THE MESH INFLUENCE IN FLUID FLOW

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ABSTRACT

The principal objective of this study is to adapting the mesh of the computational fluid dynamics to obtain a good accuracy. In the past, the experimental results were a good bench-mark for predicting ship water resistance, but due to the evolution of the technology, mathematical flow patterns can be solved by applying the RANS equations. The towing test results can by apply for a low Froude number, but for a high Froude number, all phenomena that appear along the simulation aren’t relevant because the scale effects can provide a realist vision of the phenomena for a real ship (scale 1:1). Hence, this study presents methods of improving the mesh quality by making comparisons with the experimental tests, and also presents the limit of the towing test results.

Keywords: mesh adapting, multihull, ship hydrodynamic resistance.

1. INTRODUCTION

This analysis is a continuation of the bachelor thesis that based on the fluid flow simulation around the multi hull ship.

This study used a catamaran shapes with characteristics presented in Table 1:

Table 1. Main particulars of the ship

|   |   |   |
|---|---|---|
| L | 21 | m |
| B | 6,6 | m |
| H | 2,3 | m |
| T | 1,4 | m |

2. CONTENT

Some major errors were obtained following the comparison between transposition of the towing tests and numerical simulations used for the bachelor thesis.

The transposition of the towing tests is based on ITTC standards. These standards used the wet surface of the ship and the similarity of the Froude number theory to transposition the hydrodynamic resistance of the scaled model to the hydrodynamic resistance of the 1:1 ship (real ship). This study will show that some physical phenomena that occurred during the model testing cannot be scaled.

In this analysis will show that the course mesh cannot generate physical phenomena on the free surface and leads to irrelevant results.

Hence, this study will look for ways to reduce these errors and assess the source of errors.
3. COMPARISON FOR FULL SCALE MODEL

The first step of the transposition has used the wet surface equals to 53.9 m$^2$ which represents the wet surface of one float of the catamaran (the second column of the table). The second step of the transposition has used the wet surface equals to 119.6 m$^2$ which represents the wet surface of two floats of the catamaran (the first column of the Table 2.) according to ITTC rules [2].

| S=119.6m$^2$ | S=53.9m$^2$ | CFD |
|--------------|--------------|-----|
| v [kN]       | v [kN]       | v [kN] |
| Rt [m/s]     | Rt [m/s]     | Rt [kN] |
| 3.9          | 4.3          | 3.4  |
| 5.4          | 9.6          | 6    |
| 6.6          | 27           | 18   |
| 7.7          | 36           | 27   |
| 8.9          | 40           | 32   |
| 10.1         | 41           | 33   |
| 11.2         | 47           | 34   |

As you can see the first step has maximum errors equals to about 20% and the second step has maximum errors equals to about 300%.

Hence, this step represents the beginning of the study.

4. THE ASSUMPTION OF THE ERRORS

4.1 The transposition issue

It is complicated to find a solution to transpose the turbulent flow from the scaled model to a full scale model.

For this study has used a model which has 1.4 m length and is complicated to compare a full scale model which has 21 m length with a model which has 1.4 m length because the viscosity of the water influences all flow around of the model.

The turbulent kinematic energy in the wave crest presented in “Fig.2.” has a high value and the steam lines in the area are not uniform.

Fig. 1. Comparison chart

The blue curve from the chart (Fig.1.) is for the conversion of the results which used wet surface equals to 119.6 m$^2$ [3], the red curve from the chart (Fig.1.) is for the conversion of the results which used wet surface equals to 53.9 m$^2$ [3] and the green curve from the chart (Fig.1.) is for the numerical fluid flow simulation of the full-scale model.

Fig. 2. Wave crest issue

Fig. 3. First mesh issue
4.2 The mesh issue

In numerical simulation to capture the physical phenomena needs to make a fine grid as to obtain all the parameters in all the points around the free surface [4]. Hence, it is necessary to have a fine surface mesh in the hull area.

In the full scale model numerical simulation has used an adaptive mesh along surface presented in Fig.3., but will see this method is not enough to capture wave crest phenomena [1].

Another issue of the mesh is the Kelvin free surface. The Kelvin free surface represents the refinement of the mesh in wave of the ship and is defined as a triangle in the aft and fore of the ship.

Hence, to obtain a real result of the analysis, to capture wave crest phenomena and the energy which is consummated for generate the wave crest must to use a fine refinement on the free surface which is presented in Fig.4 [6].

![First mesh issue](image1)

5. COMPARISON BETWEEN COURSE MESH AND FINE MESH

In order to solve the mesh issue, has been analyzed the maximum depth of the wave through and the maximum height of the wave crest.

The mesh along the free surface has been refined based of the dimension of the wave phenomena [5].

As we can see below, the second mesh is presented in Fig.6. and Fig.8 and is much fine along the free surface than the first mesh which is presented in Fig.5 and Fig.7.

![First mesh – fore ship](image2)

![Second mesh – fore ship](image3)

![First mesh – free surface](image4)

![Second mesh – free surface](image5)

In order to validation our assumption, these type of mesh has been applied for the scaled model and has been analyzed at 2 m/s model ship so as to compare to experimental simulation in towing tank.
The representation of the phenomena along the free surface is different for these type of mesh.

In the coarse mesh (first mesh) case, the wave crest has extended on a large distance on Y axis and the representation is not real compared with the towing tests (Fig.9.).

In the fine mesh (second mesh) case, the wave crest is the same as in the towing tests (Fig.10. and Fig.11.).

6. COMPARISON BETWEEN FINE MESH ANALYSIS AND TOWING TEST

Taking into account that for the second type of mesh we have obtained a good representation of the phenomena around the ship, we applied the second mesh for the entire range of speeds that were tested in the towing test.

This type of comparison are based on the computational fluid dynamics analysis of the scaled model (1:15) and the towing tank experimental probes of the scaled model (1:15).

In the below chart we can see that the maximum error is 5.4% on the high Froude number value, except the first error which is 12.3% and is the result of the low value of the hydrodynamic ship resistance (Table 3.).

| v  | $R_t$ (TT) | $R_t$ (CFD) | Errors   |
|----|-----------|------------|----------|
| m/s| [N]       | [N]        |          |
| 1  | 1.49      | 1.31       | 12.30%   |
| 1.4| 3.26      | 3.378      | 3.60%    |
| 1.7| 8.64      | 8.9        | 3.00%    |
| 2  | 11.37     | 11.29      | 0.60%    |
| 2.3| 12.9      | 11.97      | 7.20%    |
| 2.6| 13.44     | 12.78      | 4.90%    |
| 2.9| 15.17     | 14.35      | 5.40%    |

The red curve from the chart (Fig.13.) is for the towing tank simulation results and the green curve from the chart (Fig.13.) is for the numerical fluid flow simulation of the scaled model.
7. CONCLUSIONS

The errors which occur in last step of the study are due the trim conditions which are presented in Table 4. Hence, it is hard to compare the towing tank test and the numerical simulations.

Due to the model’s clamping mechanism on the towing tank, the model is added to a mechanical momentum that influence the hydrodynamic resistance value during the experimental analysis, as we can see in Fig.14 and Fig.15.

| v    | Q (TT)  | Q (CFD) | Q (Differences) |
|------|---------|---------|-----------------|
| [m/s]  | [grade] | [grade] | [grade]         |
| 1     | -0.12   | 0.02    | -0.14           |
| 1.4   | 0.32    | 0.46    | -0.14           |
| 1.7   | 1.33    | 2.42    | -1.09           |
| 2     | 1.97    | 2.97    | -1              |
| 2.3   | 1.16    | 2.77    | -1.61           |
| 2.6   | 0.81    | 2.52    | -1.71           |
| 2.9   | 1.45    | 2.35    | -0.9            |

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