Representation for Characteristic Curves of Hull form Using Immune Genetic Algorithm based on NURBS with Path Curve Parameterization Method*

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ABSTRACT

This study focuses on the characteristic curves representation for the hull form based on NURBS. With view to the problems in the existing NURBS method, the path curve parameterization method is proposed so that the flow field information can be introduced into the designed curve. The appropriate optimization model is constructed. And the immune genetic algorithm is used and the necessary improvement is made in order to reduce the control points. A series of typical characteristic curves of the full-scale hull form representation instances using this method indicate that it is feasible and can satisfy the requirements of the engineering design.

KEY WORDS: Hull form; characteristic curves; NURBS; path curve parameterization method; immune genetic algorithm

INTRODUCTION

NURBS is a common mathematic tool for the hull form design. The typical hull form representation methods include NURBS paths method(Yuan, 2001) and the single NURBS surface method(Lu, Lin and Ji, 2005). And the adaptive genetic algorithm has been used in the waterline approximation and design(Lu, Lin and Ji, 2007 and Lu, Lin and Ji, 2008). But there are two problems in the existing method: the redundant control points and the separating from the flow field and Ji, 2008). But there are two problems in the existing method: the redundant control points and the separating from the flow field information around the hull surface can be introduced into the designed curve. Meantime, the immune genetic algorithm is utilized and the necessary improvement is made in order to reduce the control points. The optimization model is constructed with the weights and the coordinates of the related control points as the design variables. The appropriate constraints are set. The objective function of this optimization problem is set to minimizing the maximum value among the relative difference between the typical data of the given characteristic curves and the corresponding ones of the fitted characteristic curves. A series of typical characteristic curves of the full-scale hull form representation instances using this method indicate that it is feasible and can satisfy the requirements of the engineering design. On the basis of this method, it is hoped that the data for the hull form design can be reduced and the flow field information can be considered in the preliminary stage of the hull form design.

DEFINITION AND PROPERTIES OF NURBS CURVE AND SURFACE

Definition of B-Spline Basis Function

Let $U = \{u_0, \ldots, u_n\}$ be a nondecreasing sequence of real numbers, i.e., $u_i \leq u_{i+1}, i = 0, \ldots, m-1$. The $u_i$ are called knots, and $U$ is the knot vector. The $i$th B-Spline basis function of $p$-degree, denoted by $N_{i,p}(u)$, is defined as (Piegl and Tiller, 1997),

$$N_{i,p}(u) = \begin{cases} 1 & \text{if } u_i \leq u \leq u_{i+1} \\ 0 & \text{otherwise} \end{cases}$$

$$N_{i,p}(u) = \frac{u - u_{i,p}}{u_{i+1} - u_{i,p}}N_{i-1,p}(u) + \frac{u_{i+1} - u}{u_{i+1} - u_{i,p}}N_{i+1,p}(u) \quad (Eq. 1)$$

$$N_{i,0}(u) = 1 \quad (Eq. 2)$$

Definition of NURBS curve

A $p$th-degree NURBS curve is defined by

$$C(u) = \sum_{i=0}^{n} \frac{\sum_{j=0}^{n} N_{i,j}(u) \omega_j}{\sum_{j=0}^{n} N_{i,j}(u)} P_i \quad 0 \leq u \leq 1 \quad (Eq. 2)$$

Where the $\{P_i\}$ are control points (forming a control polygon), the $\{\omega_j\}$ are the weights, and the $\{N_{i,j}(u)\}$ are the $p$th-degree B-Spline basis functions defined on the non-periodic (and non-uniform) knot vector $[0, u_0, \ldots, u_{i-1}, u_i, 1, \ldots, 1]$ (Piegl and Tiller, 1997).