Streamline Monohull Ship Form For Sea-High Speed Crafts

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***Abstract*—Sea transportation for many inhibited small islands with no transportation link to market and education center is one of the most concern for economic growth. A good reliable hull form for fast marine vehicles carrying passengers, car, and goods has been defined. The design process was to apply the concept of monohull and frigate form for good seakeeping and structural strength considering wavy Indonesian water. Smiplaning hull form was introduced to meet the criteria of fast marine vehicles and take into account streamline hull surface, fluid flow, total resistance in calm water were studied by towing tank model tests. Variation of waterline entrance angles as the main variable result good performance of 9.5^0 angle hull form more than the two others 6.5^0 angle and 11^0 angle. Sectional area dan breadth ratios to their maximum values were prepared. This as means for preliminary design and further study of the hull form.**

***Index Terms*—Hull form, Marine vehicles, Streamline hull.**

I. Introduction

MARINE vehicles for traveling among the islands in Indonesia with more than 70 percentage of the area is water to be the most convenience way to connect remote island for economy reason. Prevailing such a transportation in its turn helps people get advantages for enhancing quality of life. However, every effort to make it possible is quite tedious work for it is a fully scientific reasoning to cope with rough water environment conditions. This is the main purpose of the study I conducted back in the year 1994 [1]. The result was a series of monohull form for marine vehicles with semiplaning hull form. Semiplaning means not fully plane surface for hull form. The bow hull part was designed by adopting monohull form by Rodriques Cantierry Navale [2], a ship building company in Italy and frigate hull form of United States of America Navy for good seakeeping [3]. For the reference, these two hull form are shown in Figure. 1 and 2.

The hull form in the study was designed to have stream line fluid flow. Maximum breadth was determined for this reason was at the stern part of hull in the form of transom. For the entrance angle, iE = 9.5^0, semiplaning hull streamline flow can be stated mathematically based on stream function in two dimension flow. Velocity field in the form of; $\mathbf{V} = u\mathbf{i} + v\mathbf{j}$, where u: velocity component in x-direction and v: velocity component in y-direction. Streamline function gives that :

$$\Psi = \frac{dx}{u} = \frac{dy}{v} \tag{1}$$

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Fig. 1: Rodriques Fast ferry

hence,

$$u \cdot dy - v \cdot dx = 0 \tag{2}$$

condition to be studied statistically using generated data for model building [4].

The streamline hull lines aim to create no separation, wake or turbulent flow regime along the body of ship. This is an ideal body form to reduce either resistant and power required for advancing motion. Low resistance form is the idea to create low power as resistance can be defines as the power to move a body in fluid or power to move a body in fluid must be at least equals to resistance of the body in fluid flow. Therefore this study provides the method of hull form with low power requirement for high speed marine vehicles such as fast car-goods-passengers ferry

II. Methods and Material

A. Principal Dimensions

The dimensions were derived using a prototype of the same kind of semiplaning hull form developed by Rodriques Cantierri Navale, Mesina, Italy for the reason of hydronamic forces and monohull type and modern frigate studied by Blok, Jan J. and Beukelman, Wim (1984) for good seakeeping. Principle dimensions was defined from preliminary design. Input into the design process were number of passengers,

Fig. 2: Modern U.S Frigate

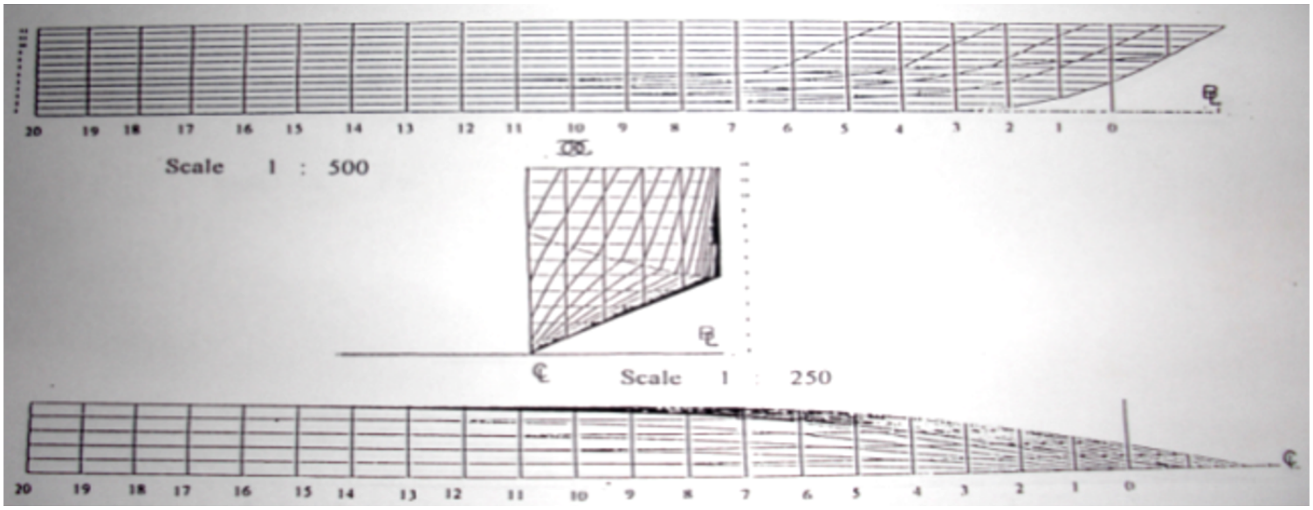

Fig. 3: Hull form lines

car/passenger ratio, service speed, and maximum cruising range.

Applying specifications obtained from preliminary design, principle dimensions of hull form as seen in the Table. I.

B. Hull form

Hull form was generated with AUTOSHIP, a ship designing software, at The Center of Ship Design, Technical University of Nova Scotia, now after amalgamating with Dalhousie University got the name of Dalhousie Technology [1]. Hull form with a set of special character as a new series of hull form;

1) Defined waterline entrance angles
2) Chine line over 0.8 L from the stern, to be called semiplaning
3) Transom stern form
4) Hull lines satisfy streamline function.

Transom stern is the flat form which is designed for the embarkation purpose. Transom stern is open to harbor for the way in and the way out of passengers, cars, and goods.

C. Model test setting up

To extrapolate the model data to full scale data, geometrical similarity and dynamic similarity had to be satisfied. Froude Law of Similarity had been adopted to carry out the process [1].

$$Fn\,(m) = Fn\,(p) \tag{3}$$

TABLE I: Principle dimensions

No	Designation	Symbol	Dimension [m]
1	Length of overall	LOA	92,50
2	Length between perpendicular	LWL	84,10
3	Maximum breadth	$B_{m}ax$	14,50
4	Depth	H	9,50
5	Draft	T	3,90

$$\frac{V}{\sqrt{gL\,(m)}} = \frac{V}{\sqrt{gL\,(p)}} \tag{4}$$

Model of the hull form was being tested in Towing Tank Laboratory. Model speed as a function of Froude number to satisfy the dynamic similarity of prototype or full scale and model. Froude number was used to define the effect of gravity to the motion. Then residuary model and prototype coefficient are the same.

$$Cr\,(m) = Cr\,(f) \tag{5}$$

$$\frac{Rr}{0.5 \cdot \rho V^2 S\,(m)} = \frac{Rr}{0.5 \cdot \rho V^2 S\,(p)} \tag{6}$$

since,

$$Cr\,(m) = Ct\,(m) + Cf\,(m) \tag{7}$$

$$Ct\,(m) = \frac{Rr}{0.5 \cdot \rho V^2 S\,(m)} \tag{8}$$

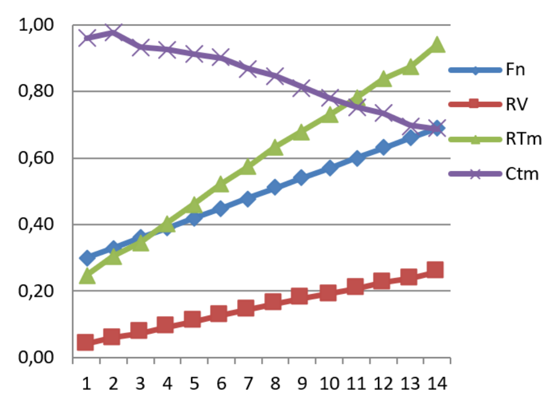

Fig. 4: Total Resistance coefficient. Fn: Froude number, Rv: Dynamometer test, Rtm: Hydrodynamic forces, Ctm: Total resistance coefficient.

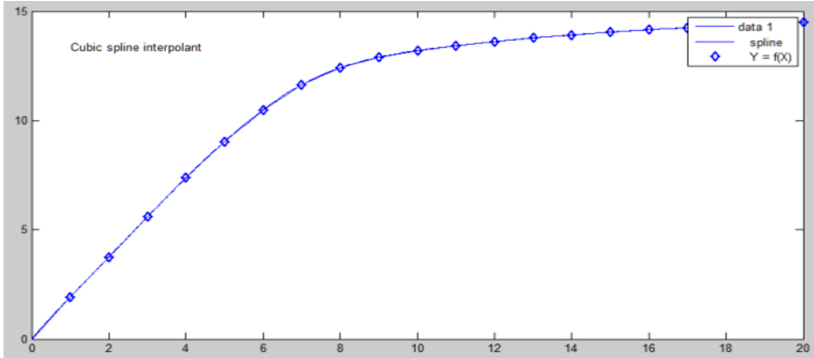

Fig. 5: Data and cubic spline line

where $Ct\,(m)$ was obtained from the experiment and $Cf\,(m)$ as equivalent plank friction resistance coefficient obtained from ITTC line. The full scale total resistance coefficient can be obtained as :

$$Ct\,(p) = Cr\,(m) + Cf\,(p) + CA \tag{9}$$

where CA is roughness allowance or model full-scale correlation factor.

III. Results and Discussion

A. Model test result

The results of model towing for LCG (longitudinal center of gravity) 0.40 L (design value) from the transom with 6.80 kg loading condition, as seen in the Figure. 4. At low speed when hydrodynamic forces do not exist, resistance coefficient increases until significant speed when hydrodynamic force begin increased by the pressure on the hull-wetted surface and water resistance coefficient starts to decreases drastically, as shown by Ctm curves. In unstable speed, hollow and hump occur and as the speed increases total coefficient decreases, this is a good performance of the hull form. Hydrodynamic forces increases as model speed as a function of Froude number increases. On the other hand, total resistance coefficient decreases. This as an effect of decreasing wetted surface. A good condition for lowering power required to generate thrust to drive the ship in speed of advance.

B. Hull form dimensions

The following are data of monohull and modern frigate representing hull form section breadth at maximum waterline. Further study on streamline hull lines, data resulted in the preliminary design was to be explored with regression analysis[5]. Data is plotted for x as length and y as a function of x $(y = f\,(x))$ with norm of residual equals to 0 (zero), represent by the legend data 1 in Figure 3. Applying Basic Function in MATLAB with spline function, norm of residual is 0 (zero). This is to identify that between data line and spline line there is no different and therefore the line is perfectly smooth. This condition is shown the Figure 4. For the function of shape-preserving interpolant, norm of residual still equals to 0 (zero). Again the hull line is proved to be perfectly smooth. This property is shown in the Figure. 5.

Further inspection with polynomial function to the degree of 10th shows a value of norm of residual which is 0.034213 for full scale data. The different slightly occur at the bow part of hull line, as in the 6. However, is not 0, and for this a review should be conducted to study the scale effect for the streamline function between full scale and model. Analysis on model data results norm of residual of 0.00068425, a small number. Somehow, this number is the direct effect of geometrical similarity as a function of dimension scale. Polynomial equation data and line as plotted show different characters as in the Figure 6 and 7 two following figures along with curves representing the data.

There exists a contrast different between the model and full scale. For model residual (ry legend) 0.00068425 is so small

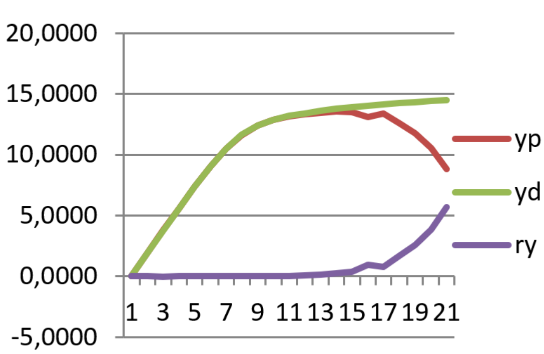

Fig. 6: Full scale polynomial regression

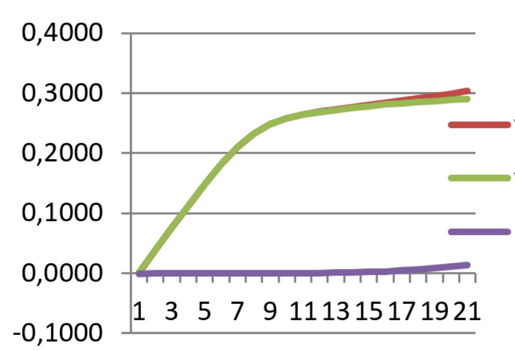

Fig. 7: Model polynomial regression

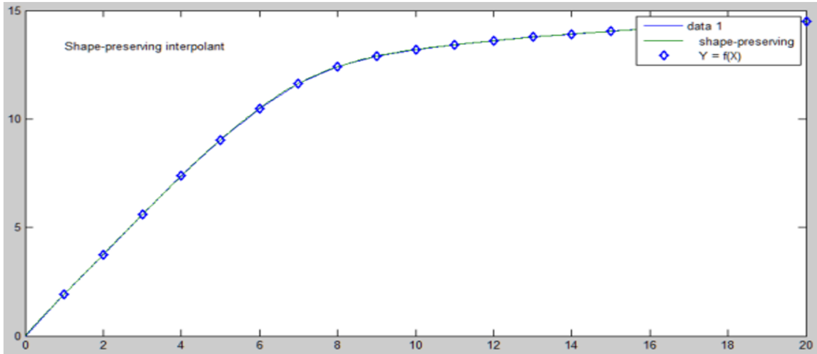

Fig. 8: Data and shape preserving

and at the end of the curve, y (yd legend) values of model larger then y (yp legend) values of full scale. On the contrary, residual 0.03421 of y values of full scale is in order of used scale and at the end of the curve decrease drastically.

The fact is polynomial regression for data obtained from full scale and model results large residual in different order. This show that defining scale for ship modeling have to be considered or there should a special method to derive adoptable scale to use in designing model for experimental works. The idea of polynomial regression is to minimize the variance of the unbiased estimator of total resistant coefficient on model building.

IV. Conclusion

After conducting the experiment and reading various resources, comparing to this hull form, here are some specific characteristics:

1) Stern in form of transom or flat is good for stern embarkation system
2) Maximum breadth at transom to certify streamline flow
3) Scale used for geometrical similarity affect streamline hull form in model testing.
4) Slender and semiplaning with small wetted surface at high speed for high hydrodynamic force impact at the hull.
5) Low draft enable moving through shallow water.
6) High dynamic forces from plane underwater surfaces lowering total resistance and reducing power to drive the ship.
7) Hull form is good for Fast Car-passenger-goods ferry in western Indonesia.

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