©SNAK, 2011

Inter J Nav Archit Oc Engng (2011) 3:225~232
http://dx.doi.org/10.2478/IJNAOE-2013-0066

Panel cutting method: new approach to generate panels on a hull in Rankine source potential approximation

Hee-Jong Choi[1], Ho-Hwan Chun[2], Il-Ryong Park[3] and Jin Kim[4]

[1]*Dept. of Naval Architecture & Ocean Engineering, Chonnam National University, Yeosu, Korea*
[2]*Dept. of Naval Architecture & Ocean Engineering, Pusan National University, Busan, Korea*
[3]*Dept. of Naval Architecture & Ocean Engineering, Dongeui University, Busan, Korea*
[4]*Maritime and Ocean Engineering Research Institute, KORDI, Daejeon, Korea*

ABSTRACT: *In the present study, a new hull panel generation algorithm, namely panel cutting method, was developed to predict flow phenomena around a ship using the Rankine source potential based panel method, where the iterative method was used to satisfy the nonlinear free surface condition and the trim and sinkage of the ship was taken into account. Numerical computations were performed to investigate the validity of the proposed hull panel generation algorithm for Series 60 (C_B=0.60) hull and KRISO container ship (KCS), a container ship designed by Maritime and Ocean Engineering Research Institute (MOERI). The computational results were validated by comparing with the existing experimental data.*

KEY WORDS: Hull panel generation; Rankine source potential based panel method; Nonlinear free surface condition; Iterative method; Series 60 (C_B=0.60) Hull; KRISO Container ship (KCS).

INTRODUCTION

Minimization of the resistance of a ship is an important issue in ship design. The resistance is determined by hydrodynamic forces, which strongly depend on the shape of the hull. Resistance consists mainly of a viscous resistance associated with the generation of a boundary layer and a wave-making resistance connected with the excitation of a wave pattern.

For most commercial ships the viscous resistance component is dominant, while the wave resistance in practical cases amounts to 10 to 60% of the total resistance, depending on the operating speed. The wave resistance is virtually zero at relatively low speeds and increases very quickly at higher speeds. The wave resistance is very sensitive on the shape of the hull and is easily influenced by relatively small design modifications, which means that wave resistance plays an important role in hull form design.

In general, the total resistance was measured at a towing tank with a scaled model. At the same Froude number, a model test produces a wave pattern geometrically similar to that of a ship and the wave resistance of the ship is theoretically predicted by that of the model. Optimizing the shape of the hull to reduce the wave resistance is a difficult task which requires both the practical experience and intuition of naval architects, while the empirical approach has been complemented by numerical analysis.

The Rankine source panel method has been found to give fairly realistic results in general, and to be quite efficient and flexible, where the nonlinear free surface condition was linearized such as for the well known Kelvin free surface condition and satisfied in an iterative manner. The Rankine source panel method has been used in many practical ship design. The use of this method caused a significant change in the hull form design procedure (Baba and Takekuma, 1975; Brandsma and Hermans, 1985; Dawson, 1977; Eggers, 1981; Gadd, 1976; Newman, 1976; Raven, 1996).

In the Rankine source panel method the quality of the panels surrounding the boundaries is very important in order to obtain reliable results. In general, computational grid for flow calculation requires some characteristics such as orthogonality, smoothness, adequate concentration, configuration like streamlines and so on. Jensen (1990) developed an efficient interface program, linking computer aided ship hull form design and the evaluation of seakeeping and wave resistance performance. The interface program took the curves from the ship hull form database, and made a panel model of the ship hull form with only minor input from the operator. The panel model was the geometric input for the calculation of seakeeping and wave resistance characteristics. Kouh and Chau (1993) generated the grid for hull forms using rational cubic Bezier curves. In the paper a hull form was defined by two sets of grid lines-transverse grid lines

Corresponding author: *Ho-Hwan Chun*
e-mail: *chunahh@pusan.ac.kr*

arranged in length direction and longitudinal grid lines arranged in depth direction. Transverse lines were first defined, the points on the transverse lines with the same curve parameter values were then fitted to define longitudinal lines. Kim and Van (1999) developed a hull surface mesh generation program, based on given station offsets and centerline profile which employed non-uniform parametric splines and generated hull surface meshes can be utilized for the Rankine source panel method immediately. Bronsart et al. (2004) proposed the automatic panel generation method of a ship hull surface for wave resistance calculation. In the paper two algorithms were presented with the objective to facilitate the fully automatic panel mesh generation and the stability of the algorithm and the applicability to all ship forms and the regularity of the panel mesh as required for CFD calculations were taken in account. Ko et al. (2011) developed the panel generation system for analyzing seakeeping performance of a ship. The system was designed to handle various kinds of ships such as ships with a mono-skeg, a twin-skeg and/or a bulbous bow in either an automatic or an interactive manner.

In the iterative method, to satisfy the nonlinear free surface condition, the panels on the hull should be changed according to the wave profile in the immediate vicinity of the ship found in the previous iteration and the generation of hull panels should be carried out automatically using the initially given hull geometry information in every iteration. It is not easy to maintain an initially given hull geometry if the ship has an intricate design or if the ship experiences excessive dynamic trim and sinkage. Therefore, the generation of the hull panels could be a particularly serious problem to tackle. In particular, there has been controversy on the panel generation for a ship with a goose-neck bulb which emerges over the free surface in severe trim or ballast condition. To solve this problem in a practical way, an additional sinkage is applied to the ship which means that the ship is enforced to be fully submerged. In this case, the numerical results are dependent on the additional sinkage condition. Therefore, a new analysis technique without the additional sinkage needs to be developed.

In the present study, a new hull panel generation technique was proposed in which the panel on the hull was re-generated, making the best use of the initially given panels. The Rankine source panel method was used with the fully nonlinear free surface condition, which was satisfied by the iterative method and the dynamic trim and sinkage were taken into account. Numerical computations were performed to investigate the validity of the proposed algorithm using Series 60 (C_B=0.60) hull and KRISO container ship (KCS) designed by Maritime and Ocean Engineering Research Institute (MOERI). The computational results were validated by comparing them with the existing experimental data.

POTENTIAL FLOW METHOD

The coordinate system moves with the ship at the same longitudinal speed but does not follow its dynamic trim and sinkage and the origin is chosen at the centerplane of the ship at the midship section, at the level of the undisturbed waterplane. The x-axis is horizontal and points astern, the y-axis is positive to starboard, and the z-axis is upward as shown in Fig. 1.

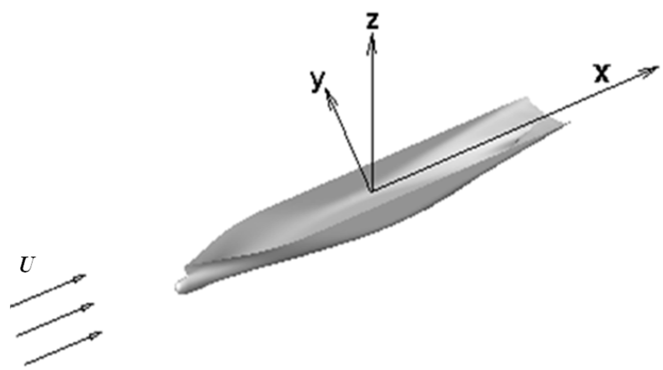

Fig. 1 Coordinate system.

In the unawareness of the viscosity of the fluid and wave breaking, the irrotationality of the incoming flow is preserved and a potential flow may be assumed in which the velocity vector is defined as the gradient of a velocity potential, ϕ. The velocity potential is governed by the Laplace equation as the fluid is assumed to be incompressible.

$$\nabla^2\phi = 0 \quad \text{in the fluid region} \tag{1}$$

Over the wetted part of the hull surface, the fluid particle should not penetrate the hull surface and the normal component of the flow velocity on the hull surface should be zero.

$$\phi_n = 0 \quad \text{on the hull surface} \tag{2}$$

where n is the unit normal vector.

On the free surface, the flow velocity must be tangential to the free surface, which means that the flow particle at the free surface should not leave the free surface.

$$\phi_x h_x + \phi_y h_y - \phi_z = 0 \quad \text{on the free surface} \tag{3}$$

where h is the wave elevation.

The pressure on the free surface, which is expressed in the flow velocities and wave elevation through Bernoulli's law, should be constant at the free surface.

$$gh + \frac{1}{2}\left(\phi_x^2 + \phi_y^2 + \phi_z^2 - U^2\right) = 0 \quad \text{on the free surface} \tag{4}$$

where U is the speed of the ship.

Since equations (3) and (4) are fully nonlinear equations, in this paper the iterative method was used to solve the free surface problem based on the Rankine source panel method.

The disturbance due to the ship approaches zero and the velocity potential should be the same as the incoming velocity potential, as the distance from the ship approaches infinity.