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A knowledge-based system for preliminary ship design for intact and damage stability in operation

SUMMARY

The paper presents some problems associated with the knowledge-based system development with special reference to stability of ships in both operational (intact) and damaged conditions at the preliminary stage of design.

INTRODUCTION

For many years computers have been frequently used as drafting and modelling tools in modern Engineering. However these mainly rely on both structural and numerical computation and do not provide a complete, end user friendly environment. There is a possibility to use the computers as a design medium where the concepts, ideas, judgements and experience can be represented in the form of symbolic non-procedural statements. Such an approach is known as Knowledge Engineering. Encoding knowledge in a logic-based manner to achieve its acquisition, representation, and manipulation, knowledge engineers intend to create design languages/environments which are, indeed, modelling knowledge-based systems.When these systems are used as computer programs they constitute a Knowledge-Based System (KBS) which is an important and interesting subfield of Artificial Intelligence (AI).

INTACT AND DAMAGE STABILITY IN GENERAL

Both the intact and damage stability still attract the attention of ship operators, designers and scientists who try to satisfy the design and operational requirements of regulatory bodies, shipyard standards or accepted good practice.The "stability" accidents constitute generally about 10% of the total number of all the accidents at sea but they belong to the most dangerous. It follows from the fact that they are very often associated with the loss of life, loss of cargo and/or pollution of environment. The damage stability is the most important measure of a ship safety in damaged condition not necessarily caused by a CRG accident (CRG : collision, ramming, grounding) [1].

A terrible example of both the loss of stability and poor damage stability is the tragedy of a Polish ro-ro ferry JAN HEWELIUSZ which sunk on the Baltic Sea in January 1993. There were both the first order and second order reasons which caused the preliminary loss of stability. For given weather condition/state of sea (wind,wave), loading condition (cargo distribution, ballast condition), ship technical reliability and crew ability the ship survivability was not satisfactory. There were a few reasons which occurred at the same time and did not let JAN HEWELIUSZ to safe her "life".

A detailed analysis of JAN HEWELIUSZ tragedy from both the design and operational point of view is going to be published by " Polish Maritime Review " too.

To analyse the JAN HEWELIUSZ survivability after the loss of stability the existing modules of the Integrated Ship Design System ISDS (see Fig. 2.) were applied. A modern approach to the ship design process was used for the ISDS system development. It eventually helped to predict the most dangerous situations when the risk of a stability accident is high. When using the system, it is the most important to be aware of the limitations which follow from the ship hull form, arrangement of internal spaces, cargo and ballast configuration (loading condition), external forces (wind, wave, current), and navigation (human factor) which have a decisive effect on a ship safety against stability accident.

It is very difficult to control a ship stability by the regulatory bodies regulations although the effort made by either the International Maritime Organization (IMO) or STAB conferences is very substantial. The nature of stability shows exactly the phenomenon of arising problems.

Both the intact and damage stability as well as capsizing should be considered as non-linear events. But there are still many problems within both the "pure" stability and survivability domain which do not allow to formulate the common stability criteria. From the analysis point of view the loss of stability and capsizing is the low probability event [2], [3], and very difficult to calculate. The existing stability criteria have been mainly obtained using the method of "trials and errors" and are based on simplified assumptions. The current stability criteria are too much related to the ship stability parameters and it is not enough to prove a good ship safety against the loss of stability. It follows from the fact that the loss of stability depends not only on the ship design stability characteristics but also on a few other factors as it is presented in Fig. 1. When the damage stability is considered then the arrangement of internal spaces should be taken into account too.

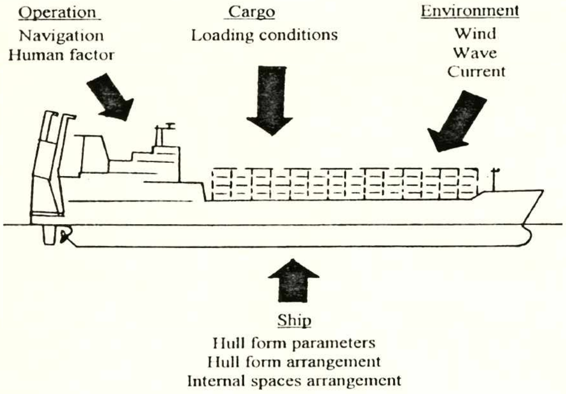


Fig. 1. Factors affecting the ship design stability characteristics

The most natural measure of safety is the probability which depends on many stochastically distributed values. It is a difficult task to find the way to calculate the probability of, particularly, non-linear events. A big effort must be done before new stability criteria based on both the probability of capsizing and risk analysis applied to the ship safety are going to be found. There are some partially successful applications of the probabilistic approach to solving the survivability problems. It mainly concerns the IMO regulations concerning the subdivision and damage stability. They are based on the probabilistic concept of survival [4] but there are still some difficulties concerning how to calculate the conditional probability of survival. There are going to be problems found when both intact and damage stability should be integrated.

To consider the ship safety is both very complicated and expert task indeed. Different aspects are interrelated. The practice shows that even the best design criteria separately for both stability and damage stability can not ensure the safety.This is why more attention must simultaneously be concentrated on all the ship safety components.

New tools must be developed to find each factor (see Fig. 1) contribution to the overall risk of capsizing when the loss of stability and poor damage stability can not secure the ship.

Before a new concept of the system for preliminary ship design for both the operational and damage stability was anticipated the system approach was applied to consider all the existing interrelations associated with the stability/survivability.

There are a lot of requirements concerning [5] :

- ship construction;
- physical characteristics of a ship;
- information available onboard and navigational aids;
- operation and navigation;
- professional qualifications of the master crew,

which must be taken into account not only when a ship is designed but also when a ship is in operation. Therefore the above requirements should be subdivided into the following categories from the practical point of view:

- design requirements;
- operational requirements.

Such a division was considered when the structure of new Integrated Ship Design System (ISDS) was accepted [5] to enable to take the operational aspects into account at the preliminary stage of design. Then the idea appeared to create two modules of the ISDS system entirely associated with both the operational and damage stability problems including the design and operational aspects together.

CONCEPT OF INTEGRATED SHIP DESIGN SYSTEM (ISDS)

Current computer aided ship design systems generally provide designers with a set of software tools to iteratively and imaginatively advance the design process. As systems of computer packages/programs they are generally design aids rather than design systems. They use the design knowledge together with processing routines in such a way that it is difficult to do substantial changes in the application software when there is a progress in design code. When the knowledge-based approach brought a possibility to separate the design knowledge from the logical processing, a vision of an "intelligent" design system appeared. The knowledge-based approach requires to codify some of the intuitive and implicit and expert rules of design that operate within the design process. The process of codification brings a lot of problems when an expert system is supposed to deal with very difficult design tasks.

The ISDS system has been constructed as a high standard "intelligent" ship design environment in the future and many possibilities were carefully considered.

The main features of the ISDS system are as follows [6]:

- ISDS system should be open;
- ISDS system structure should be hybrid-modular;
- ISDS system should include a common library of naval architecture methods;
- ISDS system should have a common library of analytical and numerical methods;
- ISDS system should give a possibility of the design assessment at each stage of design (conceptual, preliminary, detailed), but currently only in the case of intact stability/damage stability analysis.

The logical structure of the ISDS system is as follows:

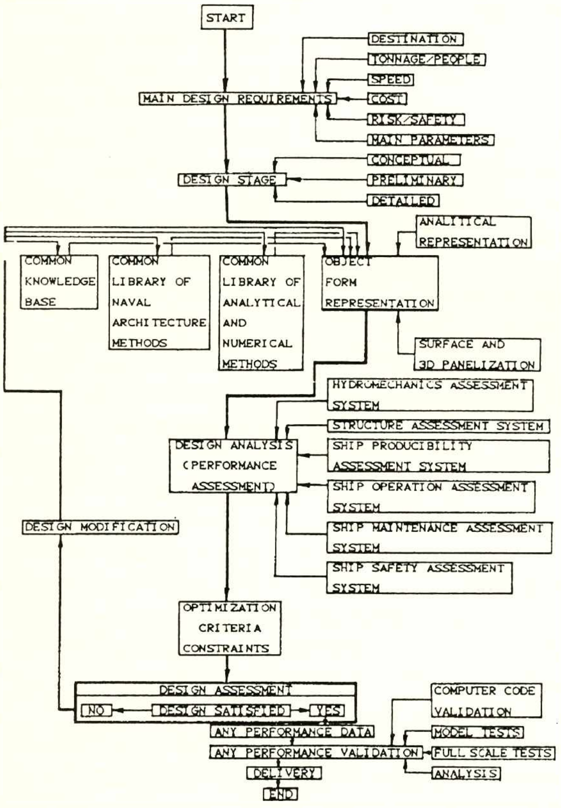


Fig. 2. Logical structure of the ISDS system

One of the most important aspects of ship design is to provide a sufficient degree of stability for intact ships and ships in damaged condition. The assessment of intact stability/damage stability according to the existing regulations, the intelligent arrangement of internal spaces, the cargo distribution and/or re-design of the hull form to provide improved safety are expert tasks indeed particularly at the preliminary stage of design. At the later stages when both the hull form and arrangement of internal spaces are fixed the ship stability safety depends mainly on the remaining components (see Fig. 1.) :

- operation;
- cargo;
- environment.

All the above elements are represented in the ISDS system by the sets of characteristics, for example, as follows:

- heading angle;
- loading condition (cargo distribution, KG value);
- wave characteristics;
- wind (wind pressure, wind direction).

The current structure of the ISDS system module for the stability assessment is as presented in the Fig. 3.

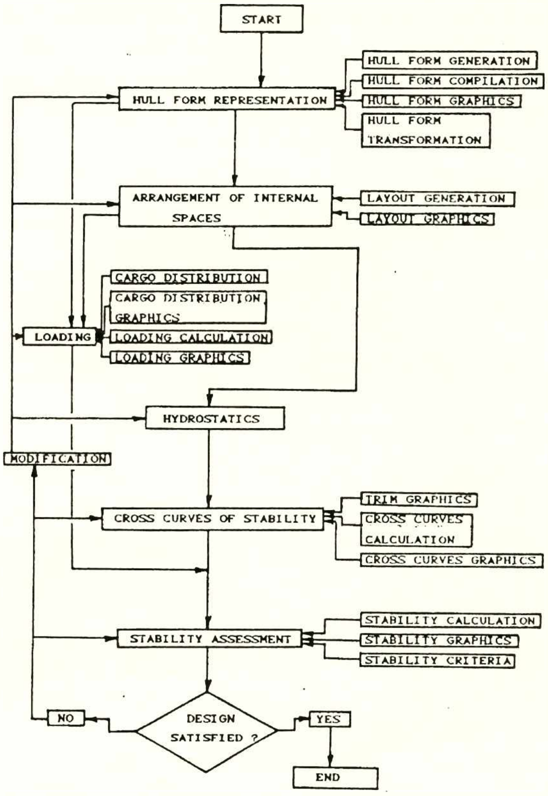


Fig. 3. Logical structure of the sub-system for preliminary ship design for stability

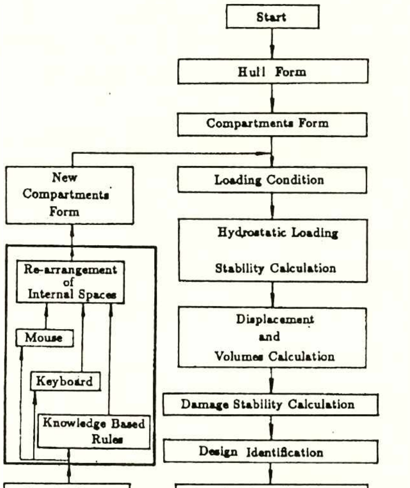


Fig. 4.Logical structure of the sub-system for preliminaryship design for damage stability

In Fig. 4 the logical structure of the sub-system for preliminary ship design for damage stability is presented.

The sub - systems should encompass the full range of activities associated with both the intact stability and damage stability of ships:

- hull form representation;
- hydrostatic calculation;
- arrangement of internal spaces;
- loading calculation;
- intact stability calculation in both the design and operational conditions;
- intact stability assessment;
- damage stability calculation at the design stage and in operation;
- damage stability assessment.

To obtain the ISDS system as an intelligent integrated design system it is needed to build into the system the knowledge and expertise of designers and operators as well as the requirements of regulatory bodies, shipyard standards and accepted good practice.

CONCEPT OF INTEGRATED SHIP DESIGN EXPERT SYSTEM (ISDES)

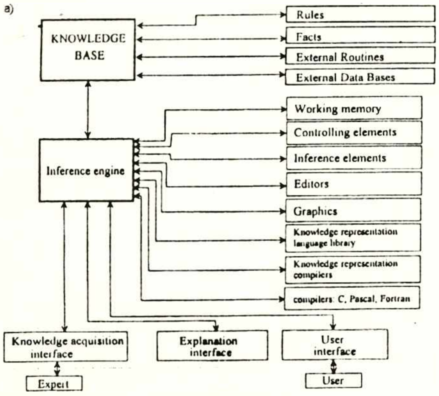
The traditional procedural approach used in computer aided ship design combines design knowledge and processing information in such a way that new advances in design code are difficult to incorporate without substantial re-programming. It can be easily overcome in the knowledge-based approach by an effective separation of the logical processing elements from the knowledge modules.Such an approach is extremely useful when we consider the ships safety where design knowledge is often both changeable and available experientially.

Generally expert systems are interactive computer programs which use symbolic inferential reasoning to deal with problems that are difficult enough to require significant human expertise for their solution.

One of the basic steps associated with the ISDES system development was establishing its structure and standards

(i.e. languages, environment and shell). The ISDES shell developed to deal with the design problem outlined above was constructed according to the structure that is common to many expert systems [7], [8], [9], [12], [13].

The ISDES shell structure is the next version of the Expert System for Preliminary Ship Design for Safety (ESPSDS) shell [10]:



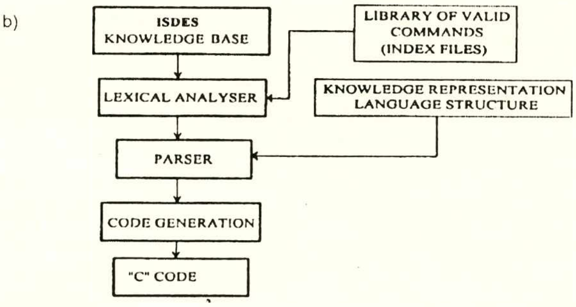


Fig. 5. Logical structure of the ISDES shell (a) and of the knowledge base compiler (b)

The main features of the ISDES shell are as follows:

1. Shell should be written in "C" language;
2. Shell should allow access to external routines written in FORTRAN, PASCAL and "C" itself;
3. Shell should use the KERNEL-based graphical capability;
4. Shell should provide possibilities to make calculations using mathematical and scientific functions like "C" itself;
5. Shell should include a knowledge representation language library to create a knowledge base;
6. Size of the knowledge base should be as big as possible.

HARDWARE AND SOFTWARE FOR ISDES

At the time of the ISDS concept development the choice of hardware was between the IBM PC/PS computers combined with the MS-DOS operational system and SUN microsystems with a UNIX based operating system, SUNOS. Taking mainly the computability of computer languages for the above systems into account, a decision should be taken to utilize a SUN microsystem as the basic central processing unit (CPU) for the ISDES. Currently because of many reasons the IBM/PS/PC workstations are applied to create the ISDES system. A SUN application is taken into consideration when the ISDES development is advanced.

SUNOS provides a very good user interface for the development of applications and the SUN workstations have a high speed processor which can greatly reduce the time taken for a program execution. The parallel computing (transputer technology) is considered to be used in the future too.

The ability of the windowing environment to run multiple applications by time -sharing the CPU is a very important factor of SUNs. Also SUNOS provides the necessary software tools for development of the ISDES system, e.g. FORTRAN, C, PASCAL, and PROLOG compilers together with a graphic primitives library (GKS, PHIGS).

Now IBM PC/PS workstations with 8-16 MB RAM and HDD 120-180 MB are used to develop the ISDES.

The software requirements have had the most important influence in the choice of the SUN microsystem for development of the ISDES. Therefore some difficulties have been found applying the IBM/PS/PC workstations.

There is a need for a graphics package which could be used for graphical output from the ISDES. It seems that the SUN Graphics Kernel System (GKS) package meets all the requirements of ISDES. In addition to the graphics package there is a need for source code compilers for FORTRAN, C and PASCAL languages which are available with SUNOS. Such a wide range of software mainly follows from the necessity of interfacing between external devices/processes, databases and existing structural packages. The serious problems with the tool software working under the MS-DOS have been overcome.

Generally the choice of software tools for development of expert systems is between the languages/environments, toolkits and shells.

The problem of choosing a software tool for development of the ISDES was solved using the Analytical Hierarchy Procedure of Saaty [11] for IBM PC/PS software, enabling the weigh up of significant factors in a decision problem "-via pairwise comparisons". Taking mainly into account that toolkits are very expensive tools and symbolic processing languages have not too many priorities the shell was chosen as a tool for development of the ISDES.

The choice of programming languages for development of the ISDES shell was then between FORTRAN, PROLOG, PASCAL , and C/C++.
The C language emerged as the preferred language for writing the ISDES shell mainly because of the following reasons [6]:

- it enables one to conveniently call external devices/processes, databases and existing structural programs written in higher-level languages;
- the UNIX operating system is written in C, hence it could be very useful to employ system calls for maximum efficiency, or to access facilities that are not in a C library.

In the case of IBM PC/PS application the shell is written partially in C and partially in TURBO PASCAL.

ISDES KNOWLEDGE BASE

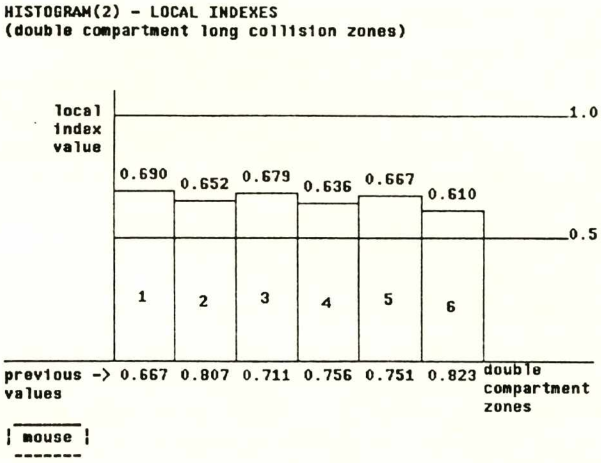
In the context of developing the ISDES with its sub-system for preliminary design of ships for intact and damage stability the main sources of good expertise to build the knowledge base are as follows:

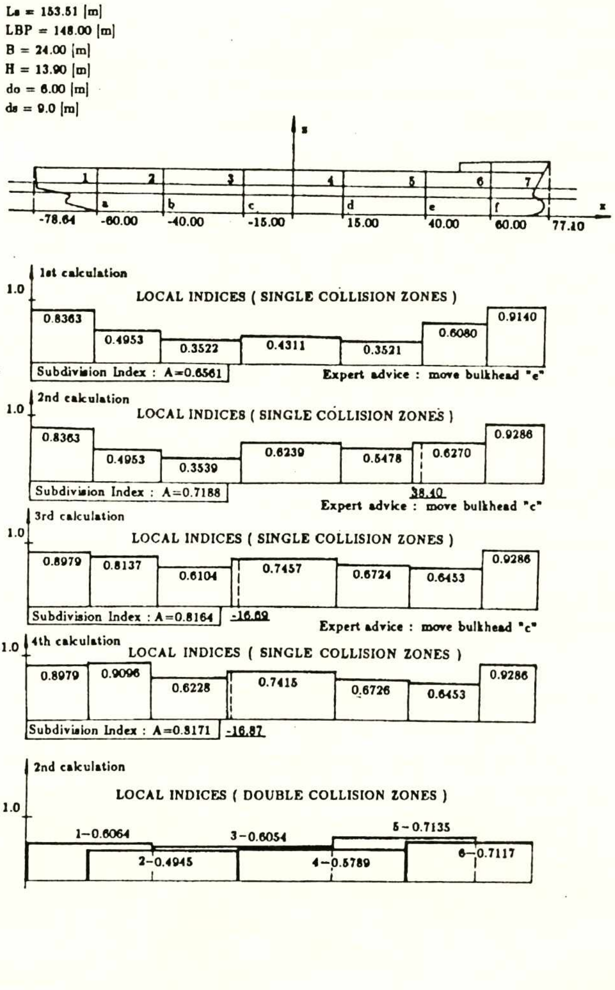
- scientists;
- designers, operators;
- requirements of regulatory bodies;
- shipyard standards;
- accepted good practice.

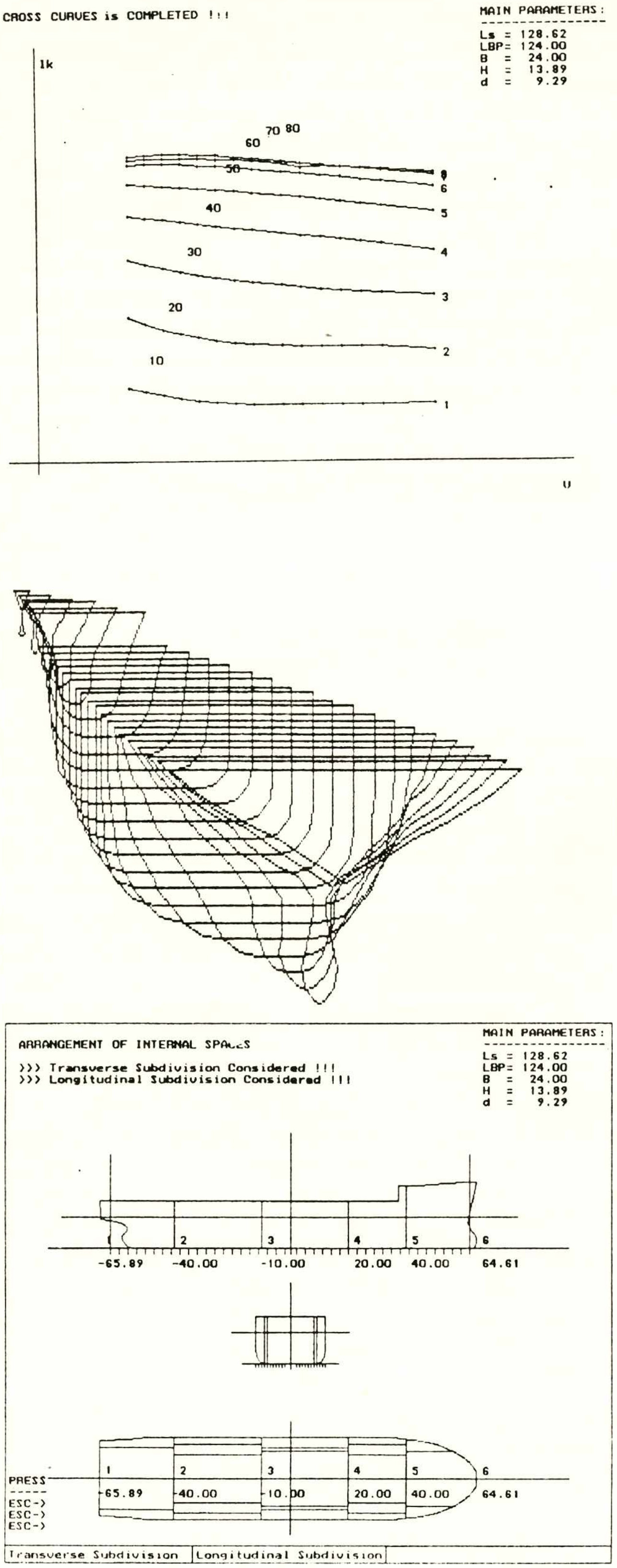
The knowledge base includes the design formulas, design rules, external processes, databases, external routines and other interfacing rules needed for the communication with the ISDES.

The knowledge base of the ISDES contains all the elements connected with the preliminary design for intact stability (see Fig. 3) and damage stability (see Fig. 4): hull form representation, arrangement of internal spaces, hydrostatic calculations, etc. The chosen elements of the ISDES knowledge base are presented in Fig. 6.

The structural routines are still under development as new complex problems have to be solved with the ISDES system. The first documentation is currently being prepared. The most important parts of the knowledge base from the stability assessment point of view are the parts dealing with the intelligent assessment of designs to test their adequacy to the reality. For example, if the stability requirements are as specified by the IMO then the given ship (hull form and arrangement of internal spaces), in the given load condition, and given environment condition (state of sea) is checked against these requirements to assess whether modifications in design are required. Next the damage stability assessment should be done to evaluate the entire ship stability safety.






CROSS CURVES is COMPLETED !!!

ARRANGEMENT OF INTERNAL SPACES

>>> Transverse Subdivision Considered !!!
>>> Longitudinal Subdivision Considered !!!

MAIN PARAMETERS:

Ls = 128.62
LBP= 124.00
B = 24.00
H = 13.89
d = 9.29

Fig. 6. Elements of the ISDES knowledge base

RESUMPTION

The above description of the ISDES system has been found interesting to publish by the author as first effects of the research project were reached. The next stage should concern incorporating more professional design routines and expertise into the ISDES knowledge base according to the system approach being the base for the ISDES system development.

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