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Numerical Prediction of Pneumatic Life Raft Performance

J. Jachowski & E. Książkiewicz
Gdynia Maritime University, Gdynia, Poland

ABSTRACT: The success of the Search and Rescue (SAR) operation depends on the correct assignation of the search area for the drifting pneumatic life raft, with particular emphasis on leeway. The leeway is directly dependent on the hydrodynamic drag and wind pressure force acting on above-water and underwater parts of the life raft. The paper presents the numerical study on the pneumatic life raft performance including hydrodynamic and aerodynamic characteristics in a wide range of operational conditions. The numerical simulation results were compared with model test results obtained in towing tank and wind tunnel. The proper prediction of life raft performance is important for determination of life raft safety function dependent on wind velocity and operational characteristics. The results of numerical simulation are in line with data available in literature and obtained from empirical investigations.

1 INTRODUCTION

The drift of the life raft is caused by the influence of environmental factors and leeway. The leeway prediction of the floating pneumatic life raft represents a difficult task for the search and rescue (SAR) because the raft tent is deformed by wind pressure making it difficult to clearly identify the raft's reference position and search area [2]. Search and rescue services use available computer applications (e.g., Sarmap) to define the area of search [10]. Unfortunately, these applications do not take into account shape variation during drift, so they are not precise for deformable bodies. On the basis of previous research by the Gdynia Maritime University, the authors created a numerical simulation taking into account the variability of the shape of the research object. This paper presents the results of a leeway simulation which take into account the variable windage area of a raft tent. The authors believe that a detailed study of leeway and it's factors could ultimately limit the search area and increase the effectiveness of rescue operation [3,4,5].

2 LEEWAY OF PNEUMATIC LIFE RAFT

The leeway of a life raft is the movement of an object on the water due to the action of the wind pressure on the above-water part of raft (F_x) and the force of hydrodynamic drag acting on the underwater part of the drifting object (F_0) as shown in Fig.1.

Considering that leeway is the movement of the raft caused by the action of wind on the above-water part of the life raft and the hydrodynamic drag of the underwater part of the raft, both forces must be taken into account. Numerical simulations carried out earlier allowed to determine: the force of wind pressure (taking into account the variable shape of the flexible structure of the raft) and the force of hydrodynamic drag. Using the previous results, a simulation of leeway of the pneumatic life raft was performed as a deformable object [11-14].

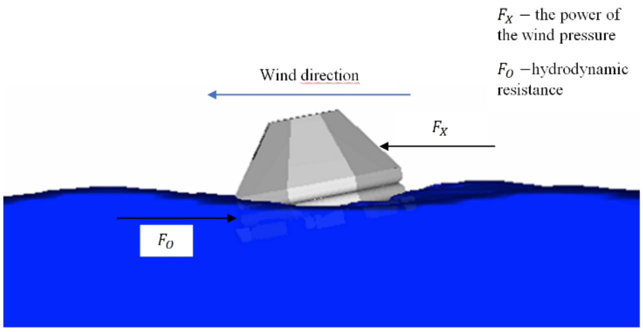

Figure 1. Forces causing leeway (source: current study, print screen of simulation)[9]

3 RESEARCH OF THE FORCE OF WIND PRESSURE ON THE ABOVE-WATER PART OF THE PNEUMATIC LIFE RAFT

Tunnel aerodynamic test of a pneumatic life raft were carried out in 2000 at the T-3 Low Velocity Tunnel f the Institute of Aviation in Warsaw. Wind tunnel tests of the life raft provided knowledge of the deformation level of life raft tent which is presented in Fig.2.

Figure 2. Life raft during wind test (research report, 2000)[15]

The results of the tunnel tests show that the value of forces is function of the shape and inflow wind. This knowledge is essential for modelling environmental conditions during numerical research.

The numerical computations were carried out using FLOW-3D. Numerical simulation based on the results of tests carried out in the wind tunnel. The shape of the raft was created on the basis of photographic documentation from wind tunnel research.

An exemplary geometric model of life raft used in CFD simulations is presented in Fig.3.

A comprehensive approach to model and numerical tests provided information on the distribution of the wind profile affecting the above-water part of the raft. Fig. 4 shows the distribution of the wind velocity field around the life raft.

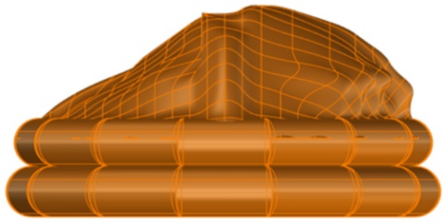

Figure 3. Example of geometry of life raft used the calculations (source: current study)[9]

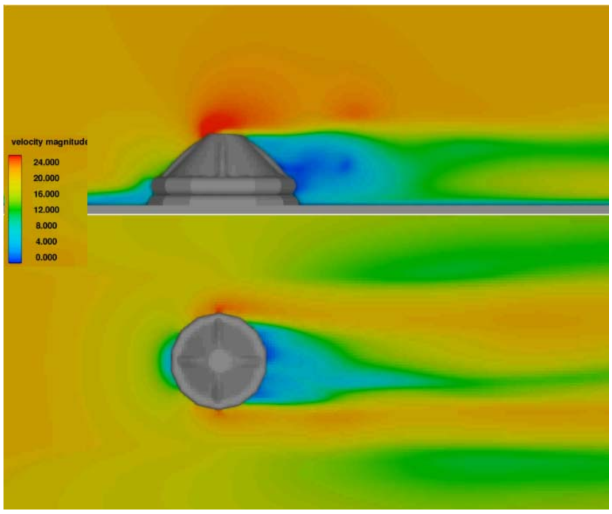

Figure 4. Aerodynamic drag in CFD calculation (source: current study)[9]

The conducted research allowed to determine and compare the averaged drag coefficient of the life raft during the experiment and CFD simulation. The obtained results are presented in Fig.5.

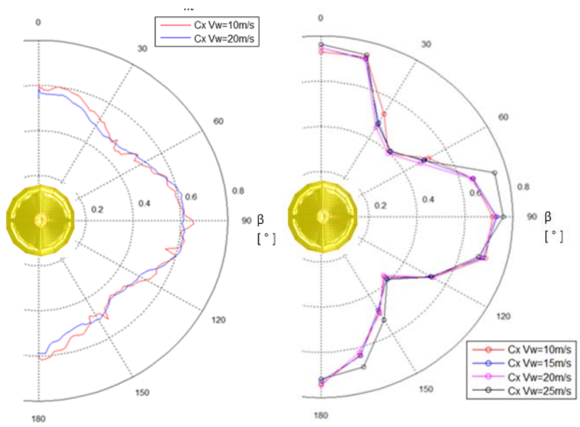

Figure 5. CFD results (left) and experimental results (right)- Drag aerodynamic coefficient (Cx) for various wind velocities and wind direction (source: current study)[9]

Comparison of the results of laboratory tests carried out at the Institute of Aviation in Warsaw with numerical simulations confirmed their convergence and correctness of the calculations performed.

4 RESEARCH ON THE HYDRODYNAMIC RESISTANCE OF THE UNDERWATER PART OF THE PNEUMATIC LIFE RAFT

The life raft towing performance has been tested in the towing tank of Ship Design and Research Centre in Gdansk.

Figure 6. Model test of the life raft in the towing tank [1]

The hydrodynamic drag of the life raft and the drift were calculated separately under calm water conditions. Total towage resistance was the sum of the life raft and the drift.

The test speeds of the life raft in the numerical and modeling tests were the same. The simulations were carried out in the established domain in calm water conditions.

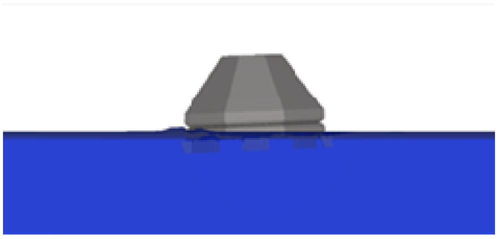

Figure 7. Model of life raft used in CFD simulation [1]

The result of the simulation obtained after the post-processing comprises the general flow pattern, the velocity and pressure fields (Fig.8) which are important elements of the conducted study.

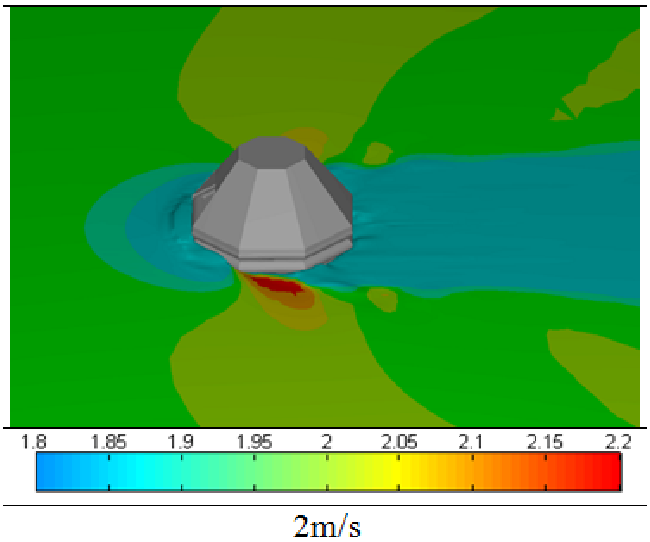

Figure 8. CFD simulation of hydrodynamic drag (source: current study) [16]

In the verification of the modeling of the flow of the pneumatic life raft using CFD methods, the following factors were taken into account: prediction of towing resistance and the behavior of the raft in calm water during towing. The concordance of the numerical calculations and the results of the experimental tests was high. The tank towing experiment and CFD calculations were performed using a full-scale prototype to eliminate any error of scale [1].

5 NUMERICAL STUDIES OF LEEWAY

In previous articles, numerical calculations of hydrodynamic and aerodynamic resistance were carried out. The obtained results were compared with the results of life raft model tests on a real scale to confirm their correctness. The convergence of the results was high, which allowed the continuation of numerical calculations in the field of leeway of the life raft. CFD simulations of leeway were performed for 2 types of life rafts. The types of life rafts are shown in Fig.9 and their parameters are shown in the Tab.1.

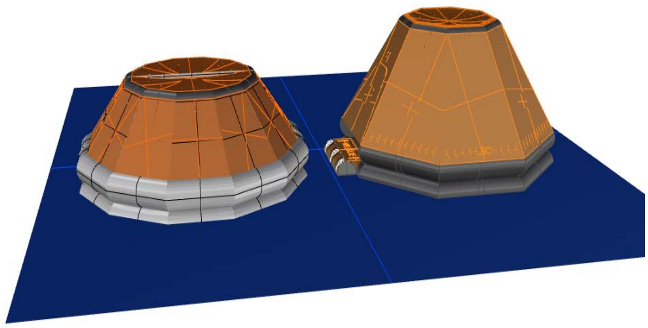

Figure 9. Two types of life rafts used for CFD calculations (source: current study)

Table 1. Life rafts data (source: current study)

	8-persons	10-persons
Life raft net weight	95 kg	100 kg
Max persons weight	660 kg	825 kg
Total weight	755 kg	925 kg

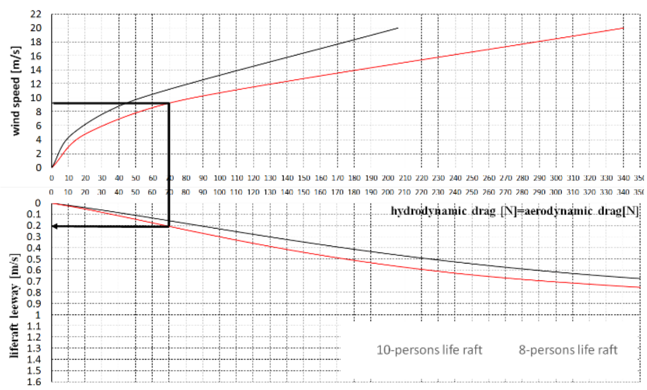

Figure 9. Graph of undisturbed leeway (source: current study)

Based on the theory of leeway, the numerical calculations assumed equality of hydrodynamic and aerodynamic resistance acting on the life raft.

Calculations were made for calm water conditions (without taking into account waves and sea currents) to reproduce the earlier conditions of experimental research. The forecast of an undisturbed leeway of the pneumatic life raft is presented in Fig.10.

The graph shows the dependence of the leeway of the life raft on the wind speed affecting its above-water part. For example, when the wind speed is 9 [m/s], the resistance of the above-water part and the underwater life raft (read from the diagram) is 70 [N], and the speed of leeway is 0.2 [m/s].

The results of the experiment and CFD calculations are summarized in Tab. 2.

Table 2. Comparison of mean aerodynamic and hydrodynamic forces obtained from CFD simulation versus wind tunnel and towing tank experiment (source: current study)

Hydrodynamic drag			
Water speed [m/s]	Mean Resistance [N] CFD	towing tank tests	Mean percentage error CFD/experiment
0.7	189	205	8%
1.5	921	957	4%
Aerodynamic drag			
Wind speed [m/s]	Mean Resistance [N] CFD	wind tunnel tests	Mean percentage error CFD/experiment
10	64	60	6%
20	250	232	7%

Summarized results in a Tab.2 for selected flow velocities. The average percentage error is in the range of 4-8%, which should be considered a good compliance for a flexible object subject to deformation during testing.

6 CONCLUSIONS

The success of the rescue operation depends on the correct determination of the search area, which takes into account the leeway of the life raft. Previous numerical simulations of the life raft's drag and aerodynamic characteristics allowed correct prediction of life raft's leeway. The knowledge of the relationship between the wind speed and the leeway speed of the life raft can directly affect the speed and efficiency of rescue operations at sea. In conclusion, the authors believe that numerical research of life raft's leeway and the results obtained may directly affect the narrowing of the search area and increase safety at sea.

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