,11E-14	3,43E-11	-6,18E-10	-2,54E-07	3,06E-06	9,4E-04	-5,64E-03	16,497E-02

leeway diversion form the downwind direction. The drogue fastening position is presented in figure 10 and the drag force is presented in figure 11.

Fig. 10 *life rafft with drogue*

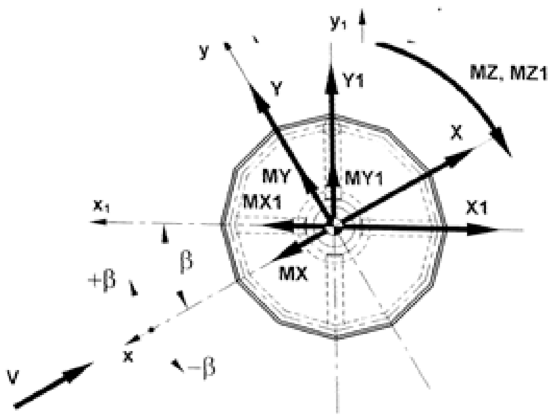


Fig. 11 *Drag force induced by drogue.*

The disturbances which induced the leeway diversion from the downwind direction are as follows:

- Asymmetrical position of the drogue,

$$MZ_D = F_D \cdot y_D \tag{5}$$

- Unequall pressure distribution in the life raft inflation chambers,
- Position of survivors inside the life raft,
- Canopy outline, asymmetrical shape of canopy,
- Shape of underwater body of the life raft.

Conclusions

The investigations conducted at sea and the model tests performed in the wind tunnel allowed to determine the influence of the asymmerical shape of the life raft canopy on the disturbances of life raft leeway velocity and direction. The disturbances have a significant influence on the position and dimensions of the determined search area and the SAR action effectivness.

Acknowledgement

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References

[1] Burciu Z. Modelowanie Obszarów Poszukiwania w Aspekcie Bezpieczeństwa Transportu Ludzi na Morzu. Prace Naukowe Transport z.50, Oficyna Wydawnicza Politechniki Warszawskiej, s.128, Warszawa 2003.

[2] Burciu Z. et. al. Opracowanie wewnętrzne Informatyczny system wspomagający akcję ratowania życia ludzkiego na morzu .W ramach Projektu Celowego dofinansowanego przez Komitet Badań Naukowych Nr 2288/C.T12-9/98. Gdynia 2001.

[3] Smolarek L. et. al. Opracowanie wewnętrzne Stateczność dynamiczna i prawdopodobieństwo przewrócenia się odkształcalnej tratwy ratunkowej na fali. Projekt badawczy nr 4T12C03827. Gdynia 2005.

[4] Fitzgerald R.B., Finlayson D.J., Cross J.F., Allen A. Drift of Cammon Search and Rescue Objects - Phase II. Contract report prepared for Transportation Development Centre, Transport Canada, Montreal TP 11673E, 1993.

[5] Final Report Review of Leeway. Field Experiments and Implementation U.S. Coast Guard Research and Development Center, Report No. CG-D-08-99, April 1999.

[6] Final Report Leeway Divergence U.S. Coast Guard Research and Development Center, Report No. CG-D-05-05, January 2005.

[7] Provisions of conventions, plans, manuals and other documents affecting SAR – Changes to the IAMSAR Manual (First Edition). Proposed by the United States ICAO/IMO-JWG/7-WP.1 February, 2000. Adoption of amendments to the International Aeronautical and Maritime Search and Rescue Manual, MSC/Circ.999-11 June 2001.

[8] Raport z badań Badania aerodynamiczne pneumatycznych tratew ratunkowych w tunelu aerodynamicznym – 5m – Raport nr 168/BA/2000/D Instytut Lotnictwa Warszawa 2000