SUMMARY

In this paper the effect of three longitudinal positions of outriggers in a Trimaran maneuvering is studied. For hydrodynamic simulations NUMELS –Numerical Marine Eng. Lab. Sharif- code is used. This software was developed for simulating three dimensional, time dependent, two phases, viscous flow coupled with rigid body motion. Different case studies have been performed and numerical results have shown good agreement with experimental data. Based on maneuvering simulation of trimaran vessel different conclusion are made. The results show that longitudinal positions of outriggers have great effect on maneuverability of trimaran.

1. INTRODUCTION

Wave making resistance is a significant component of ship resistance. It is very effective at higher speeds and will require more attention in designing of high speed ships. Normally large slenderness ratio (L/V^{1/3}) is necessary to decrease the wave making resistance. Therefore the ship hull should be as slender as possible for attaining higher speeds. But the main drawback of this effect is that the transverse stability decreases. Hence to overcome this challenge, the single body must be changed to multi-hull with proper separation distance. It means that a trimaran vessel which is composed of a main slender body and two outriggers can be appropriate solution to improve vessel transverse stability, while the efficient wave interaction, created by main body and outriggers is able to compensate for wetted surface increase and guarantees slender bodies with good stability at high Froude numbers. Trimarans share most of the characteristics of catamarans, but in few aspects, trimarans are more efficient than catamarans. Lyakhovitsky compared a trimaran with a mono-hull and a catamaran of same characteristics and showed that the trimaran is better in hydrodynamic performances compared to other alternatives [1]. In addition trimarans have some other privileges such as: extended deck, lower draft and better transverse stability compared with single body vessels. In additional, for military vessels, possibility of engine exhaust conductance between bodies makes less traceable [2]. In order to study the effect of outriggers position on trimaran resistance, some experimental tests are done and results show that the outriggers location has considerable effect in hydrodynamic performance of the vessel [3], but in vessel design, some cases such as maneuverability must be consider. Optimization procedures increasingly demand the performance of a ship to be assessed in its early design stage. This leads to a prediction tool independent of experimental results, although model tests will still be indispensable. CFD modeling based on numerical solution of the governing equations is a good choice. It must be remembered that, such a problem combines the complexity of free surface flow with rigid body motions. NUMLES code which originally developed in Sharif University of technology [13] provides an effective numerical tool for hydrodynamic simulation. Trimaran maneuvering simulation is a complex hydrodynamic problem that should be considered as multi physics phenomenon. In solving such a problem, one encounters to three subproblems which are: a) velocity and pressure distribution, b) free surface deformation and c) rigid body motion. Solving the first two subproblems results in interfacial flow simulation. By computation of velocity and pressure distribution, tangential and normal stresses are calculated. Integration of such stresses over the body yeilds to forces and moments acting on it. Solving the last subproblem, in conjunction with such values, gives a time-history of body motions in one or two phases e.g. submarine maneuvering or ship seakeeping. The important point is that, although potential theory methods [4] are capable of predicting motions with lower run time but they are not suitable where viscosity breaking waves or large amplitude motions play an important role. For many practically important cases, large errors are introduced by the potential theory assumptions. The motion of a floating body is a direct consequence of the flow-induced forces acting on it while at the same time these forces are functions of the body movement itself. Therefore, the prediction of flow-induced body motion in viscous fluid is a challenging task and requires coupled solution of fluid flow and body motions. In recent two decades, with the changes in computer hardware, ship motion simulation is the subject of many numerical hydrodynamic researches. These researches were started from the restricted motions such as trim or sinkage by Miyata [5], Hochbaum [6] Alessandrini [7] and Kinoshita [8] and continued to the evaluation of 6-DoF motions by Miyake [9], Azcueta [10], Vogt [11], Xing [12] and Jahanbakhsh et. al [17].
In this paper, numerical NUMELS software has been used. The trimaran motion and the effect of outriggers positions on trimaran manoeuvering are studied.

2. FORMULATIONS AND SOLUTION ALGORITHM
Here a finite volume time dependent three-dimensional viscous free surface flow solver is used [10]. Velocity and pressure fields are coupled using fractional step of Kim and Choi [11]. One must take into account the presence of high density ratio phases e.g. water and air in discretisation of pressure gradient integral which is treated here in a new way [10]. Also, a surface capturing method is used which solves a transport equation for calculation of fluids volume fraction. CICSAM interpolation has great advantages in comparison to other interpolations and used in this study for approximation of face volume fraction [15]. There are a variety of motion simulation strategies in numerical hydrodynamic applications. Here, a body-attached mesh following the time history of body motions is used [10]. In other words, linear and angular momentum equations are solved in each time step which results in 6-DoF motions. Such motions are applied on body and computational domain simultaneously to make it ready for the next time step. It must be noted that, all of the fluid governing equations are written for a moving control volume in Newtonian Reference system [16] which results in using relative face velocity for convection flux calculation while keeps the simplicity of equations.

As mentioned earlier, one encounters to three sub-problems in CFD simulation of ship motions. These parts which are marked with dashed lines are solved in a loop as shown in Fig.1.

3. NUMERICAL RESULTS
Coupling of rigid body motion with fluid dynamics has been studied by this software in former researches [17, 18, 19, and 20]. In those researches the numerical simulation of cylinder slamming, 2-DoF barge resistance and 3-DoF barge and 6-DoF catamaran turning maneuver has been performed and its results showed acceptable concordance with experiments.

In this study, behavior of Trimaran configurations as a 6-DoF rigid body is studied in calm water. Table 1 and Table 2 present the characteristics and configurations of trimaran, respectively. The parameters defined in table 1 and 2, are illustrated in Fig.2. The trimaran configuration is defined by the ratios \( d/L_M \) and \( s/L_M \), where \( d \) is the longitudinal distance between the bows of the main hull and the outriggers, and \( s \) is the transverse distance between the centerline of outriggers. In Table 2 and Fig.2, the under notes M and O are pointed to main hull and outriggers respectively.

Domain around trimaran body has been meshed with nearly 150000 hexahedral cells. Boundary conditions of the problem were considered as an impermeable wall and no-slip condition at the body and 6 outlet far-field conditions for sides. Fig.3 shows mesh and configuration of boundary conditions on computational domain.

<table>
<thead>
<tr>
<th>Table 1: Trimaran characteristics</th>
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<tr>
<td><strong>Main hull</strong></td>
</tr>
<tr>
<td>Length L(m)</td>
</tr>
<tr>
<td>Breadth B(m)</td>
</tr>
<tr>
<td>Draft T(m)</td>
</tr>
<tr>
<td>Displacement (kg)</td>
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<td>Wetted surface (m²)</td>
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Fig.1: Solution algorithm for numerical modeling
Table 2: Trimaran configurations

<table>
<thead>
<tr>
<th>$d/L_M$</th>
<th>0</th>
<th>0.25</th>
<th>0.5</th>
</tr>
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<tbody>
<tr>
<td>$d/L_M$</td>
<td>A</td>
<td>B</td>
<td>C</td>
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Fig. 2: Trimaran configuration with main particulars and relative position of hulls

Fig. 3: Computational domain
Applying forces and moments of maneuvering is performed by rotation of thrusters. So there is no rudder here and whole of propulsion system assumed to be rotated. Angle of rotation which applied on the trimaran's propulsion systems is 30 degrees. It should be noted that propulsion system assemble on the main hull and turning starts just after 10 seconds from the beginning of simulation. This permits the ship to reach a nearly steady forward motion due to thrusters' force. At first, various trimaran configurations are simulated at 4 m/s speed and required force to reach this speed is calculated which is shown in table 3. It is clear that for each configuration the thruster force is equal to its corresponding total resistance forces.

<table>
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<th>Configuration</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<tr>
<td>Total drag (N)</td>
<td>43.92</td>
<td>55.00</td>
<td>48.24</td>
</tr>
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Fig.4 shows the time history of ship speed for different configurations. It can be seen that for A configuration decreasing speed at turning is more than other configurations. Path of ship's center of gravity is shown in Fig.5. In the turning circle, The diameter of rotation circle for A configuration is most magnitude and for B and C configuration is close together.

In Fig. 6 trim angle of the vessel are shown. It is obvious that when the side bodies stem are aligned with main hull stem, the vessel trim is more than B and C configuration and when the three bodies stern of vessel are aligned (C configuration), trimaran has least trim angle. Therefore when the outriggers are in front of vessel (A configuration), it leads to a large trim angle which causes some section of side hulls come out of water and therefore stability decreases. In Fig.7, heel angle of various trimaran configurations is plotted. It can be seen that A configuration has least heel angle and its magnitude is near 1.5 degree, but oscillation magnitude is more than other configurations. Drift angle of three different configurations is also plotted in Fig.8. It is clear that trimaran with A configuration has not stable drift angle. Fig.9 shows Time history of yaw speed. It can be seen that A configuration has lowest yaw speed. Least yaw speed and unstable drift angle for A configuration can be reason of largest diameter of turning circle relate to other configurations.
Figs 10~12 includes few snapshots of trimaran and free surface around it during turning maneuver. The unsymmetrical waves generated during turning can be seen in this figure. Figs 13 and 14 are better view of rout close to the starting point of maneuver.
Fig.11: Free surface for B configuration

Fig.12: Free surface for C configuration
4. CONCLUSION
Maneuvering of a trimaran vessel has been investigated in present paper taking into account 6-DoF rigid body motion. Numerical results show that outriggers position has great effect on trimaran maneuverability. Based on these results, it can be seen that when the bow of three bodies are aligned, it is not an appropriate configuration for maneuvering, because in this case, vessel trim causes outriggers to come out from water, therefore stability decreases. With comparison B and C configurations, the circles of turning have almost same diameter but since C configuration needs less thrust force than other case, so it is more efficient configuration, from resistance point of view.
5. REFERENCES