INTERNATIONAL MARITIME ASSOCIATION OF THE MEDITERRANEAN (IMAM)

IMAM'93

VI CONGRESS

Proceedings of the VI-th Congress of the IMAM

Edited by Peter A. Bogdanov

VOLUME I

15 - 20 NOVEMBER, 1993
Varna, BULGARIA

CONTEMPORARY SHIPDESIGN WITH THE AID OF COMPUTERS

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ABSTRACT

The computer plays an important role in contemporary shipdesign. With the aid of the computer the designer is able to execute state of the art naval architectural calculations in the early design stage.

SARC has designed a software package called PIAS for the computer aided shipdesign. PIAS contains a large variety of modules for hull generation, hull definition, stability calculations in intact and damaged condition. Modules for resistance, propeller calculations and weight calculations are also available. All calculations are according to the most recent regulations from the International Maritime Organization. The recent regulations concerning the probabilistic damage stability (IMO MSC(19)58) have brought many designers into difficulties. SARC has designed the tools which enable the modern designer to continue his work in a relatively easy manner. The use of a computer has proved to be inevitable.

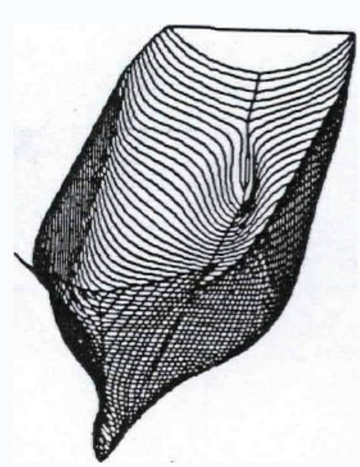
INTRODUCTION

The Scheepsbouwkundig Advies en RekenCentrum **SARC** B.V. (naval consultancy and engineering centre) in the Netherlands is a company founded in 1980 with activities in the following fields of naval architecture:

1. The development of the software package **PIAS**, Program for the Integral Approach of Shipdesign.
2. Performing naval calculations in service.
3. Development of tailor-made software on client specification.

A normal design spiral may look something like this:

1. Hull design
2. Resistance and propulsion
3. Lightweight estimation or calculation
4. Compartments
5. Intact- and damage stability
6. Longitudinal strength



In order to discuss the contemporary shipdesign with the aid of computers we will describe subsequently the use of PIAS in each design stage. The topic of the probabilistic damage stability will be discussed more thoroughly, while also describing some difficulties in the implementation of the regulation.

1. HULL DESIGN

In general the naval architect applies one of the following two methods in order to come to a new hull design:
1) Hull transformation
2) New hull design from scratch (hull-form generation)

1) A new hull design is generated from an existing hullform. For example by transforming the sectional area curve (SAC) for a larger displacement or for shifting the centre of buoyancy at the same displacement. This process that used to be done by hand can be done by means of the computer with the hull-form transformation module. The working of the module can be divided in two parts:

a) lineair scaling, which means that the existing hullform can be scaled linearly in length, breadth and/or draft.
b) transforming the SAC, by altering the blockcoefficient, the longitudinal centre of buoyancy or midshipcoefficient.

The result is a new SAC from which the displacement, block coefficient and longitudinal centre of buoyancy can be calculated immediately on screen. If the result does not satisfy the designer, he can perform a new transformation on this last SAC or on the original SAC. This interaction between designer and computer results in a very quick insight in a new design.

2) A complete new design has to be made. Only the main particulars are known at the start of the design, like deadweight, speed, maximum draft, cargo space. This implies a certain length, breadth, blockcoefficient and longitudinal centre of buoyancy. First the sectional area curve (SAC) is drawn and the displacement is determined from this first SAC. After some alterations this SAC is the basis for a first linesplan which complies (as much as possible) with the SAC. Then the linesplan has to be altered to comply with other criteria, for instance machinery requirements regarding enough space or alterations on the aftbody for propulsion efficiency.

This design spiral is the same when using PIAS. First the SAC is designed on the computer and at any stage the displacement, longitudinal centre of buoyancy and block coefficient can be calculated. The SAC can be edited very easily until the desired shape has been achieved. It is also possible to let the computer calculate the required modifications of the SAC and adapt it accordingly. This new SAC is then used to generate a new hullform by means of the computer. About seven transverse cross sections have to be defined on the graphics screen of the computer. From each transverse cross section the area is known from the previously designed SAC and it is now possible to adapt the approximated shape to the desired shape in order to get the correct area. When all transverse cross sections have been defined it is possible to generate any other intermediate cross section. In this way it is possible to generate a complete hullform by means of only a few transverse cross sections.

To check if this new hullform correctly fairs cross sections, waterlines, diagonals and buttocks can be plotted on paper and on the computer monitor. If the designer is satisfied with the result the displacement, block coefficient and longitudinal centre of buoyancy can be calculated of this new hullform. If the results comply with the original SAC the hull-design is completed, otherwise the designer has to adapt one or more of the transverse cross sections and then generate a new hullform, calculate the displacement etc. and so on.

For an experienced PIAS-user the design of a new hullform as described above takes about 2 hours for a simple hullform as a yacht up to 16 hours for a difficult container ship with a bulbous bow or a vessel with a propellertunnel.

Another activity for the naval engineer often is making calculations of an existing design. This differs a lot from the designwork described in point 1 and 2, because the hullform and all other particulars are already known. This is also the reason why PIAS has a completely different program to define an existing hull design:

3) An existing hull design is defined by transverse cross sections, without the use of a sectional area curve. These transverse cross sections can be defined in two ways:
a) The offsets are typed in the computer.
b) The transverse cross sections are taken from the linesplan and put on a digitizer. This digitizer is then used to point the coordinates of a cross section. This method is quick and easy to use. The number of cross sections and their position is free to choose. It takes about 1/2 to 3 hours to define 20 ordinates.

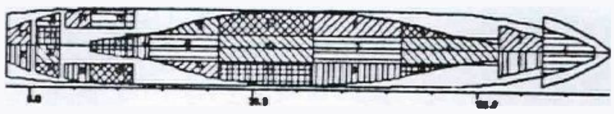
After the hullform has been defined appendages can be added, for example a rudder, deckcamber, superstructures or a bowpropeller. Several predefined appendages are available in PIAS, but if the shape of the appendage is too complex there is also the possibility to define this complex appendage seperately and add it to the original hullform. This mechanism ensures that every floating object can be defined in PIAS.

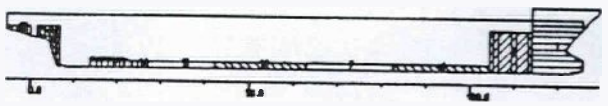
2. RESISTANCE AND PROPULSION

With respect to the geometry the hull-form now meets the specifications of the designer. The next step is to check the hydrodynamic aspects and the resulting propulsive power in order to reach the required service speed. PIAS contains some standard methods for the prediction of the resistance. The method mostly used and found most accurate is the method according to Holtrop and Mennen [Ref.1]. The results from the resistance prediction are used for the calculation of the required shaft horse power for a given propeller. If the propeller is not known, which is mostly the case, the optimum propeller is calculated by PIAS. The calculated propeller is of the B-series type [Ref.2] or can be a ducted propeller of the Ka-serie [Ref.3]. If the vessel does not reach the required service speed the propulsive plant must be changed. If this is not feasable the hull-form can be changed in order to reduce the resistance or to reduce the thrust deduction fraction. This can be done by optimizing the main parameters of the hullform to reduce the resistance. If this results in altered main parameters, for example a change in longitudinal centre of buoyancy, the current hullform can be transformed (see paragraph 1.1) and the design spiral must be run from that position on again.

3. COMPARTMENTS

In order to perform stability calculations the internal geometry of the ship can be defined. Several tools are available in PIAS to define tanks and other compartments of the ship. All defined data can be checked on the computer monitor and on paper either in sections or in three dimensional views. These compartments are also available for the damage stability calculations.





4. WEIGHT ESTIMATION

Before the designer is able to perform any stability calculation the weight of the light ship and the position of the centre of gravity in longitudinal and vertical direction has to be calculated or estimated.

In most cases the construction is not yet known in the preliminary design stage, so the designer has to make an estimation for the light ship weight and the position of the centre of gravity in longitudinal and vertical direction.

It is also possible to define all construction parts in PIAS. However, for the total light ship weight also the weight for arrangement and outfit of the ship have to be added. After that sectionweights, the total light ship, the weight distribution, moments of inertia and section moduls can be calculated. The weight distribution can also be used for the longitudinal strength calculations.

5. STABILITY CALCULATIONS

If the shipdesign, which is a result of the designprocess as described above, meets the requirements of the shipowner and the weight is calculated or estimated, the design has to be checked for compliance with the appropriate criteria of the International Maritime Organization (IMO) and local authorities. This may have a serious impact on the shipdesign and it is therefore of major importance to perform stability calculations at an early design stage. The major field of expertise of SARC concerns the stability calculations including all kinds of stability requirements. Therefore a large variety of different computerprograms has been developed, from intact stability to damage stability. It is not within the scope of this paper to describe all features, but a shortlist is given in the appendix 1.

The output of all calculations and calculation algorithms complies with international requirements and has been approved and accepted by the authorities.

6. LONGITUDINAL STRENGTH

With the hullform, the light weight distribution and the compartments defined before, the longitudinal strength can be calculated. The stability conditions and the longitudinal strength conditions are equal, so it is possible to define a loading condition for which both the stability and the longitudinal strength is calculated. If the moment of inertia is known, either as a given figure or from the construction module (see paragraph 4), the sagging or hogging can also be calculated. Maximum values for the shearforce and bending moment can be given and each longitudinal strength condition is tested for compliance with these values.

7. PROBABILISTIC DAMAGE STABILITY

So far the design of a new vessel is pretty straight forward. The alterations which are necessary to be made in order to comply with regulations and shipowner requirements can be determined fairly easy. If the new design concerns a dry cargo vessel with a length of over 100 metres, the part of the design discussed in paragraph 5, however, can be mistified considerably for a designer without the proper experience or the proper tools. SARC has experienced to be a guide for the Dutch designer. The reason for this is that we have succeeded to manufacture a tool which enables the designer to check a vessel for compliance with the probabilistic damage criteria according to IMO MSC(19)58, even in a preliminary design stage. To get a better insight in the difficulties when designing a vessel according to this regulation, the method and the accompanying problems will be described briefly.

7.1. Probabilistic concept
(IMO MSC(19)58)

As an amendment to the SOLAS convention 1974 a new part B-1 has been added to chapter II-I which applies to cargo ships larger than 100 metres and constructed on or after 1 February 1992. The probabilistic concept considers the probability of a damage occurring at any longitudinal position of the vessel. In addition, for each damage case the probability of survival is calculated. The sum of the product of these probabilities for all damage cases results in the "Attained subdivision index". This index must be equal to or larger than the "Required subdivision index".

The "Required subdivision index" depends on the length as follows :
R = (0.002 + 0.0009*Ls)1/3 (1)

where: Ls = subdivision length, which is the greatest length of the water-tight vessel

The "Attained subdivision index" is calculated as follows:

$$A = 0.5*AL + 0.5*AP \qquad (2)$$

where: AL = the subdivision index for the vessel at deepest draft
AP = the subdivision index for the vessel at partial draft

The deepest draft corresponds with the summer draft of the ship. The partial draft is the light ship draft plus 60% of the difference between the light ship draft and the deepest draft. AL and AP are both calculated as follows:

$$A = \Sigma p_i s_i v_i \qquad (3)$$

where: i = the number of the damage case
p = the probability that a damage case occurs
s = the probability of survival in a damage case
v = the probability that a damage case occurs within the assumed vertical extend

The factor pi is dependent of the geometry of the damaged compartment(s) and the position in the vessel. If a damage case consists of a wingtank and an adjacent compartment inboard, the factor pi is reduced by the factor (1-r). The factor r is calculated according to a formula dependent on the position of the inner bulkhead from the centreline and the non-dimensional length of the damage case.

7.2. Deviations from probabilistic concept
The probabilistic calculations should result in a total sum of probability of occurance of any damage of 1 (one). This makes it possible to check the calculations afterwards by summing the product pirivi for all damage cases. If this sum is larger than 1 some damage cases are counted twice or some compartments overlap; if this sum is smaller than 1 not all possible damage cases are calculated or not all compartments of the vessel have been included in the calculation.

However, the latest interpretations according to the 'Explanatory notes' [Ref.4] prescribe that in the case of a multicompartment damage the factor ri is calculated for each sub damage separately. This may result in negative probabilities, which is not covered by the probabilistic concept.

7.3. Difficulties in translating the rules into algoritms
In the first place some difficulties were encountered in interpreting the regulation for determining the longitudiunal boundaries of each compartment. These boundaries are used for the calculation of pi.

The main problem was to determine the penetration depth, which is represented by the factor b. This parameter is described by means of a complicated definition. The IMO must also have had difficulties and has therefore tried to clarify the intention of the definition of b by means of examples in the Explanatory Notes ('Legislation by example'). The main problem of determining the factor b may occur in cases where a longitudinal bulkhead has no constant distance to the centre plane.

If we consider the following example of a subdivision of 3 compartments in any part of the vessel (figure 1) and the boundaries of the damage case of simultaneously flooding of compartment 1 and 2 are determined (figure 2), the boundaries are as given in figure 3.

. Extensions in damage stability calcula-ns

Due to 25-4 paragraph 7 it is sometimes cessary, if the authority requires so, to calcu-e so called 'minor damages'. These cases sume the double bottom to be intact whereas compartment above the double bottom is oded.

Non-watertight openings, like air-ventila-ons, and weathertight openings always cause oblems. The compartment flooded through an ening may be included in the damage case.

Flooding through damaged pipes. This means at either constructive measures must be ap-ied to withstand the flooding through the pipes .e. remote controlled valves) or the flooding rough the pipes must be taken into account in e damage stability calculations.

) The damage stability calculations must be xecuted for any stage of flooding. The lowest robability of survival is is valid for the damage ase under consideration.

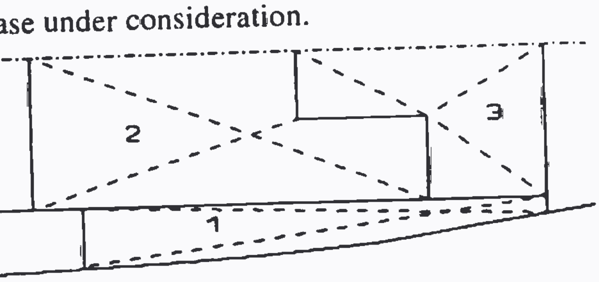


Figure 1

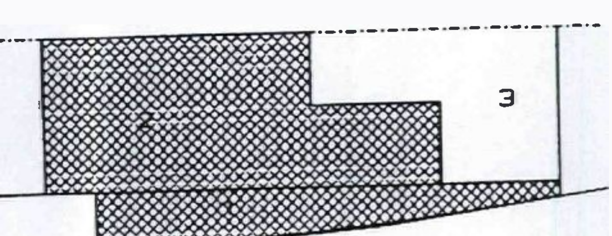


Figure 2

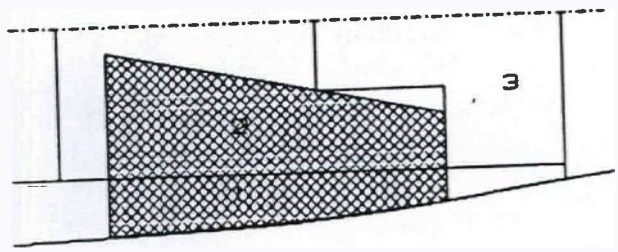


Figure 3

7.5. Presentation of results

Since there is not yet a standard of presentation of the results of the probabilistic damage stabil-ity, each authority requires a different presenta-tion. In regulation 25-8 it is described that the master must be supplied with data of the maxi-mum allowable vertical centre of gravity to comply with both intact and damage stability requirements. But how the calculation must be presented to the authorities for approval is not described.

7.6 Hardware requirements

In a later stage of the design the calculation has to be more accurate. This results in an exponen-tial growth of the number of damage stability calculations. As calculations may take 24 hours on a SUN microstation SPARC 1, it would take 55 hours on a IBM personal computer 80486/50 MHz. This shows that for design purposes it is recommendable to use a modern microcom-puter.

7.7 Resume

The described facts in this paragraph make clear that although the probabilistic damage stability is basically not too complicated, the actual manu-facturing of a suitable computer program has proved to be reasonably difficult in the way that we want to make it as easy as possible for the designer. The following points summarize this paragraph :

1. Some deviations from the concept like the negative probability of occurance of a damage, make the method more complex.
2. Without the explanatory notes the legislation cannot be adopted correctly. Especially the para-graph on the determination of the mean penetra-

tion depth can not be interpreted correctly without the use of the explanatory notes.

3. The introduction of so called minor damages, intermediate stages of flooding, taking into account the flooding of compartments via pipes and openings, causes the attained subdivision index to decrease dramatically (in most cases), which can only slightly be compensated by enlarging the number of damage cases to be calculated enormously. Plus the fact that the flooding through pipes of compartments makes the definition of the damage cases a lot more time consuming.

4. The fenomenae described in point 3 made us design a program which generates all possible damage cases, including minor damages, compartments flooded through immersed openings and compartments flooded through damaged pipes. This ensures that the designer is only troubled with the actual design problems and not with the interpretation of the regulation and with the definition of the damage cases manually. This saves the designer a lot of time, since the number of damage cases can be in the order of a few hundred.

5. The number of damage stability calculations is not necessarily equal to the number of damage cases. If each damage case is calculated for three intermediate stages of flooding (25%, 50%, 75%) and the final stage of flooding; and as an average for each damage case two minor damages are calculated; then for each damage case six damage stability calculations are executed. If the internal geometry on starboard is not equal to portside all calculations must be performed for damages on star-board and on portside. This explains the long calculation time and therefore we advise to use a microcomputer instead of a personal computer (see paragraph 7.6). PIAS is available at this moment (October 1993) on a SUN Sparstation 1.

6. Since the intermediate stages of flooding, the flooding through openings and through damaged pipes and the minor damages have such a large influence on the attained subdivision index in nearly all cases we have investigated, which was so dramatic (we have encountered cases with a reduction of 20% of the attained subdivision index due to the effect of pipes) that the vessel did not comply with the requirements, we wonder if the formula for the required subdivision index was determined taking into account these effects.

7. For the forthcoming legislation of the same probabilistic damage stability criteria for vessels smaller than 100 metres, we hope that the International Maritime Organization will consider the abovementioned points.

8. In addition to point 7 we hope that a new legislation will contain all regulations, which bear only one construction, without the aid of so called explanatory notes which in fact are part of the legislation. In the Netherlands, for example, the explanatory notes have the status of guidelines for the interpretation of the actual regulations.

9. In order to help the designer to make a first subdivision in an early design stage SARC has investigated the possiblity of designing a generator for the internal geometry: a sort of floodable length curve as we know for passenger vessels. The floodable length curve determines the position of the main bulkheads; the generator for the internal geometry does the same for a first design of the compartments, in such a way that the generated damage cases just have a probability of survival of 1 (one).

8. CONCLUSION

Modern legislation requires complex calculations in an early design stage. Furthermore, advanced methods have become available with the use of computers, which enable the designer to complete a design spiral more quickly. In a fraction of the time needed in the past for one design alternative, the designer is now able to optimize the design with the aid of the computer equipped with the proper tools. The computer may prove its indispensability in every design-stage. Appendix 1 gives an overview of the applications of PIAS in the different aspects of the design.

In the case of vessels for which the IMO MSC(19)58 regulation (probabilistic damage stability) is applicable the computer is undoubtedly indispensable. The number of calculations which are necessary to be executed and the adoption of the regulations can no longer be carried out without the help of a computer. The fact that it is not possible to make a prediction of the behaviour of a new design concerning the probabilistic damage stability, makes it even harder for a designer to estimate whether his design will comply with the requirements or not.

Although each and every designer has to get used to the method of designing a vessel in compliance with IMO MSC(19)58, we have the experience that with the help of PIAS every designer is capable of making a good design within reasonable time. However it remains a question of trial and error to a certain extent. In order to help the designer to make a first subdivision in an early design stage SARC has developed a generator for the first rough subdivision of the vessel. In this way it is not completely up to the designer to think out a first subdivision. Our experience is that this is a helpful tool.

Furthermore SARC has put a lot of effort in developing a tool to generate all possible damage case, including:

- cases where compartments flood through non-watertight openings
- cases where compartments flood through pipes connected with damaged compartments
- so called 'minor damages'

This tool relieves the designer from the task of defining all possible damage cases, which might contribute to the attained subdivision index. Our experience and the experience of the users of our system is that this generator is indispensable for making a correct calculation for a vessel in compliance with IMO MSC(19)58.The time needed for a complete new design of a 150 metres containervessel, which includes the hulldesign, propulsion, internal subdivision, intact stability, longitudinal strength and damage stability can be estimated for an experienced PIAS-user to an average of 60 hours. The probabilistic damage stability is executed on a micro-computer in this case. The lightship weight must be estimated by the designer, since in this stage of the design details of the construction are not known yet. When the vessel does not comply with the probabilistic damage stability requirements the calculation has to be repeated after some alterations to the design have been made. One cycle for the probabilistic damage stability calculations takes about 8 hours on average.

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APPENDIX 1

HIGHLIGHTS OF PIAS

PIAS is an integrated computer program for designing the hullform of the ship in the preliminary design stage. In addition all naval architectural calculations are executed according to different international regulations. PIAS guarantees an optimized design of the hullform within short time. PIAS is currently available for all IBM compatible Personal Computers (MS-DOS) and SUN Sparcstation computers (UNIX). Calculation results can be routed to various kinds of printers and plotters.

An extensive manual in English and the consistent user interface makes the program very user-friendly. The output of the several modules can be selected in several formats and languages.

The program is already in use by the majority of Dutch shipyards, shipowners and naval architects. Furthermore we have clients in France, Belgium, Poland and Romania. Also several universities in and outside The Netherlands use PIAS for educational purposes.

To get an insight in the possibilities of PIAS see the following list (which is only an extract of our package): Hullform definition : hullform generation, hullform generation of developable surfaces, input of existing hullform, hullform transformation, input of hullform defined in SIKOB. Hydrostatic calculations : calculation of inclining test, hydrostatic particulars, cross curves, bonjean curves, tank capacity tables, calculation of freeboard, launching calculations, intact stability including windmoment and non-watertight openings, grain calculations, maximum allowable VCG' with a variety of criteria, stability for hopperdredgers, longitudinal strength calculations. Damage stability: deterministic damage stability, maximum allowable intact VCG' to comply with damage criteria, curve of floodable length, probabilistic damage stability for passenger vessel, probabilistic damage stability for general cargo vessel. Construction: several modules are available to define the construction, to calculate steelweight, sectionweights, longitudinal weight distribution and section modulus of the cross section. Hydrodynamic calculations: Several resistance calculations : Holtrop & Mennen, Oortmersen, Savitsky for planing hulls, resistance for pontoons (Holtrop cs.), resistance and sideforse for sailing vessels. Propellercalculations acc. to MARIN B-series and for ducted proppeller (Ka-series). Conversion: PIAS has interfaces with other software packages for structural design: AUTOCAD (DXF format), IGOS, EAGLE.