Development of a system for computer-aided design of ship hulls

M. Ventura*, C. Rodriguesb, C. Guedes Soares*
*Unit for Marine Technology and Engineering, Instituto Superior Técnico, Universidade Técnica de Lisboa, Av. Rovisco Pais, 1096 Lisboa, Portugal
bEstaleiros Navais de Viana do Castelo, 4900 Viana do Castelo, Portugal

Abstract

The paper describes a software system, developed to assist hull design of ships with the emphasis in the link between the preliminary design and production. It includes modules for preliminary design, hull surface definition, generation of hull structural elements and management of information for production. The modules of preliminary design are oriented to assist the designer in the definition of the midship section scantlings and in the production of hull classification drawings. The system has tools to generate the hull shape and includes capabilities of curvature analysis and fairing of lines, intersection of the hull with decks and with conical elements. A module for the definition of seams and butts and for the development of plates is also available. The system was developed to run on personal computers so that it can be attractive to small and medium shipyards with limited computing power. The modules of hull structures were developed using the graphics engine of a commercial drafting package, and they allow the fast generation of structural elements by the use of parametric components.

1 Introduction

A software system has been developed to work on personal computers assisting the design of ship hulls and the structural elements. The system was conceived to support the work that is conducted after the preliminary design of ships up to providing the information for production.

The CADESNAV-PC system has been developed for Estaleiros Navais de Viana do Castelo, a shipyard in the north of Portugal, which wanted to replace its in-house system operating on a mini-computer by a system operating on compatible
personal computers. The specification of the system followed closely the existing one and some of the solutions adopted resulted from the existing practices of the shipyard which should be reflected in the system.

**Figure 1** Organisation of the CADESNAV-PC system.

The system is composed of one module to define the hull geometry and another one to define the ship structure and to transmit that information to the production department in an appropriate way.
The first module has as input the hull geometry defined by the offsets of the transverse sections as produced in the preliminary design. It has tools to manipulate and visualise the data as well as to improve its quality through fairing.

The second module starts from the definition of the hull surface and allows the design of the ship structure, having a database that stores all structure components, not only with the shape but also with additional information for production such as welding data, for example.

The database is interfaced by a management module that produces different listings of information as required by different departments and workshops of the shipyard.

2 Module for Hull Shape Definition

In this system, the hull surface is represented by a grid of space curves. The curves are modelled by cubic splines [1] and the whole information is stored in a Geometry Database [2].

The initial input consists of a set of boundary lines and transverse sections (Fig. 2) defined by 3D coordinates of points, manually introduced or digitised from a preliminary body plan. The boundary lines considered are the flat-of-bottom and flat-of-side tangency lines, the stem and stern profiles on the centreline, the contour of the main deck at side and the knuckle lines, if any.

The input points are first fitted by cubic splines. The curvature of the resulting curves can be evaluated by porcupine representations (Fig. 3), allowing the
detection of undesirable inflections even on a normal sized computer monitor. The curves can be faired on a semi-automatic basis, between user selected points, using either a least square approximation or an algorithm based on piecewise circular arcs.

The intersection of each boundary line with every transverse section is then computed, and the points obtained are inserted in both curves. These inserted points define, on the respective curves, the limits of continuous segments. Depending on the type of boundary lines, the connection between two segments is made either continuous, with an imposed tangent value, or is considered as a knuckle.

After processing the transverse sections, the waterlines and buttocks are computed by intersection of the existing curves with the boundaries and the sections and processed as described above. The process is iterative, and can be repeated until the designer is satisfied with the quality of the model, both in terms of fairness and coherence.

Once the model is concluded, any planar curve on the hull surface resulting from the intersection of the hull with a plane either parallel to one of the reference planes (Fig. 4) or inclined, can be computed and exported to any CAD system compatible with the DXF [3] file format.

As the openings normally found on a ship hull, like hawse pipes, thruster tunnels and scoops, are in general obtainable from the intersection with a cylindrical or conic shape, the system computes these intersections (Fig. 5). The user must only define the conic shape by two points on the axis line and the corresponding circular radius.
The distribution of the plates on the hull shell is defined by the grid of seams and butts. First the main butts are generated, similar to normal transverse sections. In each ship block the seam lines are then generated by inputting the off-sets on the longitudinal centerline plan. The system projects these lines over the shell surface obtaining the correct 3D representation. Secondary butts between the seams can be obtained if necessary. All the seams and butts are subjected to a processing and have an internal representation similar to the hull lines.

3 Module of Hull Structure Design

3.1 Preliminary design

Since the minimum scantlings of the midship section required by the Classification Societies are constant along about 40% of the length of the ship, their definition is one of the first steps of the basic design, and of great importance for other tasks such as the estimation of the hull steel weight and the elaboration of a preliminary specification of materials (plates and profiles), which are reasons enough to welcome any contribution to speed its turn around time. The speed up of the midship section scantlings definition reduces the response time of the designer, and is also a contribution to the quality of the design, due to the larger number of technical solutions that can be generated and evaluated.

The first approach to the dimensioning of the basic structural elements is made generally based on the requirements of the Classification Societies. Since software for the basic dimensioning of components has been made available by various Societies, it was defined as target of this module to start from there and to try to reduce the time of production of the classification drawings and the related tasks. To summarise, the goal of the module that concerns preliminary design, is to assist the designer during the phase of the midship section scantlings definition, producing simultaneously the corresponding classification drawings and creating data that can be used in other tasks such as weight estimation.

The module is based on the following general characteristics [4]:

- Quick generation of a model of the midship section, geometry and structural elements (Fig. 6)
- Use of elements, both plates and profiles, that contain not only dimensional definition (length, thickness, etc.) but also geometrical data (section area, inertia and centre of gravity) as attributes
- Interactive insertion and edition of all the elements
- Computation of the global midship section characteristics at any time

Regarding the production of the classification drawings, the system provides the following capabilities:
292 Marine Technology and Transportation

- Parametric drawing of the midship section moulded shape, based on typical dimensions such as breadth, depth, rise-of-floor, bilge radius and deck camber, to generate sections in the absence of a body plan
- Parametric drawing of structure elements such as profile sections and standard brackets and also of openings, manholes, profile cutouts, drain holes, selected on graphical menus (Fig. 7)
- Drawing of stiffeners with automatic adjustment of the length to the reinforced plate contour
- Automatic dimensioning of plates and profiles
- Automatic insertion of the table with the results of the last computation of the section characteristics
- Automatic generation of several drawing annotations and insertion of welding symbols

As a complement to the preliminary design work, the system also assists the designer in the generation of parts and materials lists and in the computation of areas, weights, and centre of gravity of components.

![Figure 6 Midship section model.](image1)

![Figure 7 Graphical menus.](image2)

3.2 Hull Design for Production

This module is organised to treat separately the structural elements, plates and profiles, belonging to the internal structure, which are planar, from those of the outer shell, which can be curved [5].
The system modules for the generation of the structural elements were developed to work in the AutoCad work environment in order to profit from its graphical engine. Any hull lines required may be obtained by interrogating the Geometry Database and directly imported into AutoCad without interrupting the work session. Routines to draw parametrically defined standard parts like brackets, or to insert openings, manholes, profile cutouts, drain holes, stiffeners, and so on were developed and are easily accessible from graphical menus.

The generated structural elements are stored in a Structure Database. The data is organised in a hierarchical order according to the assembly level and contains besides the geometrical description, data required for the management of production, such as the material specification, the fabrication sequence, the estimated production man-hours and the location of the storage parks.

The hull shell plates can be developed by the system, generating drawings defining the plate contour, the dimensions of the bounding rectangle and the lines of intersection with the frames and other plate girders (Fig. 8). Lines of iso-curvature can also be represented to assist the forming work. Profile bending drawings, containing the inverted curve and edge preparation can also be produced to assist the shop in the production of curved profiles [6].

The elements stored in the Structure Database can be retrieved to produce 3D block assembly drawings, to generate shop drawings, or to be interactively located in the raw plates, producing nesting drawings (Fig. 9). The information regarding the distribution of parts in the plates is fed back into the Structure Database.

### 3.3 Production management

The output of the system is not only given in the form of drawings. To manage the information required to produce and assemble the ship structure components, a series of lists are produced by the system, identifying the components of each
block, set or subset, listing the required materials, listing the processing sequence in the shop, accounting for the estimated and final man-hour required, etc.

4 Conclusion

A system has been developed to assist the design of ship structures and the planning of the fabrication process. The system operates in compatible personal computers in a local network and it uses as graphical interface AutoCad, a commercially available general purpose drawing package.

Although the development of this version is completed, several aspects of the system can and will be improved by continued testing and updating.

Acknowledgments

This system has been developed since 1991, being partially supported by a research grant provided by the Portuguese Ministry of Industry, through its financial program PEDIP.

References


