On Application of Multi-pole Expansions to Roll Damping of a Rectangular Box

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1. INTRODUCTION

The roll damping has been a subject of intensive research due to its practical importance in ships design. The method of multi-pole expansions is a very useful tool in the calculation of hydrodynamic coefficients when the multi-poles are expanded in a coordinate system in which the body boundary is a coordinate surface (Ursell 1949). When the multi-poles are expanded in polar coordinates, the method of multi-pole expansions is easily suitable to solve hydrodynamic coefficients of cross sections of ships which are very close to the circular sections. However, when the cross section deviates from the circle, the method is not applicable to estimate the hydrodynamic coefficients. To cope with this problem, Ursell-Tasai method was suggested (Tasai 1959). The non-circular cross sections are transformed to a new plane where the cross sections become circle. The method of multi-pole expansions is possible in the transformed plane. The ability to express the non-circular cross sections in circular form in the transformed plane is of importance. The usual practice is to use 3 terms. To deal with rectangular cross section, the present study employed up to 7 terms. The corresponding flow field and free surface elevation are presented. The results are compared with those of boundary element method. The flow field was also analyzed with PIV measurement. The results are compared with each other.

2. MULTI-POLE EXPANSIONS

When it comes to the multi-pole expansions the potential of a certain flow field is represented as a sum of singularities which are located within the structures. The singularities satisfy governing equations, free surface boundary conditions, bottom boundary conditions, and radiation conditions. The coefficients of the singularities are determined in a way that the linear combination of the singularities satisfies the corresponding body boundary conditions. The asymmetric potential is used to deal with roll motion with appropriate boundary conditions. To achieve more accurate transformation of the floating body, the number of parameters in Lewis form was increased up to 30 terms by using least square method. The improvement of the accuracy in the transformation is shown in Fig. 1.

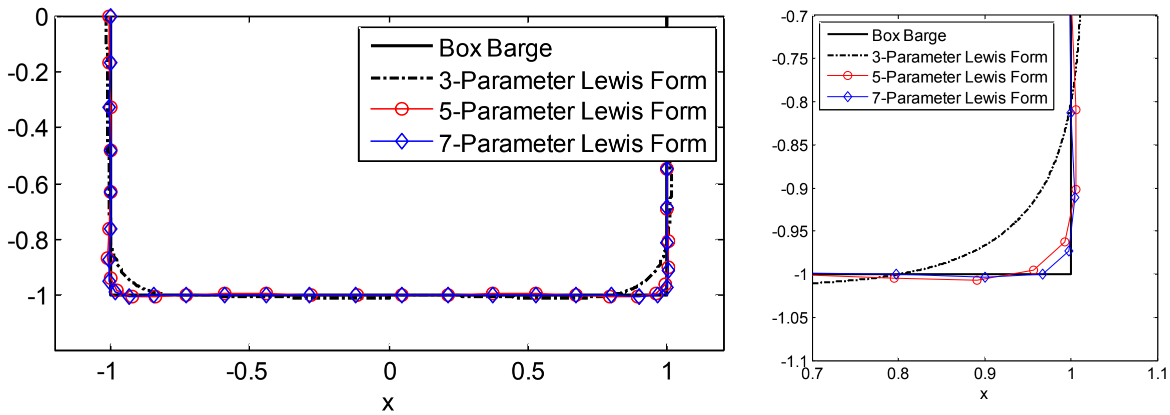
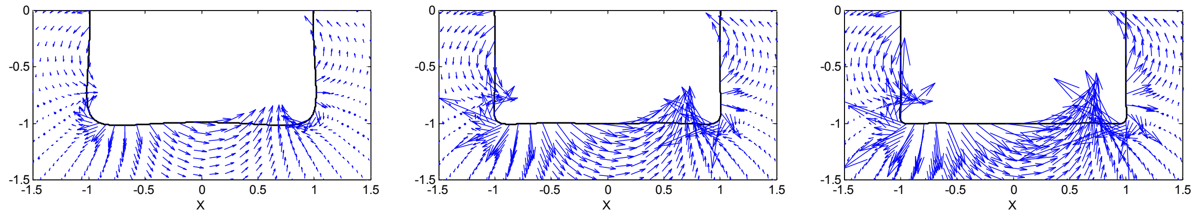
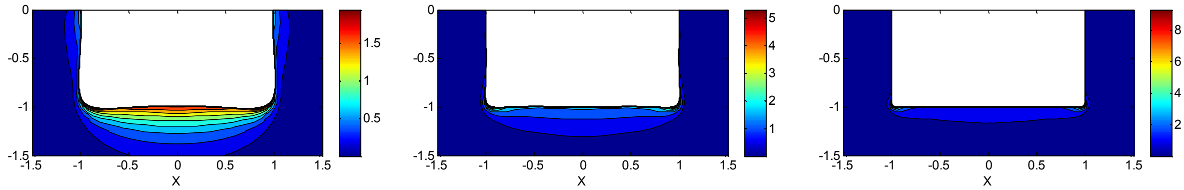


Fig. 1 Hull Form for Various Number of Parameters



N = 3 N = 5 N = 7

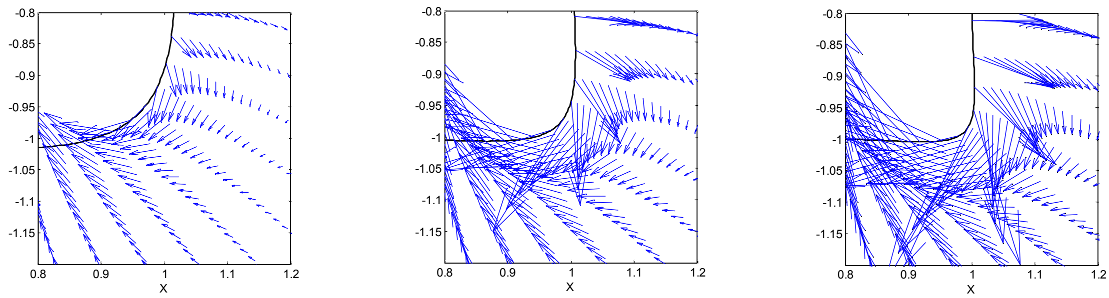
Fig. 2 Flow Field for Various Number of Parameters



N = 3 N = 5 N = 7

Fig. 3 Contour Field for Various Number of Parameters

The flow field was calculated from the stream function. The resulting flow fields are presented in Fig. 2. As the number of parameters is increased, the magnitude of the velocity around the corner increased. As the number of parameters increases the corner of the rectangular box expresses singularity. The contour plot of magnitude of the velocity is presented in Fig. 3. Fig. 4 shows the magnified view of the velocity vector field around the corner. The damping coefficients are presented in Fig. 5. To check the results of multi-pole expansion method, the numerical results of boundary element method is also presented in the figure. Constant panel is used in the computation. The total number of meshes used in the computation was 90. The pulsating source Green function was adopted in the computation. The increase of parameters increases the accuracy when compared with boundary element method. Since the boundary element meshes can trace the rectangular shape, the increased parameters yields better agreement with the results of boundary element method.



N = 3 N = 5 N = 7

Fig. 4 Flow Field for Various Number of Parameters at the Corner

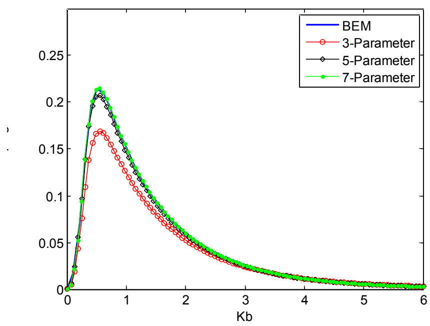


Fig. 5 Roll Damping Coefficients

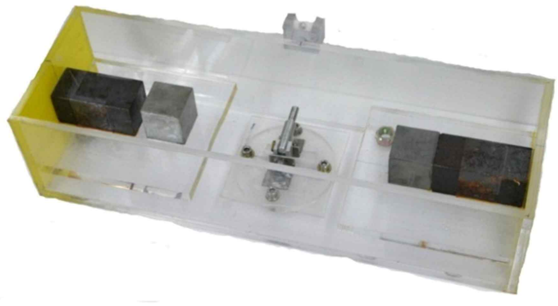


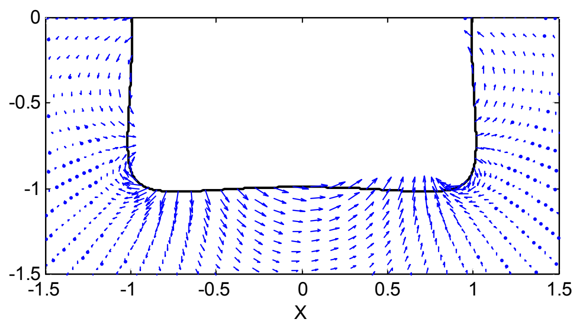
Fig. 6 Rectangular Box

Table 1 Model Dimensions and Hydrodynamic Characteristics

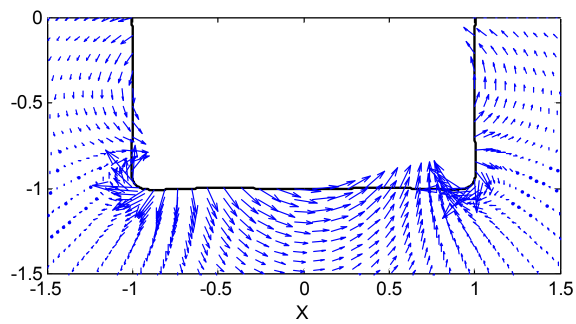
Items	Value
L X B X D	0.60 X 0.20 X 0.15 m
Material	Acryl
KG	0.0638 m
KB	0.0485 m
Draft	0.0970 m
GM	0.0191 m
k_{zz}	0.0646 m

3. EXPERIMENT

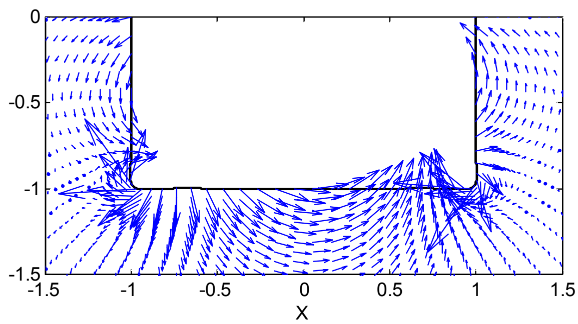
Experiment was carried out the compare the corresponding flow fields. The rectangular box model dimension and hydrodynamic characteristics of the model is shown in Table 1. Fig. 6 features the model. The flow field was measured by PIV. The flow field is presented in Fig. 7 to compare with computed results. The model was in a phase of counter clockwise rotation from the mean position. The flow fields measured near bottom of the model are very close to those of computation except the vortex generated around the corners. However, the measured flow fields near the free surface show quite different behavior when they are compared with computed results.



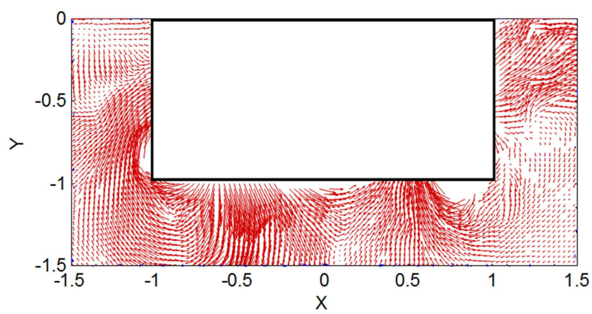
N = 3



N = 5



N = 7



PIV Results

Fig. 7 Computed Flow Fields Compared to PIV Result

4. CONCLUSIONS

The method of multi-pole expansion is a quite powerful tool when the accuracy of transformation of the cross section of a ship is achieved. Since the velocity potential and stream functional form are obtained in closed form solution, the degrees of freedom in hydrodynamic analysis are higher than any other numerical schemes. As the parameters of the Lewis form increases the value of damping coefficient is in good agreement with the results of boundary element method. PIV measurement confirms that the lower part of the flow field shows good agreement with computed ones except the vortex generated.

ACKNOWLEDGEMENT

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