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Application of knowledge-based engineering in ship structural design and optimization

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ABSTRACT

This paper presents an application of knowledge-based engineering in containership cargo tank structural design and optimization. Ship design is such a complicated multi-discipline task that design experiences and examples are indispensable. In this proposed knowledge-based system, experiences of design experts, design rules and successful previous designs are stored in the knowledge base. In the design process of new ship structures, the relevant knowledge are automatically distracted from knowledge base and executed together with the knowledge reasoning technique. Both design rules method and Interpolation method are introduced into this system. The design results fulfill the design constraints and requirements, therefore design errors and mistakes can be avoided. What's more, design cycle can be reduced significantly. So it can be an appropriate way applying knowledge-based engineering in ship structural design. What's more, Finite Element Method is employed to carry out the strength analysis, and reliability analysis is performed with Monte Carlo Simulation by introducing uncertainty of design variables under seawater corrosion.

1. Introduction

Computer-aided design (CAD) has played an important role in many areas with the rapid development and wide use of computers. Traditionally, ship design and research was carried out with human labor, which is not only time-consuming but also error-prone. So, it is necessary to introduce computer aided design into modern ship design. As demonstrated by Kim et al. (2012), CAD has taken roots in ships and offshore structures design in the past decades, and we have witnessed the applications not only for visualization purposes but also for other analytical purposes (e.g. basic structural form design, configurational design, design of final dimensions, simulation of motion characteristics, structural form design with outfitting and machinery items, propulsion system design with/without rudder, bulkhead arrangement design, and detailed layout designs, design of required plate sizes and thickness for production, design of heating pattern for welding and joining, material requirement planning and scheduling, and work assignment for technical workers, etc.). Proved to be so successful, knowledge-based engineering (KBE) has now become one of the most active branches of intelligent design in CAD, especially in the mold design engineering, automobile manufacturing industry and so on Zhao (2002). For example, Kulon et al. (2006) developed a KBE design system which generates forging molds directly by contours of parts. It integrates all of the mold design process, and users just need to enter the part geometry, materials and other information. Besides it achieved user interaction through network access, greatly improving design efficiency; Chapman and Pinfold (2001) came up with an automobile structural design and analysis system. This system allows the user to easily adjust the structure and assess both strength and economics in the design process, and any duplication of modeling is avoided. Finally the system derives the structural design with minimum cost while fulfilling the strength requirements.

The ship design is a complicated task which is multidisciplinary and multi-objective in nature, and it largely depends on designers' experience. Designers need to consider a number of competing aspects in ship design. So it is necessary and applicable to develop an expert system to cope with this tough task. Many people have made attempts in KBE application. For example, Chen et al. (2009) successfully achieved hull deck design with the knowledge-based engineering; Lee (2006) studied the maneuvering of damaged military vessels with knowledge system. He found that the ship can maintain good floating posture by adjusting the ballast, which enhances the chances of human survival. This system can be a useful tool for the ship operators to practice maneuvering of ship. Cai et al. (1997) studied midship section design system by dividing cross-section into several typical modules. Through the use of standardized rules knowledge, expertise, and a typical cross-section databank, they obtained the cross-section with minimum area.

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Nomenclature

L_{pp}	ship length between perpendiculars (m)
D	moulded depth (m)
B	moulded breadth (m)
d	draught (m)
C_b	block coefficient
s	space between beams (m)
h	deck calculation of pressure (m)
l	beam span (m)
W	minimum section modulus of beam (cm^3)
V	speed of ship (kn)
K_L	coefficient of high strength steel corresponding to longitudinal strength
K	coefficient of high strength steel corresponding to local strength

An extensive survey of challenges in current ship and floating structure design and analysis is made by Sharma et al. (2012), and the following challenges remain active: to develop novel approaches to extract design and production information from previous designs and use them intelligently in the new design and production schemes, to develop comprehensive functional design approaches, etc.; to apply the modular approach in the ship/floating structure design with real concept utilization, industrial participation and applications; integration of disciplinary simulation tools into complex engineering environment of CAD/CAM/CAE/FEM/CFD, integration of different geometric models; to develop integrated computational approaches in CFD, FEA and manufacturing simulation based upon input geometric definition and so on.

This paper discusses how to apply methods of knowledge-based engineering in containership's cargo block structures design, and integration of design and analysis. Thus some of the challenges mentioned above are addressed in this paper, e.g. the methods to extract information from previous designs and use them in the target ship design, modular approach (standard sections or bulkheads) in ship design, and integration with FEM tools based on geometric model information. The performance of hull structural design is improved with the help of KBE. Additionally, reliability analysis is carried out with FEM by introducing uncertainty of design parameters, and conclusions are made by comparing results from both design rules method and Interpolation method. The aims of this paper are to develop a knowledge-based engineering system by the acquisition of design knowledge and pervious designs, to improve design efficiency and quality, and to discuss the influence of design parameters uncertainty on the structural performance.

2. Knowledge-based engineering

Knowledge-based engineering is a kind of artificial intelligence technology, and it uses the principles and methods of artificial intelligence to address difficult problems. The core of knowledge-based engineering is to integrate professional knowledge, domain knowledge, users' maturity design experience, the choice of design parameters based on experimental data, material data, users' feedback, and relevant design standards and norms into the design of software through the logical judgments and deduction, achieving product intelligent design (Helvacioglu and Insel, 2003). A concise definition of KBE is given by Kim et al. (2012) as follows: KBE has roots in computer aided design (CAD) and knowledge-based systems and from early success as a support system for a design engineer within the context of product design to the basis for generative design, it can have a wide scope that covers the full range of activities related to Product Lifecycle Management (PLM) and Multidisciplinary Design Optimization (MDO). The scope of KBE includes design, analysis, manufacturing, and support.

As demonstrated by Zhou et al. (2007), knowledge-based engineering connotation includes: knowledge acquisition, knowledge representation, knowledge reasoning, with its emphasis on reusing product design knowledge, design experience and other kinds of knowledge in design, developing new and optimal products at the top speed.

Knowledge acquisition refers to acquiring knowledge from knowledge sources, such as design expertise, design standards, product specifications, design experience and successful precedents, etc. Fig. 1 shows a general approach of knowledge acquisition.

Knowledge representation refers to expressing problems and storing knowledge in a computer-interpretable representation, which can facilitate computers to take advantage of the knowledge base and solve complicated and difficult problems. Simply speaking, knowledge representation translates human language into computer language (Zhou et al., 2007).

Knowledge-based reasoning refers to the deductive thinking process which is deducing another judgment from judgment known according to a strategy. Designers express the product knowledge base including expert knowledge, experience knowledge, specifications and precedent through knowledge-based engineering to guide designer in the design process. The reasoning methods include rule-based reasoning (RBR) and case-based reasoning (CBR). The method of RBR is mainly used for specific parameters based on knowledge advisor and knowledge expert work system. The method of CBR is used for product and part design similar with previous design cases based on product knowledge template.

In this paper, CBR and RBR are both employed in ship structural design.

The user-friendly interface provided by the software system helps users export and import design information and manufacture information to achieve a joint of deliberation of human–computer to address problems, and the design process of knowledge-based engineering is illustrated in Fig. 2.

The ship structural design system based on KBE includes user interface, knowledge base, and inference engine. The user interface provides user a quick search and check of knowledge

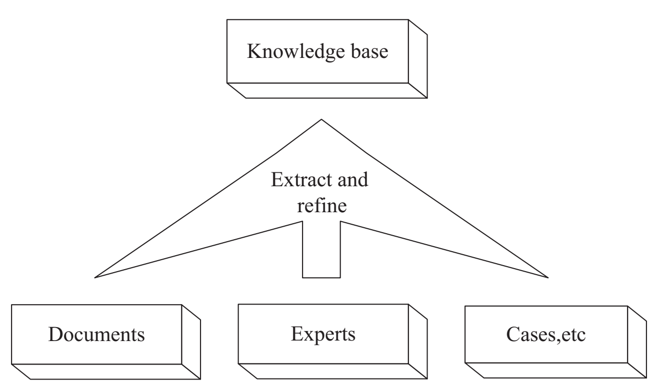

Fig. 1. Knowledge acquisition.