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# INVESTIGATION OF THE SIDE WIND EFFECTS ON THE PASSENGER FERRY IN ROLLING MOTION CONDITIONS

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***Abstract***

*The article presents the investigation results of selected effects of the side wind on the passenger ferry in sea condition. The computational fluid dynamic (CFD) analysis has been carried out in order to calculate the forces and moments acting on the ship superstructure during rolling caused by waves. The performed analysis shows the impact of rolling amplitudes and periods on results. The use of CFD method allows calculating the vertical centre of pressure with various rolling parameters. Numerical analysis has been performed for real size ship model in transient condition.*

*The main object of the research is to define the influence of the wind dumping effect on wave rolling motions. Additional wind dumping effect (besides of other effects) is intending to use in response amplitude operator (RAO) calculations (next part of researches). It is possible that use of additional wind dumping effect will reduce the rolling amplitudes, and consequently reduce ship accelerations due to rolling motions. Reduction of accelerations (especially horizontal), should decrease the requirements due to number of cargo lashes/belts equipment and minimize the lashing time. From other side it should shorten required harbour time and reduce the ship speed, what is the best way to save the fuel.*

***Keywords***: *wind forces, passenger ferry, CFD analysis*

## 1. Introduction

One of the most important things for ship economy is to make the time needed for reloading as short as possible. Important part of the time is taken by cargo securing. In most cases, ferry ships are intended for operation on one route with characteristic wave spectrum. It is possible to calculate ship acceleration and next to define required number of securing equipment depending on weather forecast. Ship owner has no influence on the weather, but during ship design, there are some possibilities to improve seakeeping performance. Roll accelerations are the most important from point of view requirements of number securing equipment. Due to that, their accurate calculation should be the key to shorten cargo-securing time. There are a few computational methods to define ship moves and accelerations. One of the most popular and the easiest methods is use of rules of classification societies (PRS [6], LR [4], DNVGL [2] etc.). In most cases, it is the most conservative approach basing on empirical formulas and some ship particulars. The second type is use of specialized software (ShipMO [3], Seakeeper [7], etc.) basing on semi empirical methods. The next method is use of computer software which is able to solve motion equation in time domain (AQWA[1], ORCAFLEX[5]) basing on panel method. In this kind of software, it is possible to take into account user procedures improving accuracy of ship motion prediction.

The object of researches shown in this article is only one of the tasks, which will provide to take into account the influence of air transverse forces and moments in the time domain and their influence on roll motions and accelerations. This first task is numerical calculations of ship transverse forces and moments from air in time domain for forced rolling.

In next steps the method of introducing of results into computational software [1, 5] will be performed.

## 2. Analysis methodology and assumption

For calculation new concept of RO-PAX ship has been taken into account.

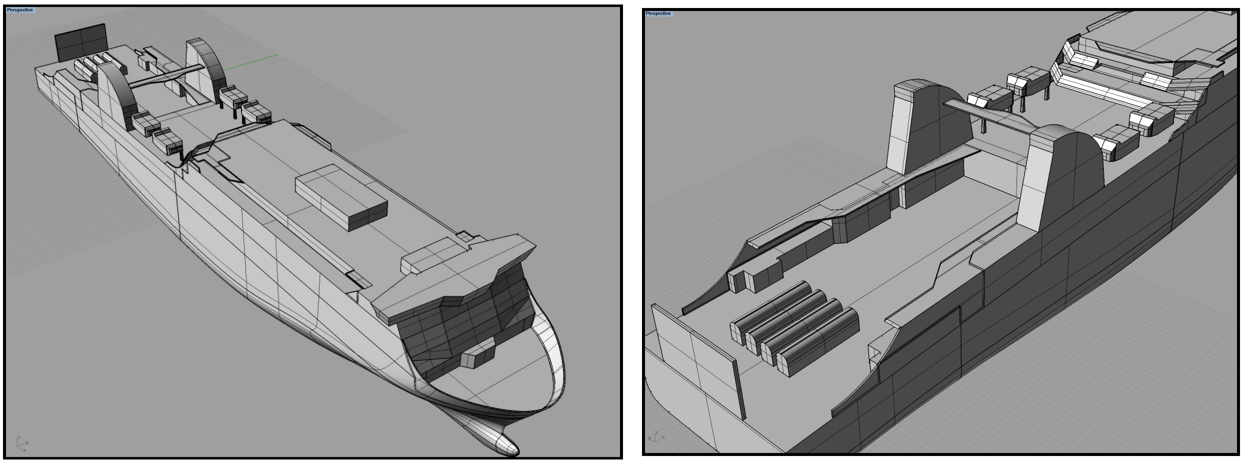

*Fig. 1. General view of geometry of analysed ship*

Main dimensions of analysed ship are following:

| | |
|---|---|
| Length O.A. | abt. 191.5 m; |
| Length B.P. | 178.00 m; |
| Breadth moulded | 30.20 m; |
| Breadth max | 30.80 m; |
| Depth to main deck | 9.20 m; |
| Depth to upper deck | 15.45 m; |
| Draught | 6.30 m; |
| Service speed (15 % SM) | 15.0 kn; |
| Deadweight | abt. 8 000 t; |
| Lane length | abt. 2750 m. |

There are at least a few methods to calculate forces and moments of moving body in time domain by use of Computational Fluid Dynamics (CFD). One of them is to run full ship model in two-phase flow (water and air). The main advantage of this approach is the most physical behaviour. Main disadvantage is the most time consuming calculation of free surface flow, which is not subject of the analysis. Of course, it would be possible to perform full calculations even on waves, but because of time limits for analysis, this method has not been taken into consideration.

In order to reduce flow only to air method of "domain in domain" has been used. There are two mesh domains with independent meshes. Inner mesh is moved according to assumed rolling equations. On the boundaries of the inner mesh, solution is interpolated to outer mesh. Main domain has been shown on Fig. 2 whilst example of mesh has been shown on Fig. 3.

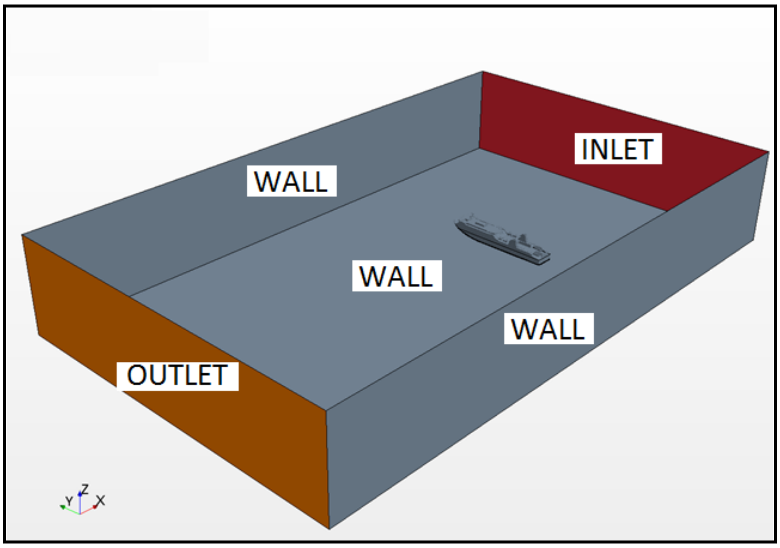


*Fig. 2. Boundary condition on main domain*

The analysis environment has been set incompressible, unsteady. Airflow velocity has been assumed constant 10m/s. Turbulent realizable k-epsilon model has been used. Bottom, top and sides have wall boundary conditions (no shear stress option) have been used. Calculation has been performed on range of typical periods and roll amplitudes for ferry ship. Analysed rolling condition taken into consideration has been shown in Tab. 1.

*Tab. 1. Rolling conditions taken into consideration*

| Numbers of condition | Period T [s] | Max heel angles [deg] |
|---|---|---|
| 1, 2, 3 | 12 | 8, 12, 15 |
| 4, 5, 6 | 15 | 8, 12, 15 |
| 7, 8, 9 | 18 | 8, 12, 15 |

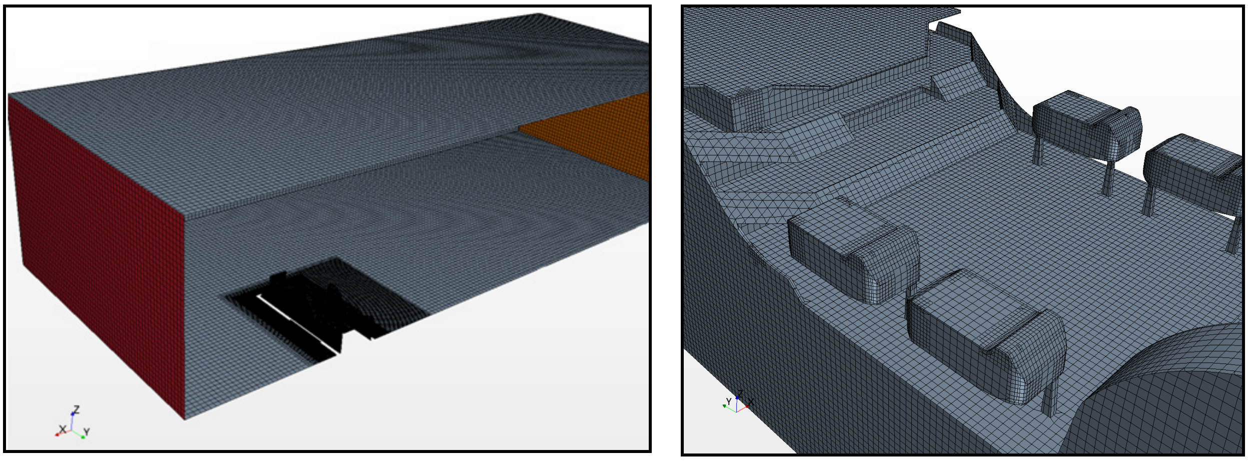

*Fig. 3. Example of mesh used in the analysis*

Proper initial condition for analysis has been achieved in preliminary steady state analysis (without ship roll moves). When preliminary solution has been done, transient analysis with defined ship rolling moves has been set.

## 3. Results

Various rolling condition have been analysed. In order to remove the influence of initial condition each run of calculation lasts two times longer than considered period. For example for period 15 s calculation time has been set 30 s. Only second period has been used to obtain the results. Examples of flow vector velocities in the section of midship area have been shown on Fig. 4 and 5. Fig. 4 shows the same heel angle but in different rotational directions.

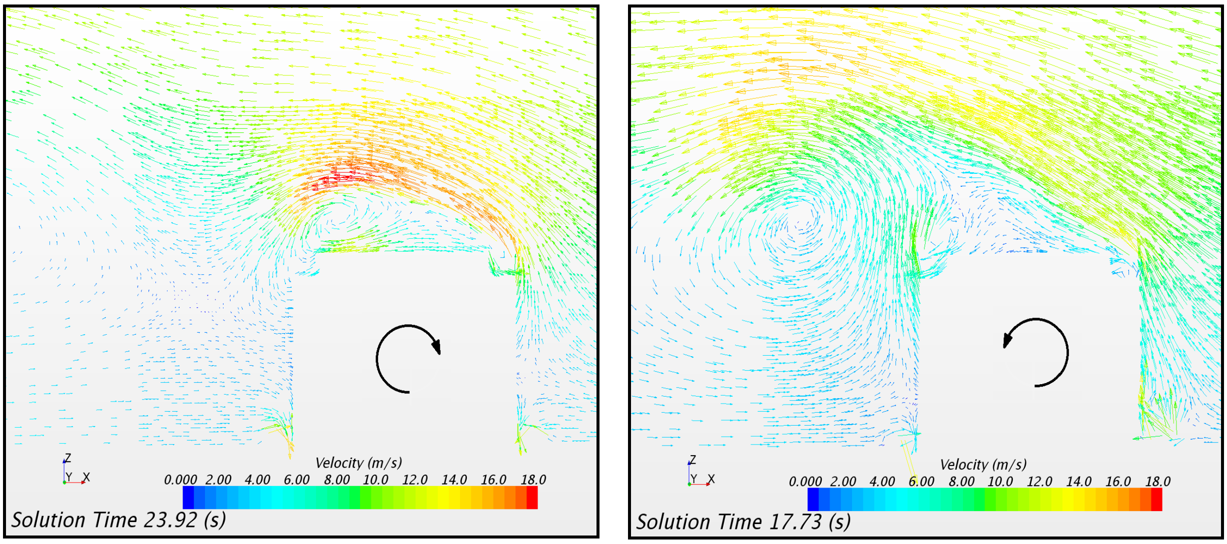


*Fig. 4. Flow vector velocities plot on section in midship region (T=12 s, Max heel angle 15 deg)*

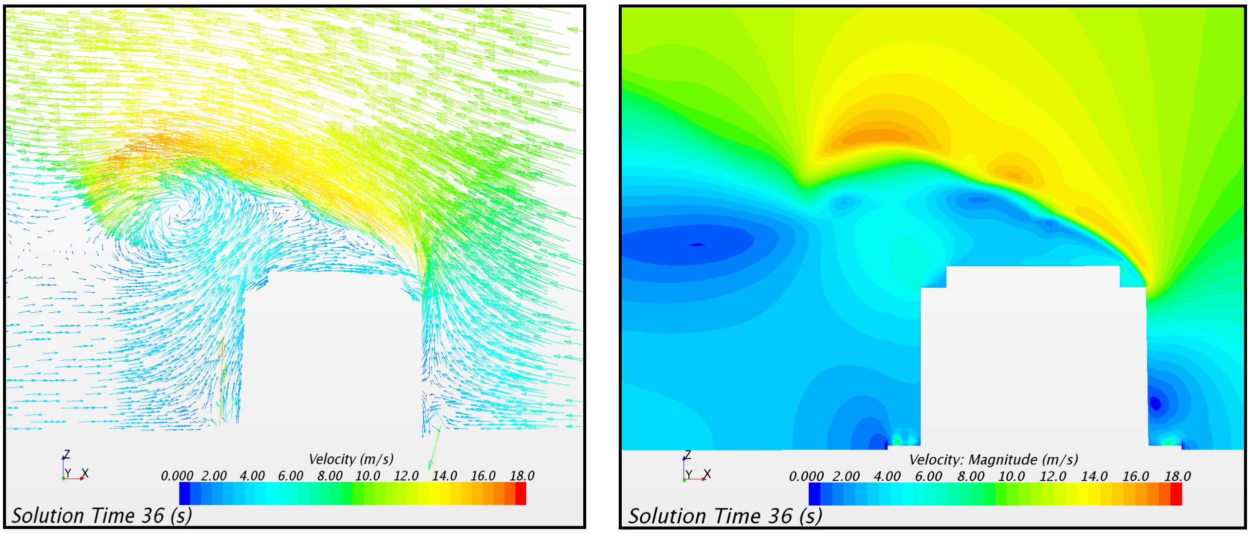


*Fig. 5. Flow vector velocities and velocity magnitude plots on section in midship region (T=18 s, Max heel angle 15 deg)*

Besides of midship section, stern section has been shown (see Fig. 6) for two maximum heel angles (both sides). It has be noted how different swirl structures depending on direction of rotation are. Swirl structures causes increase or decrease local flow velocity.

The most important results have been shown on Fig. 7 to 12. There have been shown how forces and moments changed in the time depending on period and maximum assumed heel angles.

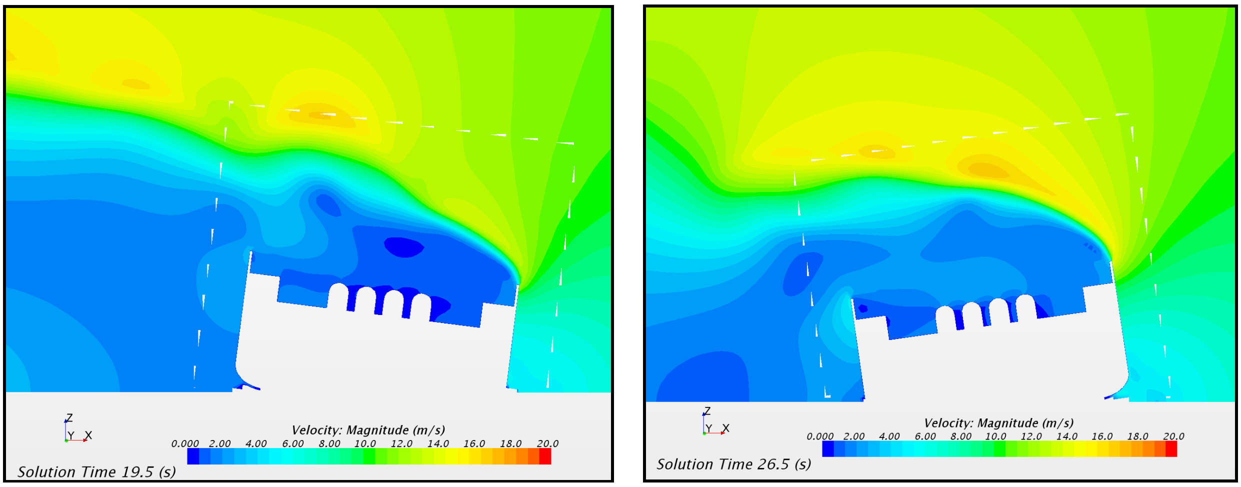


*Fig. 6. Flow vector velocities plot on section in midship region (T=15 s, Max heel angle 8 deg)*

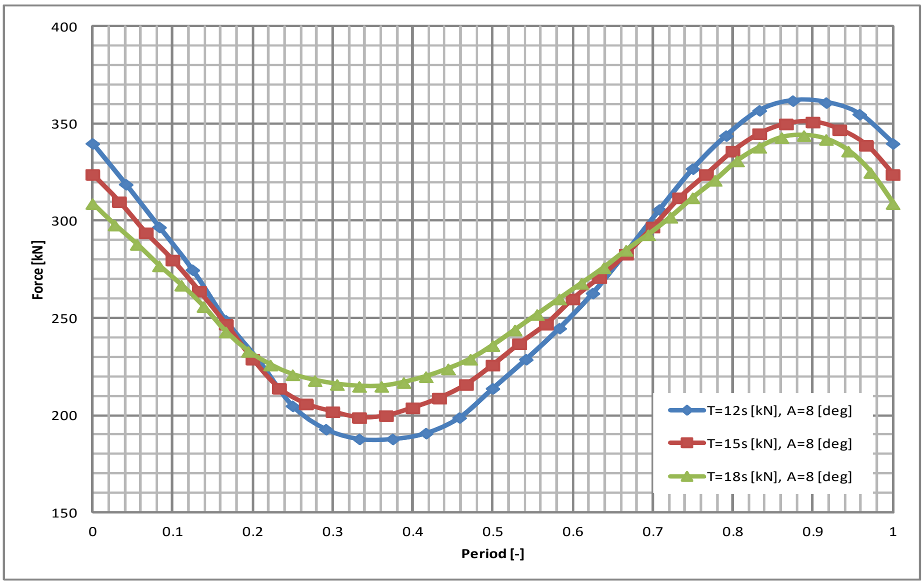


*Fig. 7. Transverse force [kN] for maximum heel angle 8 deg and periods 12, 15 and 18 s*

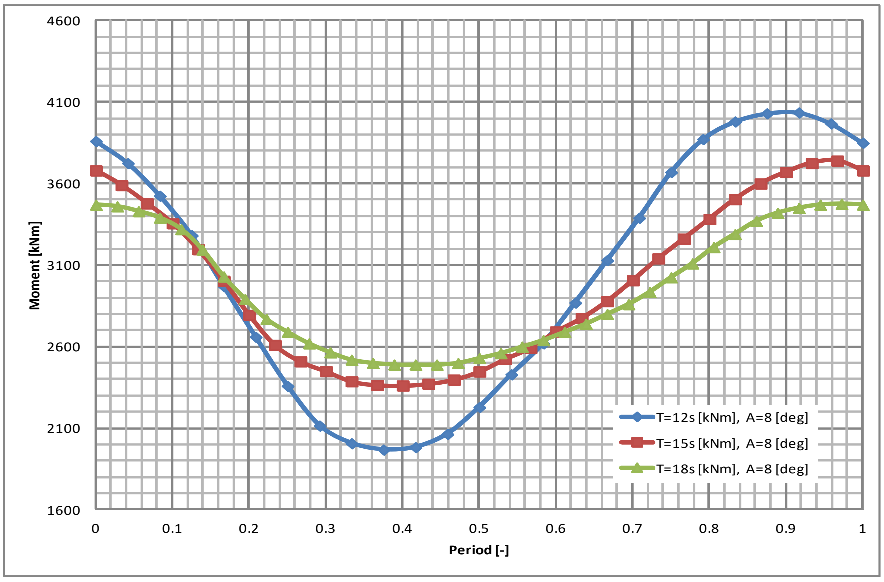


*Fig. 8. Righting moment [kNm] for maximum heel angle 8 deg and periods 12, 15 and 18 s*

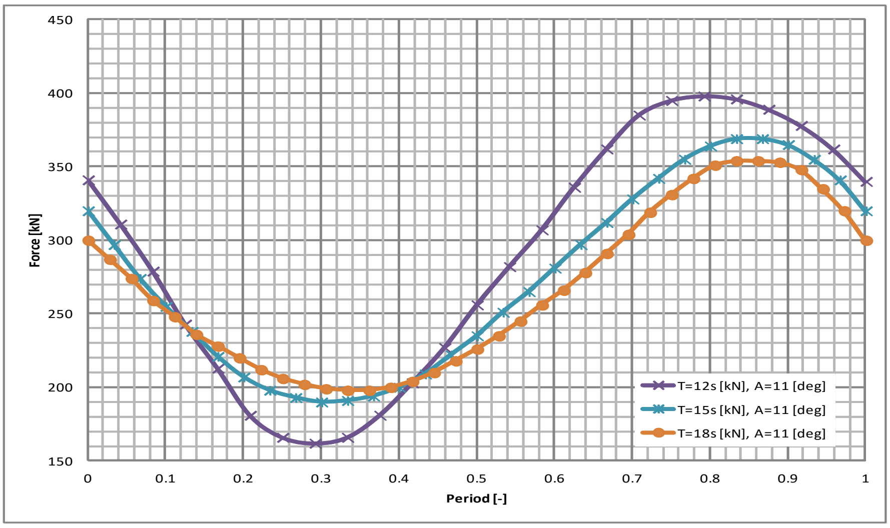


*Fig. 9. Transverse force [kN] for maximum heel angle 11 deg and periods 12, 15 and 18*

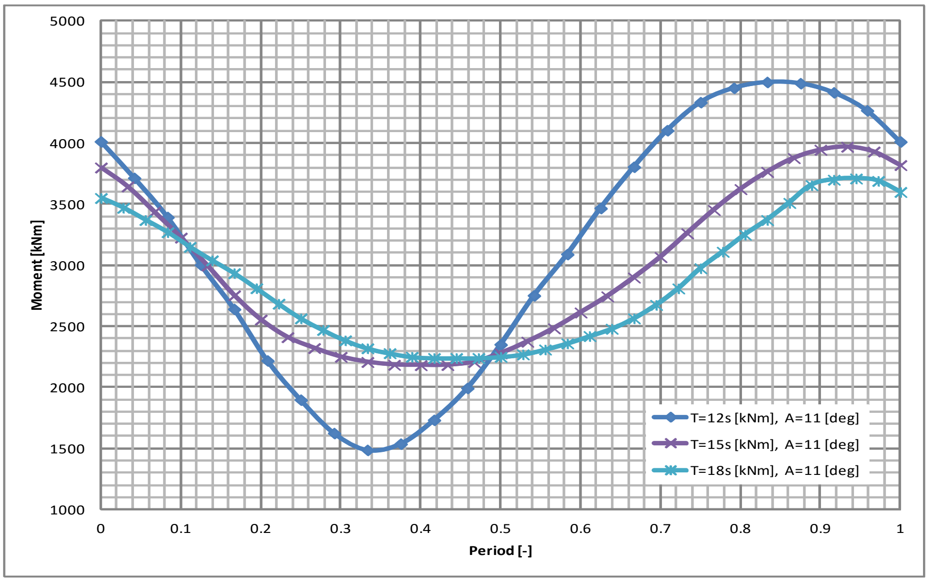


*Fig. 10. Righting moment [kNm] for maximum heel angle 11 deg and periods 12, 15 and 18 s*

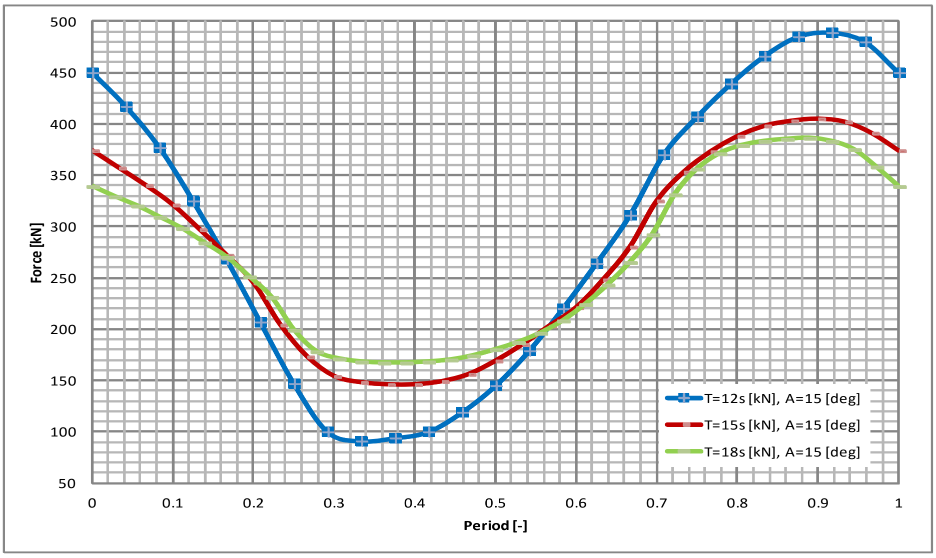


*Fig. 11. Transverse force [kN] for maximum heel angle 15 deg and periods 12, 15 and 18s*

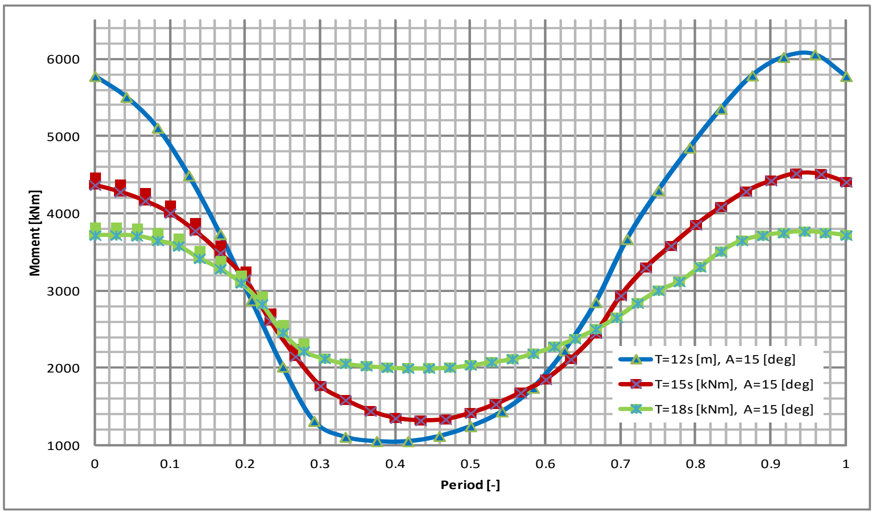


*Fig. 12. Righting moment [kNm] for maximum heel angle 15 deg and periods 12, 15 and 18 s*

## 4. Summary and conclusion

Result obtained from the analysis shows the wide range of forces and moments from ship move in the air (Tab. 2).

*Tab. 2. Resultant transverse forces and righting moments acting on the ship*

| Period [s] | Max angle [deg] | $F_y$ min[kN] | $F_y$ max[kN] | $M_x$ min [kNm] | $M_x$ max [kNm] |
|---|---|---|---|---|---|
| 12 | 8 | 185 | 342 | 1970 | 4020 |
| 15 | 8 | 200 | 350 | 2350 | 3750 |
| 18 | 8 | 215 | 362 | 2500 | 3470 |
| 12 | 12 | 160 | 400 | 1500 | 4500 |
| 15 | 12 | 190 | 370 | 2200 | 3970 |
| 18 | 12 | 200 | 355 | 2300 | 3700 |
| 12 | 15 | 90 | 490 | 1050 | 6070 |
| 15 | 15 | 145 | 405 | 1380 | 4450 |
| 18 | 15 | 165 | 385 | 2000 | 4000 |

In one case (T=12 s, Max angle=15 deg) the difference between minimum and maximum is near six times. It should be noted that moves of ship in wind environment gives the additional dumping effect. Taking this additional dumping effect into software and calculation of corrected seakeeping characteristics should decrease ship roll moves and transverse accelerations.
Next level of researches will focus how to take this kind of results into seakeeping analysis software and the direct comparison of achieved results.

## References

[1] *AQWA User Manual*, ANSYS, Inc. Release 14.5 Southpointe, 275 Technology Drive, October 2012.
[2] *DNVGL Rules For Classification*, 2016.

[3] *Documentation for Program SHIPMO*: *a Database for Ship Motions*, 1998.
[4] *LR Rules and Regulations for the Classification of Ships*, 2016.
[5] *OrcaFlex Brochure*, Orcina Professional software for engineering professionals.
[6] *PRS Rules for the Classification and Construction of Sea-going Ships*, 2016.
[7] *Seakeeper Windows Version 16 User Manual*, Formation Design Systems Pty Ltd 1998-2011.