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Hull Form Generation by Using Fuzzy Model

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Abstract

This paper discusses the hull form generation from fuzzy model constructed with actual ship data using fuzzy concept.

SAC, which is the most important factor in the hull form generation, is expressed by a fuzzy model describing the relationships among design parameters, which have a great influence on SAC, through model identification process with the actual ship data and design parameters. Then, we can infer the SAC of an aimed ship through the process of fuzzy inference and decide the offset of a front view by making the fuzzy model between SAC and offset as well.

In conclusion, this paper makes a step forward from the geometrical definition, which has been used for hull form generation so far, to direct mathematical formulae about the relationship between design parameters and offset. So, if the design parameters are given, we can generate the hull form taking such properties into account.

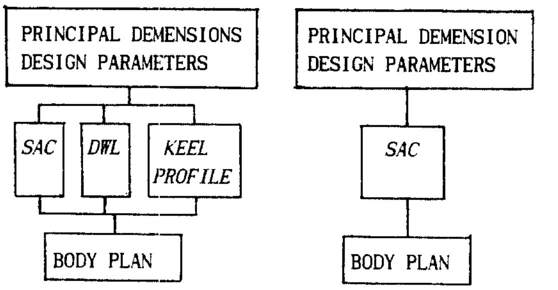
1. Introduction

A relatively accurate decision of a hull form is essential to estimate a main engine horse power and a ship cost in the initial design stage. Therefore, many designers have elaborated to express a hull form in mathematical ways. Recently, due to the rapid development of computer technology, new methods of describing the hull form have been developed.

There are several hull form generation methods that can be used in the initial process of ship design. For example, the standard series approach, lines distortion from parent lines, and form parameter design method can be illustrated.

Though the standard series approach and lines distortion from parent lines have been widely used due to their simplicity, they have a limitation in the sense that they can only generate a hull form, similar to the standard hull form, within the restricted distortion range. Thus, if the distortion range is widened, it leads to degeneration of a whole hull form. The form parameter design method expresses an aimed hull form in a mathematical way by combining form paramters that define the hull form. It is quite useful in calculating geometrical and numerical properties. It can also generate any kind of hull form which satisfies designer's demand. However, the form parameter design method can be affected by the way how the form parameters are combined. For example, if the hull form is expressed in a polynomial, which requires relatively simple calculations, problems may arise such as an increase of an order of polynomial and oscillation of a curve when the number of form parameters increases. Moreover it is impossible to express the hull form which has vertical tangent vector. When B-spline is used in expressing the equation by combining form parameters, there are several merits such as a guarantee of the enough continuity, permission of local control, the possibility of expressing discontinuities and straight curve and easiness of anticipating a shape. But it requires many trial and errors to determine form parameters for a new hull form. Thus it accompanies many difficulties to use when the designer is not equipped with the experienced knowledge. In addition, form parameters are not general kinds of design paramter but confined form definition paramters having only geometrical characteristics like position, slope, curvature, area, moment, and centroid. Because the hull form generation from form paramters has a chance to bring about an unexpected performance problem and a design fault which are not within the design constraints, it definitely requires overall consideration about design conditions, design parameters and a hull form. Since ship design is a complex process and it needs many feedbacks at design stage, it has been difficult to generate a hull form that satisfies all the requirements when we use above mentioned methods.

On the contrary, an application of a fuzzy model to hull form generation makes it possible to express not only a general design kowledge concerned with a ship design but also an experienced kowledge which can be only transferred verbally mathematically. Traditionally the hull form has been determinded so far by producing and considering basic curves of SAC, DWL, and keel profile. But with hull form generation fuzzy model, the hull form can be generated from SAC only. The Fig. 1 shows the difference between the two approaches. This paper discusses the hull form generation from fuzzy model constructed with actual ship data using fuzzy concept.



(a)general design method (b) fuzzy model method

Fig. 1 Comparison of hull form generation procedures

2. Fuzzy Modelling of SAC and Body Plan

Fuzzy modeling means a process that expresses global relationships among parameters in a system in mathematical models. Though a statistical method has been used for this mathematical modeling, it has been still difficult to find out a global function of complex nonlinear systems. Fuzzy modeling used in this paper puts its basis on finding a set of local input-output relations describing a system. This is meant to analyze a nonlinear structure of a system by input-output data analysis and to regard the structure as a kind of superposition form made of several linear relation structures. This view is adequate to establish relationships among design conditions, principal dimensions, and hull forms.

In this paper, two-step fuzzy modeling is considered. The first step is the fuzzy modeling process to get SAC from design condition and principle dimensions. The second is a fuzzy modeling process to generate a body plan from SAC. The method suggested by M. Sugeno and G.T.Kang is used to identify the fuzzy model.

2.1 Fuzzy Model

A fuzzy model is one that expresses a complex system in the form of fuzzy implications. The identification of fuzzy model means a process which decides a model expressing a system from minimum number of fuzzy implications. The fuzzy implication that we use is of the following form;

$$R^i: \text{ If } x_1 \text{ is } A_1^i \text{ , } x_2 \text{ is } A_2^i \text{ , } \cdots \text{ , } x_m \text{ is } A_m^i$$
$$\text{then } y^i = c_0^i + c_1^i x_1 + c_2^i x_{12} + \cdots + c_m^i x_m$$

where, A_j^i is a fuzzy set defined by trapezoidal type, and y^i is the output form of the i-th fuzzy implication.

Given an input $(x_1^0, x_2^0, \ldots, x_m^0)$, the output y is inferred by taking the weighted average of the y^i's.

$$y = (\sum_{i=1}^{n} W^i y^i) \,/\, \sum_{i=1}^{n} W^i \qquad (1)$$

where, n is the number of fuzzy rules, and the weigt W^i implies the overall truth value of the premise of the i-th rule for the input

$$W^i = \Pi_j \; A_j^i(X_j^o) \qquad (2)$$

A fuzzy model is built by physical properties of a system, observation data, empirical knowledge, and so on. Here we use the input-output data of actual ship in a fuzzy model identification, which consists of two parts :structure identification and parameter identification. The algorithm suggested by M. Sugeno and G.T.Kang is used to identify the fuzzy model.

2.2 Fuzzy Modeling of SAC

SAC has the greatest influence on determining a hull form in an initial designing process because it describes the most basic properties of a hull form. It is a reasonable procedure to decide SAC from estimated parameters, but it is also very difficult since the complex relationship between parameters and SAC has to be considered overall. To solve the problem, the relationship between parameters and SAC is described as a fuzzy model. In the fuzzy modeling, it is assumed that principal dimensions and design parameters are given. L/B, B/D, C_b, Vs, LCB, C_p-Curve, F_n, C_m, are used as input data for model identification. The definition and the range of each design parameters is given below.

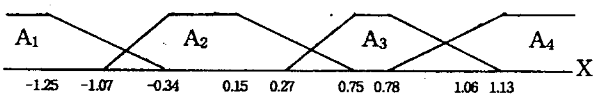
L/B : Length between Perpendiculars(m) / Moulded Breadth(m)
B/D : Moulded Breadth(m) / Design Draft(m)
V_s(kt) : Design Speed (des)
C_b : Block Coefficient
C_m : Midship Coefficient
LCB(%) : Longitudinal Center of Buoyancy
F_n : Froude Number

The range of the each design parameter

$5.5 < L/B < 8.63$	$0.97 < C_m < 0.99$
$2.39 < B/D < 4.31$	$-2.08 < LCB < 3.64$
$14.0 < V_s < 24.6$	$0.13 < F_n < 0.25$
$0.53 < C_b < 0.83$	

As defined so far, each parameter is usually known as a crucial element in determining SAC, and it is selected synthetically with a view of a designer. Through the fuzzy model identification, we decide which parts of SAC these parameters influence, and which parameters mostly affect in determining SAC. As the result of the fuzzy model identification, the premise variable of SAC fuzzy model is the longitudinal axis X, and consequent variables are X, C_b, LCB and F_n.

In conclusion, each sectional area of SAC is much more influenced by parameters, X, C_b, LCB, and F_n. It is possible to express the system using only these parameters. In addition, we can generate a model which has more performance index by adding parameters relatively easily established in design stage as consequent variables of SAC fuzzy model. However, if we use too many input variables, we may end up with creating a too much complicated model. The resultant fuzzy models are given in Fug. 2.



L^1 : If x is A_1 then $Ax = -0.421 + 0.941X + 0.922Cb - 0.029LCB - 0.304Fn.$

L^2 : If x is A_2 then $Ax = -0.362 - 0.009X + 0.755Cb - 0.014LCB + 0.238Fn.$

L^3 : If x is A_3 then $Ax = 0.069 - 0.712X + 1.601Cb + 0.056LCB - 0.453Fn.$

L^4 : If x is A_4 then $Ax = 1.167 - 0.371X - 0.878Cb - 0.006LCB - 0.454Fn.$

Fig. 2 The fuzzy model of SAC

2.3 Fuzzy Modeling of Body Plan

The fuzzy models can be categorized into two groups when we make fuzzy model to express body plan. In case of having a lot of input-output data of an actual ship, after fuzzy modeling of the relationship between each parameter and a body plan offset, the fuzzy model can determine the offset according to a design condition and parameters. In the other case, the fuzzy model can be identified in a confined hull form.

The major advantage of fuzzy model is the flexibility that if a fuzzy model is achieved by an adequate reflection of nonlinear structure, any hull form of similar type can be generated easily.

On the contrary, its defect is that it requires much actual data to model the system. Therefore actual data is necessary to generate the hull form using fuzzy modeling technique. Because of lackness of the actual offset data, this paper puts its emphasis on presentation of the possibility that we can generate a body plan from SAC only rather than general hull form generation from various design parameters.

The relationship between SAC and body plan offset is constructed into fuzzy model and actual ship data such as X(section), each sectional area Ax of SAC, Z(depth), Y(breadth) are used. There are some problems in expressing a stern and a bow which vary abruptly with Ax variation in spite of the advantage of fuzzy concept. Therefore, emphasising the variation of a stern and a bow which have much variation, the total area is divided into 4 regions as shown in Fig. 2

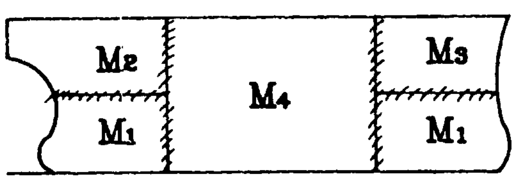
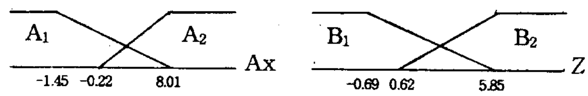


Fig. 2 The divided sections of body plan data.

After all, the fuzzy model of body plan has four fuzzy implications and premise variables are Ax and Z, and consequent variables are X, Ax and Z. One of fuzzy models of body plan is shown in Fig. 3



L^1 : If Ax is A_1 and Z is B_1 then $Y = -0.2539 - 0.0392X + 0.0335Ax - 0.8972Z$

L^2 : If Ax is A_1 and Z is B_2 then $Y = 4.4746 + 0.1019X - 3.4270Ax - 0.8338Z$

L^3 : If Ax is A_2 and Z is B_1 then $Y = 0.2539 + 0.0711X + 0.3127Ax + 6.7425Z$

L^4 : If Ax is A_2 and Z is B_2 then $Y = -0.5801 + 0.1605X - 1.8177Ax + 4.9294Z$

Fig. 3 The fuzzy model of body plan

3. Hull Form Generation

3.1 SAC Generation

The SAC inferred from the SAC fuzzy model of Fig. 2 is shown in Fig. 4. Considering the SAC characteristics, a value greater than 1 is defined as 1 and a value less than 0 is defined as 0.

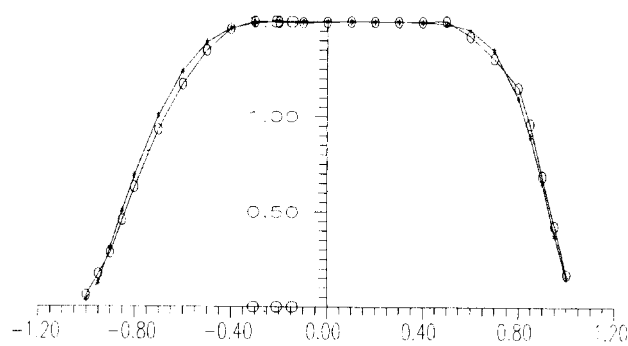


Fig. 4 SAC inferred by fuzzy model of SAC (C_b = 0.8081, LCB = 2.431, Fn = 0.162)

3.2 Generation of Body Plan

The total area of body is divided into 4 regions and for each region a fuzzy model is identified. Each model consists of 4 fuzzy implications.

For generation of body plan, the sectional area Ax is inferred from the SAC fuzzy model by using X, C_b, LCB, and F_n, and the offset Y is inferred from each body plan fuzzy model.

Since each sectional data has been superposed in the modeling process, relatively good results can be obtained with the few data. But the body plan obtained from 4 fuzzy models tends to be unnatural at the boundaries of 4 regions.

To conclude, as shown in Fig.5 and Fig.6 for comparision, a new hull form relatively similar to an actual ship data is generated.

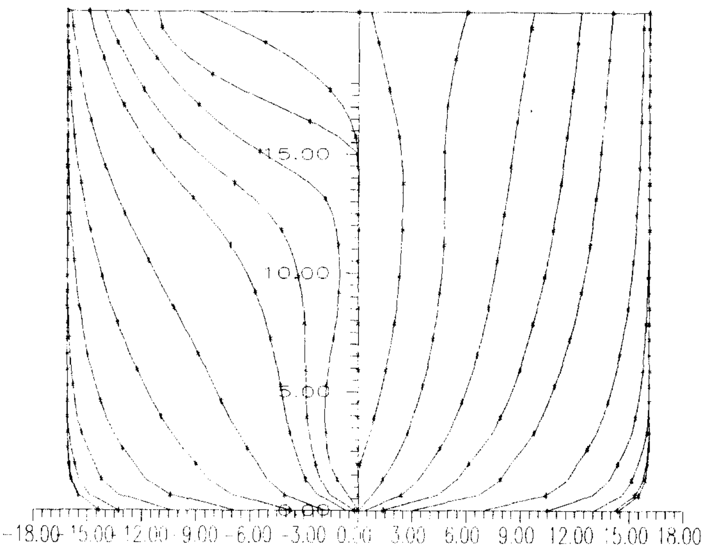


Fig. 5 Body plan of actual ship
(C_b = 0.8081, LCB = 2.431, Fn = 0.162)

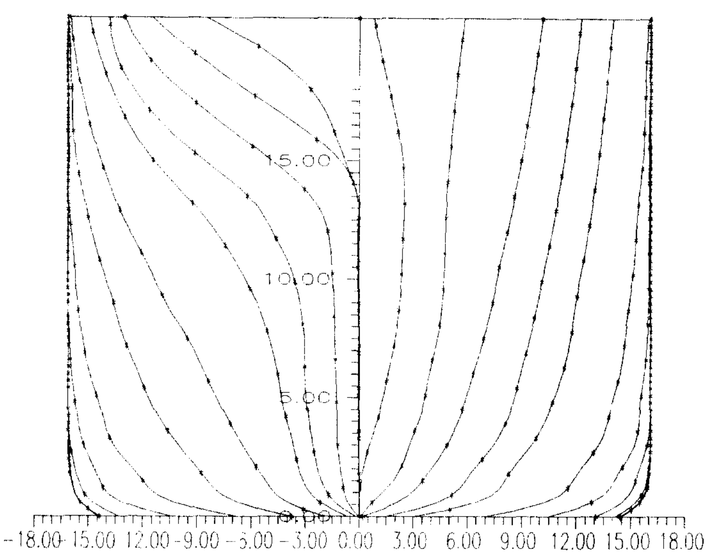


Fig. 6 Body plan of inferred ship
(C_b = 0.8081, LCB = 2.431, Fn = 0.162)

Conclusion

1. It is possible to construct fuzzy models of SAC and body plan using the fuzzy theory, which express the relationship among the design parameters, SAC, and offsets.

2. The suggested fuzzy models can generate the SAC which satisfies the design condition and the design parameters

3. It is possible even for an inexperienced desginer to generate a hull form wihtout DWL, Keel profile to statisfy design parameters and design conditions only from the SAC obtained in conclusion 2.

References

[1] S.Y.Kim and S.Y.Kang, "Hull Form Generation using B-spline Form-Parameter Method", Journal of the Society of Naval Architects of Korea, Proceeding, November, 1990.

[2] Creutz, G., "Curve and Surface Design from Form parameters by means of B-splines"(In German), Doctoral Thesis, University of Berlin, 1977.

[3] D.F.Rogers and J.A.Adams, "Mathematical Elements for Computer Graphics", 2nd Ed., McGraw-Hill Pub, 1990.

[4] D.Dubois and H.Prade, "Fuzzy Sets and Systems: Theory and Application", Academic Press, New York, 1980.

[5] A.M.Reed and H.Nowacki, "Interactive Creation of Fair Ship Lines", Journal of Ship Research, Vol.18, pp.96-112, 1974.

[6] H.Lackenby, "On the Systematic Geometrical Variation of Ship Forms", Transactions INA, Vol. 92, pp.289-316, 1950.

[7] S.Y.Kim, "hull form generation by B-spline surface method", KRISO, Research report, 1991.

[8] H.Thieme, "Uber Grundlagen fur den mathematischen Linienri eiines Frachtschiffes", Schiffstechnik, BD. 3, 1955/56.

[9] M.Sugeno and G.T.Kang, "Structure Identification of Fuzzy Model", Fuzzy Sets and Systems Vol. 28, pp.15-33, 1988.

[10] T.Takagi and M.Sugeno, "Fuzzy Implication of Systems and Its Applications to Modeling and contro l", IEEE Trans. Systems, Man and Cybernetics, 15-1, pp.116-132, 1985.

[11] H.Nowacki, G.Creutz, F.C. Munchmeyer, "Ship Lines Creation by Computer-Objectives, Methods and Results", The Society of Naval Architects and Marine Engineers, 1977.