A User-Oriented Interactive Model for the Conceptual Design of Bulk Cargo Ships

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Abstract

This paper describes a design model for the conceptual design of ships. Existing design models have problems such that their operating mode of batch versions cannot reflect the design procedures in reality. Reliability of the results is low because the performance estimations are based mainly on empirical formulas. To improve the problems of existing design models, a new design model has been developed. The new model consists of an interactive user interface, a database of main engines, a database of particulars of existing ships, and ten modules for performance estimations. To develop such a user-oriented system, the concept of graphical user interface (GUI) is adopted.

1. INTRODUCTION

Ship design has the characteristic that every ship should be designed separately. Because ships are tailor made, every ship is different. Only one ship is ever produced from one design. The shipbuilding industry is at an extreme in which it needs a flexible manufacturing system. In particular, inquiry design or conceptual design must be done within time and data constraints if it is to survive in keen competition.

During the conceptual design stage, designers must prepare alternative designs which satisfy the shipowner's requirements. The technical performances of each alternative are analyzed and compared. The designs without technical problems are further considered in economic terms. Measures of merit for shipowners are considered simultaneously with the shipbuilder's profit.

Designs should be finished within a limited time interval. To overcome this difficulty, ship designers have been interested in the development of a computer system to accomplish the conceptual or initial design rapidly and exactly [1,2,3]. To date, most of existing systems

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for this purpose have been developed outside Korea. However, there have been some recent efforts to develop such systems within Korea [4,5].

As the conceptual design is the initial stage in designing a ship, a designer should not only work with his creativeness but also consider factors which affect the final design. A computer system which supports the conceptual design must have a design model to help creative design activities. It must also have the flexibility to adapt to varying circumstances. Because most of existing conceptual design systems are executed in batch mode, they are not flexible. They heavily rely on empirical formulas, so that resulting estimations include noticeable errors. For example, an empirical formula which has been developed based on old ship data cannot forecast the trends toward weight reductions according to the application of new technologies.

This paper explains the development process of a new conceptual design model for ships intended to solve the problems of existing systems. Main contents and results are as follows:

- Development of an interactive design module which supports the 'trial and error' method that is practiced in shipyards.

- Development of databases to support the design model. User requirements for the databases are surveyed and the databases are implemented through the conceptual design and the logical design stages. Databases with particulars of existing ships, hull forms, and main engines are constructed.

- Development of a graphical user interface (GUI) to improve the efficiency of the trial and error method and the interactive design model.

2. DESIGN MODEL

2.1 Framework of the Design Model

A design model can be regarded as a computer representation of the design process and design methods of an application domain. The model enables users to simulate the design process. Therefore, the performance of a design model is dependent on how well design processes and real world methods are represented in the model.

Different design sequences are followed by different designers. Different design methods are applied according to differences in design environments or designer's experiences. Also, it is not easy to modify the developed design model once it is completed. Design of such a model should contain as many factors as possible.

The design model of Figure 1 has been developed through discussions with designers of four Korean shipyards. The difference in design methods of each shipyard is considered. The interactive design model has 'back tracking' functions at each principal design stage in order to support the method of design by 'trial and error'. To estimate the ship's performances, the design model is connected to the databases. Data items can be scanned and extracted from the databases. The next section describes the principal modules which constitute the design

Table 1: Input data for the owner's requirements module

Primary Input Data	Optional Input Data
-Type of ship	-LBP
(Bulk carrier, Tanker)	-Breadth
-Deadweight	-Depth
-Cargo hold volume	-Draft
-Design speed	-Cb

model, BASCON.

2.2 Functions of Individual Modules

The functions of the principal modules that constitute the design model are as follows:

1) **Module for shipowner's requirements:** This is the module that reads the basic data needed to design a ship. The data consists of a set of shipowner's requirements. Categories of input data are divided into the primary input data and the optional input data as shown in Table 1. The primary input data must be supplied by the user. Supply of the optional input data is optional. Default values will be used automatically for data items which are not supplied.

2) **Mother ship selection:** This module shows a list of similar ships. The similar ships are searched for in the database containing ship particulars, which are categorized according to ship type and required deadweight. If more detailed information is required by a user, the module retrieves the whole performance data for a particular ship from the database. For example, a midship section of a bulk carrier, which is retrieved from the database, is displayed in Figure 2. When the user selects a ship from the database as a reference ship, its data is stored as the mother ship data. This data is then used in the later estimation of the performance for the target ship. Because this design model is developed based on the concept of similar ships, users must select a mother ship from the database.

3) **Determination of Principal Dimensions:** If the value of some of the principal dimensions are supplied as the primary input data, the dimensions are then fixed. If values of the principal dimensions are not supplied, this module gives tentative values estimated from empirical formulas. Users should then determine a set of principal dimensions through the comparison with data from the mother ship.

4) **Selection of optimal main engines:** Functions of this module include prediction of resistance and propulsive performances, and data query from the main engine catalog database. The procedure of main engine selection is as follows. Estimation of the resistance and propulsive performances [6], estimation of the delivered horsepower (DHP), primary selection of candidate engines from the engine database considering both sea margin and engine derating, and then secondary selection of a reduced number of candidates. Information about the candidate engine models like layout diagrams, derating ratio, RPM, and SFOC (Specific Fuel Oil Consumption) is displayed.

If one engine model is selected based on the displayed information, an operating point is found from the layout diagram where the DFOC (Daily Fuel Oil Consumption) is minimum. In this process, the bisection method [7], one of optimization methods, is used. The user finally selects one model considering DFOC, engine weight, engine size, cost, and accessaries such as vibration damper and balancer. Figure 3 displays characteristics of one engine model.

In the previous design models, the MCR (Maximum Continuous Rating) of a main engine is determined by simply including sea margin, engine derating, and shaft efficiency to the estimated DHP. This figure usually does not match with any model manufactured by engine makers. Previously, this discrepancy propagates to other design calculations in these old models. For example, to estimate engine weights and engine room lengths, empirical formulas based on MCR values are used. This results in an inaccurate estimation of light ship weight and required ship length. The old design models have reliability problems because they do not use the database of engine catalogs. The new module solves these problems by applying the data of real engines such as engine power, RPM, SFOC, size, and weight.

5) **Compartment subdivision:** This module subdivides the ship into 4 to 5 divisions longitudinally; stern area, engine room, pump room (it works only for tankers), cargo holds, and bow area. Frame space and the number of frames are estimated for each division. The length of the engine room is determined by considering the shaft generator, propeller shaft, and passage way. The length of the bow area is determined by considering the minimum length required by the classification rules. The cargo hold area is further subdivided by consulting the mother ship data and the manufacturing standard of the shipyard.

6) **Weight estimation:** Light ship weight is estimated by adding four groups of weights; hull weight, engine weight, outfit weight, and electrical weight. Two methods can be used to estimate the hull weight at the initial design stage. One is to use empirical formulas, the other is to use data of similar ships. Although empirical formulas are effective when data of similar ships is not existent, the estimation results from the formulas are sensitive to the original data used to construct the empirical formulas. The arrangement of the ship, material used, and building year are important factors. Also the estimation errors are generally large with empirical formulas. The accuracy of an estimation can be improved if data from similar ships can be used. In this module, formulas recommended by DNV and Lloyd are used where the steel weight is estimated from existing ship data. Outfit weight is also estimated from existing ship data. Weight of the main-engine is estimated from the module for main engine selection.

7) **Hull form variation:** In order to obtain an adequate hull form which satisfies the shipowner's requirements on cargo capacities and has good hydrostatic characteristics, one is chosen from a database of existing hull forms. Hull form variation is performed afterwards. Hull form variation is done according to the Lackenby method [8]. Dimensions of LBP, B, D, T, Cb, and LCB should be satisfied. Modified hull form is used in the hydrostatic calculation module. In order to obtain the precise sectional shapes of cargo holds, the variation of hull form near the bow and stern is considered. The hull

form offsets at positions of transverse bulkheads are obtained by interpolation method. See (9) below for details.

8) **Design of midship section shapes:** Figure 4 shows an example of a definition of the midship section shape for a double-side and double-bottom tanker. The module determines the shape of the midship section based on the data of similar ships stored in the databases.

9) **Sectional shapes of cargo holds:** The sectional shape of a cargo hold near the midship maintains its shape inside the parallel middle body, but near the bow and stern the shape changes according to variation of the hull form. To obtain precise capacities of a cargo hold, an exact shape definition of cargo sections is needed. In this module, longitudinal variations of sectional shapes are defined by the hull form variation module, and the data of midship section is determined by the midship section design module, as shown in Figure 5.

   The required minimum tolerance between the side shell and end point of the double bottom is obtained from the empirical knowledge on manufacturability, for example, the minimum tolerance for welding. If, at some point, the minimum tolerance between the double bottom and the side shell is too small, a kunckle point is inserted. The position of the kunckle point can be modified. Any sectional shape of cargo holds can be displayed by graphics function. After the sectional shapes of cargo holds are decided, they are used for volume calculations.

10) **Calculation of volume capacity:** Volumes of cargo holds, ballast tanks, and the engine room are calculated by combining the hull form data, compartment division data, and sectional shapes of cargo holds with the hydrostatic calculation package.

3. DATABASES

In ship design procedures, data of existing ships are heavily used except for the design of a totally new concept ship. As the technological development of a ship design accelerates, the role of the management of existing ship data is important. Designers should find out the design data of similar ships which have been built recently. The data of similar ships should be analyzed and structured. The database must be implemented. If the database is utilized, the quality of the ship design can be improved. Also the time interval of a ship design can be shortened .

In this paper, the database of existing ship particulars, hull forms, and main engines have been implemented by using the ORACLE [9] relational database management system. The databases can be accessed via Pro*FORTRAN [10] from the design model BASCON. Normal database queries can be executed through the SQL*Plus, a language of ORACLE. Designers can scan, extract, and modify the data of similar ships from the databases.

3.1 Database Design and Implementation

An analysis has been performed to identify the demands of database users. Conceptual and logical design of the database is followed by the implementation. The implementation

Table 2: Database schema for the particulars database of existing ships

Entity, Relation	Attribute
SHIP_ID	SHIP_ID
IDENT	SNAME, STYPE, OWNER,···
P_P	LOA, LBP, B, D_MLD, ···
LENGTH	HOLD, FORE, AFT, ER, ···
WEIGHT	WHOLD, WER, WMACH, ···
CAPACITY	NHOLD, NDKS, VOLG, ···
SPEEDPOWER	VS, VS_RMCR, METYPE, ···
ARRANGE	NFRAMES, FRAMES, ···
CARGO_HAND	HATCH, CRANE, LDECK, ···
CREW	CAPTIN, DKH_AREA, ···
PNT_PROT	P_SHELL, ANODE, ICCP, ···
EQUIP	ANCR, MOORRP, WINDL, ···
VENT_FF	VENT_HOLD, VENT_ER, ···
AUXMACH	AUXBL, EXHBL, DGME, ···
NAUEQUP	RADIO, LBRADIO, RDF, ···
LIFESAVE	LB, RB, WINCH, DAVIT, ···

process of the database of ship particulars is explained as follows:

1) **Analysis of user's demands:** Data items of similar ships are identified and grouped. Logically-related items are grouped together from the point of ship designers. Because the grouping and numbering schemes are different in each shipyard, deletion of overlapping items and inclusion of new items are necessary.

2) **Conceptual design of the database:** 18 entities are identified as Table 2 from the semantic relationships of 250 data items. Since there is a functional subordinate relation between attributes of the ship-ID entity and attributes of the other entities, the relation between the ship-ID entity and the other entities are defined as many-to-one relation.

3) **Logical design of the database:** To design the relational database schema, candidate relations are identified by investigating the dependence among entities. Overlapping relations are discarded.

3.2 Construction of the Database

Three databases have been constructed from main particulars of existing ships, hull form data, and main engine data. The data is supplied from 4 major shipyards in Korea.

1) **Main particulars database:** It contains data of 20 ships, bulk carriers or tankers.

2) **Hull form database:** It contains hull form data of 7 bulk carriers. Each of them represents a typical hull form of different size ranges.

3) **Main engine database:** It contains about 130 data sets of B&W or Sulzer engines.

The number of input data in these databases is small at present. A large number of ship data can be put into these databases at the time of shipyards operation. The database schema and utility functions can be used without modification.

4. GRAPHICAL USER INTERFACE (GUI)

Nowadays more emphasis is given to the good GUI designs, because a user can handle the computer system or applications more efficiently and friendly through it. A GUI is developed for this design model BASCON with the domain C language of Apollo workstation and the M-PLOT [12] as graphic tools.

The developed GUI helps users to avoid input errors because it provides an easy input mechanism. It helps to visualize the calculation results and various output from each module. For example, the GUI sends an error message with a warning sound if the user inputs a wrong data such that the anticipated input data is a positive number with a fixed range and the input data is outside of that range. The GUI gives textual warning messages too. Also, the GUI provides textual output and pictures simultaneously. The user can judge the result of the design more quickly and correctly.

A new version of GUI which is independent of hardware platforms is under development. It uses the OSF's Motif [14], which is based on the de facto standard window system, X-Window system.

5. CONCLUSIONS

A new design model for the conceptual design of ships is developed, which is based on an analysis of shortcomings of the existing conceptual design systems. The newly developed design model provides an interactive working environment and supports the actual design process more smoothly. The quality of design work can be improved because the data of similar ships in databases gives an accurate performance estimation. Furthermore the GUI enables the user to handle the system more friendly. The summary of the main results of this paper is as follows:

- Databases of existing ships have been constructed. By applying the databases, the accuracy of performance estimations is improved.
- The practicing technologies of shipyards such as the main engine selection, selection of the engine room length, and determination of the sectional shape of the cargo holds have been applied. These improvements were possible through a close cooperation with shipyard engineers.
- The interactive design model reflects the design concept of the practicing engineers.
- Ease of use is achieved due to the GUI environment.

Further modifications and improvements will be continued in this design model. Future research topics are as follows:

- Stability calculation module.

- Design module for container ships.
- Hardware independent Motif version of the GUI module.
- Application of an expert system to guide novice designers.
- Interface or integration with the other design systems.

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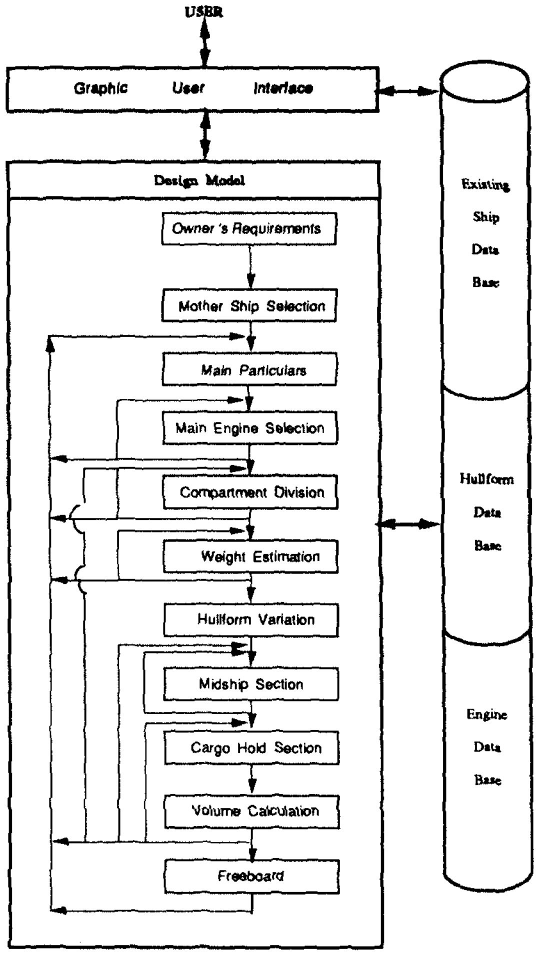

Figure 1: Design model and system configuration

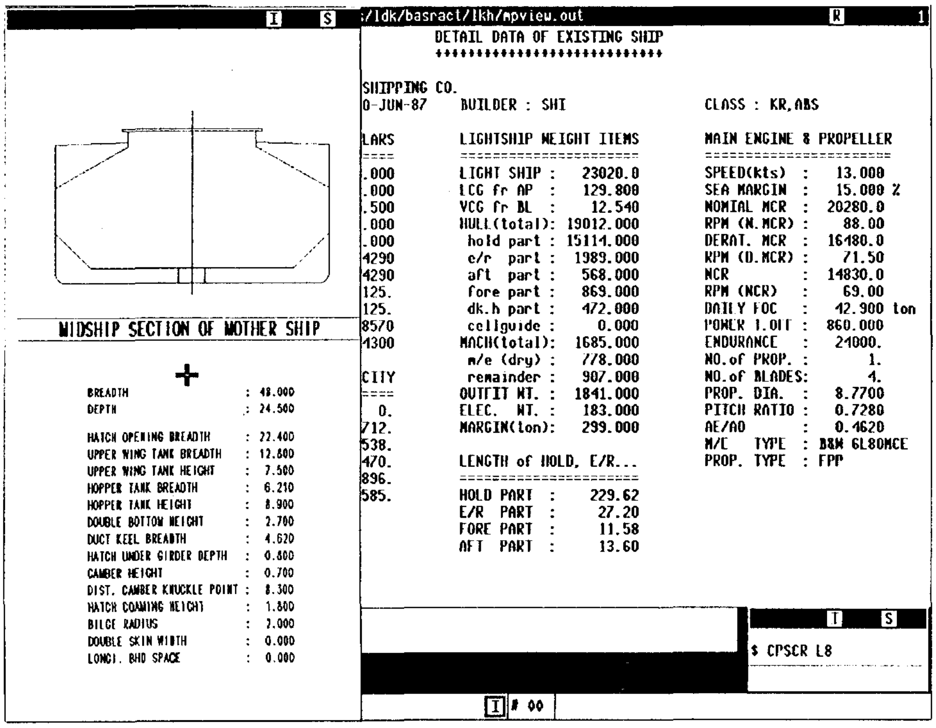

Figure 2: Midship section of a ship selected from the database

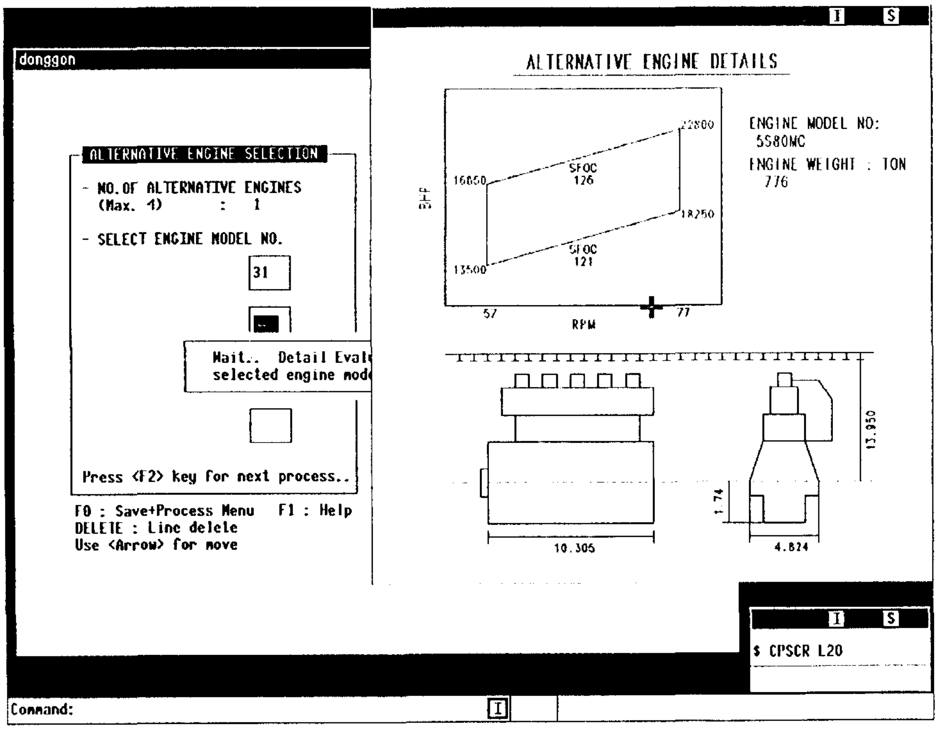

Figure 3: Display of characteristics of a main engine

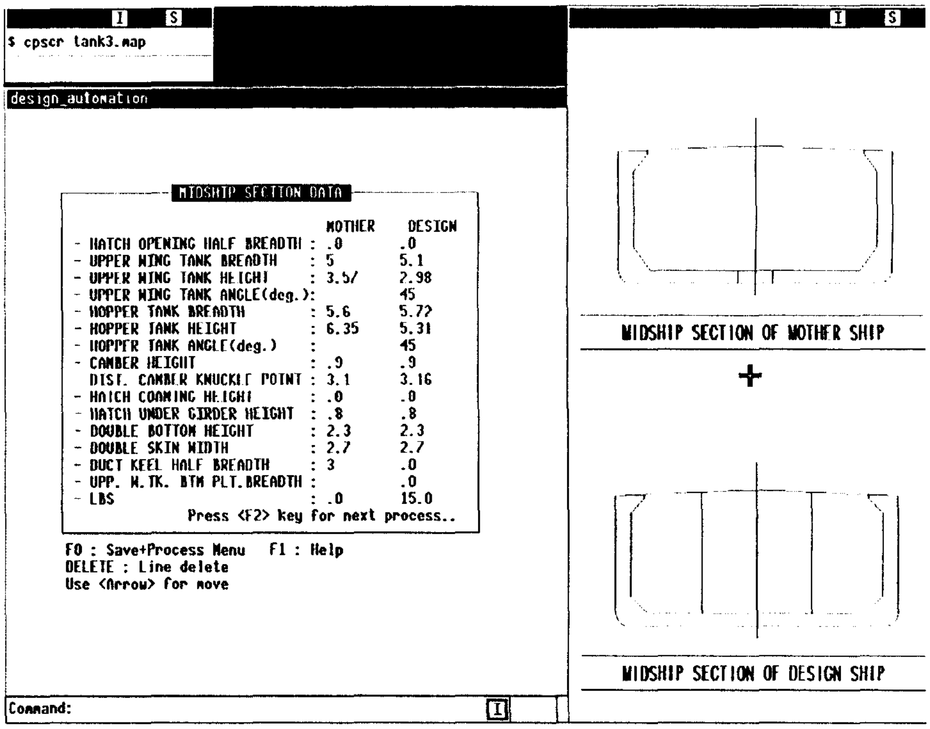

Figure 4: Determination of the midship section for a double-sided tanker

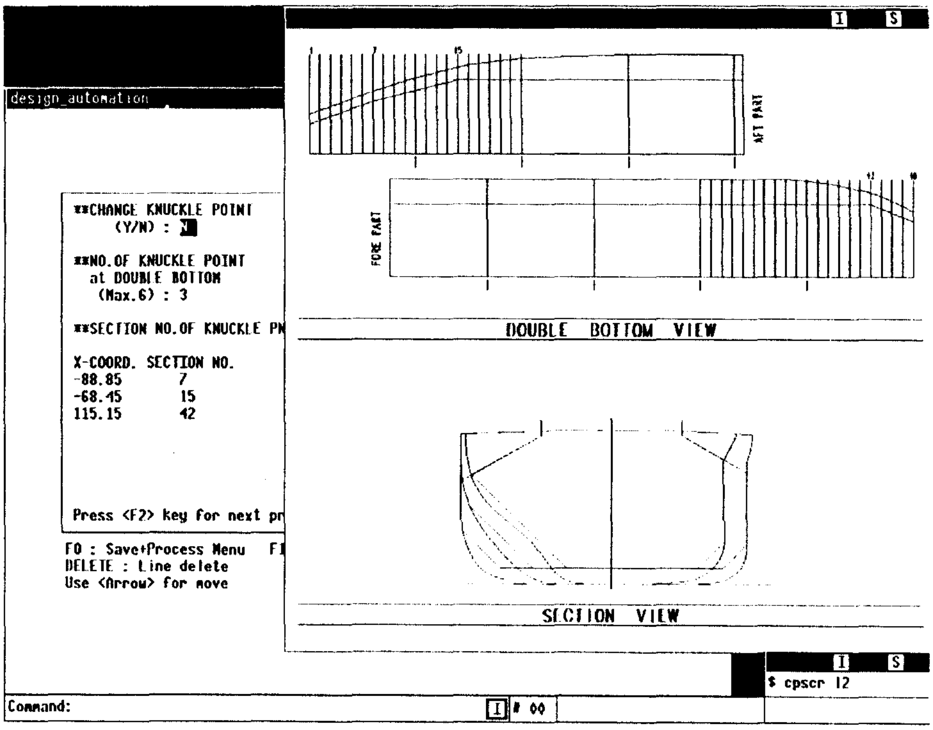

Figure 5: Display of sectional shapes of cargo holds