PREDICTING THE ABILITY OF SURVIVAL AFTER DAMAGE IN TANKERS

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Abstract

To meet the demand of current operating conditions, tankers design requires arranging many different sized cargo tanks designed to transport loads of many different characteristics. Besides, today all tankers are designed to operate at any degree of tank ullage. The above implies that the load conditions a vessel is likely to encounter during its operation at sea is practically impossible to foresee. Despite of this, the Captain must have sufficient, and precise, information to be able to determine the capability of survival of the ship in view of any type of damage that might occur. Moreover, the capability of survival, due to the present design of the vessels, varies greatly depending on the load conditions at departure.

Today, rules do not require that vessels carry damage condition calculators on board. Even when they exist, many Administrations do not accept them as elements of prediction and demand that there be a paper document with the information that will allow the Captain to determine the ability of survival of the vessel and his options for action in case of damage.

This paper means to demonstrate how these documents are worked out and what the result is. Furthermore it means to explain how the Captain can use it and show how awkward and difficult it is, questioning the possibilities of their being used and useful.

1. INTRODUCTION:

Today, operators demand that the design of tankers allow them to transport loads of different types and characteristics. The cargo can differ from one compartment to another, and the vessel can be loaded in many different ways. Furthermore, the vessels are designed to operate at any tank ullage.

This, which is quickly said and easily stated, means that it is practically impossible to foresee all the load conditions a vessel may encounter during its operation at sea. Still, the Captain must have sufficient, and accurate, information to enable him to determine ship's capability of survival in face of any possible type of damage. However, today ship design criteria makes this capability of survival after damage greatly dependent on the load conditions at departure.

At present, damage condition calculators on board are not required by the rules. Moreover, many Administrations do not accept them as predictive elements and demand that the information which may allow the Captain to determine the vessel's capability of survival is printed on paper. That is, the Captain must refer to an awkward and bulky paper document to determine his options for action in case of damage, when his attention may be distracted by the critical moment of the damage itself.

2. STANDARD CONFIGURATION

In general, the cargo area of all the modern tank ships is built following either of the two configurations shown in Figures 1, 2 and 1A. Both have a double hull bulkhead in accordance with the MARPOL Rules. Internally, they have either a bulkhead on the centre line or two bulkheads, each one at least a fifth of the ship's breadth from the hull side. The cargo zone is further divided by transversal bulkheads that are not always continuous. The ballast tanks are placed on the double hull and are usually divided along the centre line in the double bottom.

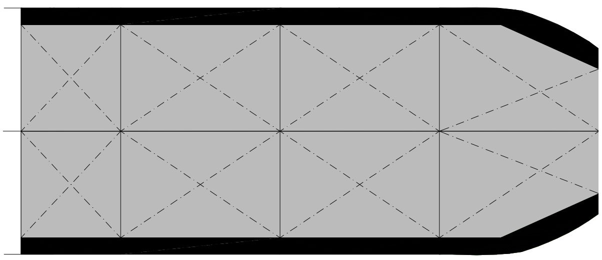


Figure 1

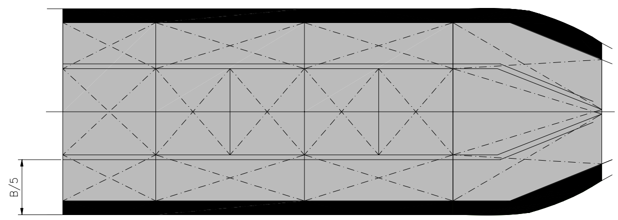


Figure 2

From the after damage stability stance, the problems encountered are equivalent in either of the two configurations presented (it must be kept in mind that the interior bulkheads are not considered damaged).

On the other hand, the required height of the double bottom implies that the cargo tanks will not be flooded in case of bottom damage. For this reason, from here onward in this paper, these damages will not be considered. However, it must be kept in mind that they have to be taken into account since these damage cases are often critical.

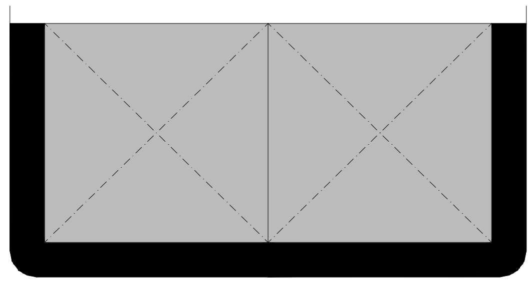


Figure 1A

The problems to be approached in this paper are those dealing with damage to the hull side affecting the hull side cargo tanks.

3. SPECIFICS IN AFTER DAMAGE STABILITY CALCULATION FOR TANKERS

Figure 3, which represents a typical damage case, suffices to understand that the fundamental problem is the asymmetrical damaged considered.

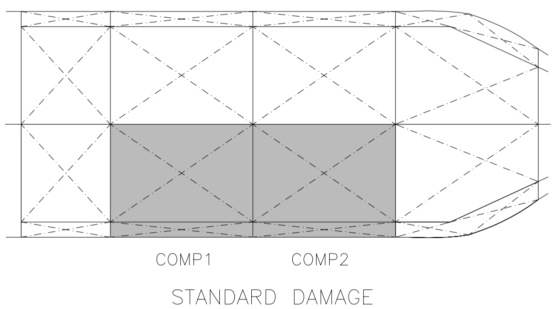


Figure 3

As already mentioned, these ships have a great range of cargo possibilities, and the following parameters may vary in each tank:

- Ullage or percentage to which the tank is filled.

- Density of the transported cargo.

The first variable would be comprised between 0% and 96% and, in principle, has no restrictions, which makes it a continuous variable.

The second variable depends on the design conditions of the vessel and, in principle, a variation of between 0,7 t/m^3 and 2,1 t/m^3 is normal. Theoretically the variation between these two values could be considered in steps, and these would be defined according to the densities of the products the ship has been designed to transport. However, due to the great number of products available, this variation can also be considered continuous.

It is important to point out the important effect the previously mentioned variables have on the capacity of survival after damage, especially considering that damage cases are mostly asymmetrical. Thus, very different situations can occur, for example:

1. If, prior to the damage, the tanks were nearly full of a product having a density close to 1, the list produced by the damage would be small.

2. In case the tank had been empty, or full of a very low density product, the damage would have produced a great list, inclining the ship towards the same side of the damage.

3. If the product transported had been of great density, the list after damage would have been great, inclining the ship to the opposite side.

These very different behaviours indicate the importance of the departure load condition in the capability of survival after damage.

It must be kept in mind that, in general, the flooding of at least two adjacent compartments must be considered when studying this type of vessels, and both variables defined above must be taken into account for the two compartments.

For this type of ships, fixing the percentage to which the tanks are filled and the density of the cargo product determined in the two compartments studied, does not mean that the draught and trim of the vessel is unquestionably defined. Rather, this depends on how the remaining, undamaged, compartments are loaded. Therefore, each damage case must be studied in a broad range of draughts and trims.

In other types of ships it is normal to have the information of the capacity of survival after damage by means of one of the two following documents:

- The study of all the possible damage cases in all the probable cargo conditions. This type of studies is valid for those vessels for which the possible cargo conditions are very well defined.

- The study of minimum GM (or maximum KG) of the vessel (Figure 4), depending on the ship's draught and trim conditions. This type of study does not consider the manner in which the vessel is loaded. That is, it places the vessel in a theoretical draught and trim position and determines, for this position, the admissible minimum GM for each possible damage case. Afterwards the Limiting GM is found, which is the smallest of these minimum GM's. These kind of studies are valid for vessels operating in very different load conditions, but in which the capacity of survival after damage is not greatly conditioned by the manner in which the ship is loaded.

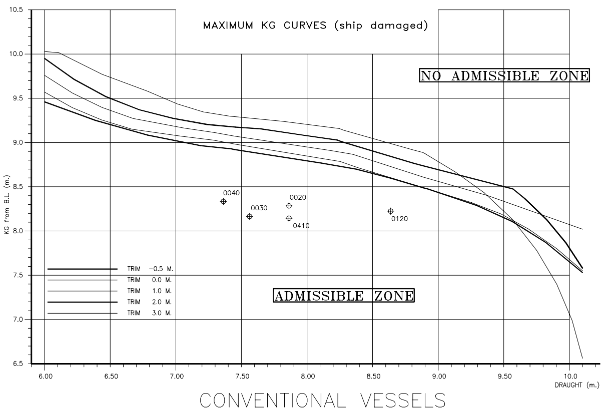


Figure 4

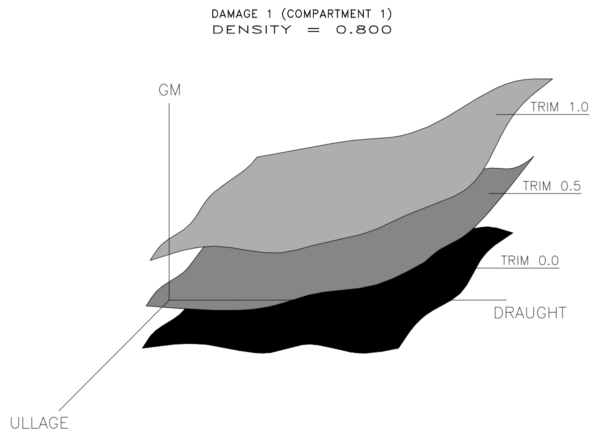


Figure 5

Evidently, neither of the above procedures meets the requirements for the type of vessels considered in this paper. A new method which can allow estimating the capacity of survival after damage must be sought.

In view of these considerations, a different and specific calculation and documentation procedure must be contemplated for these ships.

4. CALCULATION PROCEDURE

The complex features of the stated problems make impossible to seriously consider the achievement of a simple calculation procedure, capable of comprising the entire casuistic.

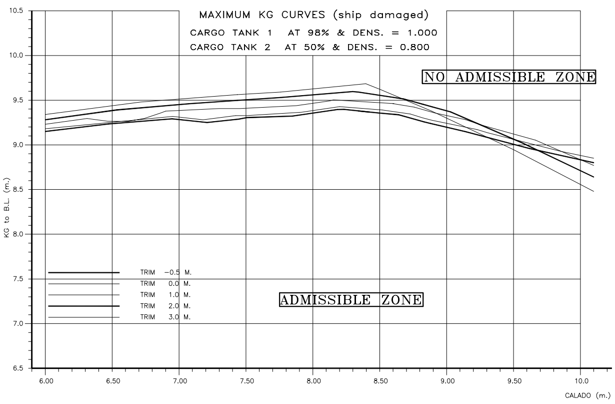
The procedure proposed for these calculations is based on obtaining a curve of minimum GM for each of the damage conditions studied and for each tank ullage and product density.

That is, for each damage condition studied, a set, or “family”, of surfaces would be obtained. These would be similar to what is shown in Figure 5, where the axis X and Y represent the draught of the departure condition and the ullage of the damaged compartment and on the Z axis the required GM minimum. Each of these surfaces would define the trim situation.

There would be, for each damage, as many families of surfaces as densities of products studied.

The above is valid for cases of damage in one compartment. In principle, damage in two compartments should consider a constant condition of density and ullage for one of the compartments and both parameters would be varied in the other one, obtaining a set of families of surfaces for this situation. By varying the ullage and the density of the cargo different sets or families of surfaces would be obtained.

In order to simplify the work and utilization of the results, the surfaces are cut into planes with constant ullage, obtaining a collection of curves. (Figure 6).



FOR ONE PARTICULAR DAMAGE

Figure 6

For the sake of clarity, an example has be considered: the case of damage in two compartments represented in Figure 3, in which the aft compartment has been identified as “1” and the forward one as “2”. The tanks have been filled to 0%, 25%, 50%, 75% and 100% with cargo densities of 0.7, 0.85, 1, 1.30, 1.60 and 2.

The process will be as follow:

- First the ullage and density of compartments 1 and 2 will be fixed. With this information the draught and trim will be varied to obtain a collection of curves, each curve corresponding to the trim. These curves will be valid for the fixed ullage and densities.

- Then, and keeping the conditions of compartment 1 fixed, those of compartment 2 will be varied, obtaining the pertinent successive collections of curves.

- Once all the possible variations of compartment 2 are completed, the conditions of compartment 1 will be varied, obtaining another collections of curves.

Therefore, for each damage case studied, a set of collections of curves will be available, each curve representing the minimum GM in a given condition of ullage and cargo density of each compartment.

In the above example (5 different ullages and 6 different densities), in case of damage of two compartments, there will be 900 collections of curves of the type represented in Figure 6.

Should there be ten possible damage cases, there would be a total number of 9000 collections of curves.

Each collection of curves would correspond to a specific damage cases and a specific ullage and density of each compartment.

Evidently, in order to simply its use, the different ullages and densities should be reduced. In case three different ullages and three densities were used, keeping the same number of damages, 810 collections of curves would be obtained.

5. INFORMATION AND PROCEDURES USED BY THE CAPTAIN

The captain of the vessel shall have, readily available, the collections of curves mentioned previously. The draught and trim of the vessel, as well as the density and ullage of each of the ship’s compartments is known from the initial load condition at departure.

With this information it is possible to select, for each damage case, the collection of curves to be used and among these curves, obtain the GM minimum with the draught and trim for each damage case. As it will not be possible to have available all the possible ullages and densities, these will be interpolated from the nearest values.

Performing the calculations described above for all the damage cases, a global GM minimums could be obtained as the minimum of the GM minimums of each damage case. This minimum must be compared with the GM of the ship's load condition. In accordance with the calculation procedure used, corrections for actual free surfaces have been made only for the damaged compartments. It is for this reason that comparisons must be made, subtracting from the GM corrections, the sum of mentioned damaged compartments corrections. However, for simplicity's sake, it should be compared with the corrected GM of the actual departure load condition. This solution, besides being a sufficiently close approximation, has the advantage of guaranteeing permanence in a safe zone.

Evidently all above calculations are very awkward and time consuming. They require very organised systematisation and procedures. Of course, the entire calculation system described can be programmed and included in a computer to make its use easier. However, the use of a computer is not acceptable to determine the possibility of survival after damage directly. It does not seem probable that a calculation method such as the one described is acceptable, and therefore all the information and procedures must be available on paper.

6. CONCLUSIONS

As can be seen in all the above, despite the existing complexity, it is possible to provide the Captain of the ship with a paper document that will allow, with sufficient accuracy, to learn the possibility of survival after damage depending on the characteristics of the damage case as well as the characteristics of the departure load conditions.

It is important to point out the two inconveniences of this prediction method:

1. The operational system is very complex, which makes us think it would not be of great use to the Captain in critical moments.

2. Besides, the damage cases it considers are those prescribed by the rules and the result is the value of the minimum GM to comply with the rules criteria. In case the damage produced were not one of the cases foreseen in the rules, there would be no information available. Even if the damage coincides with one of the cases in the rules, the different parameters that can be expected from it (list, GM, buoyancy, etc.) will not be known, and thus, the capacity for action will be very limited.

Obviously, the Captain will have, not only the families of curves previously described, but also the tables with all the necessary parameters depending on the different variables (damage, ullage, density, …). An example is the table in Figure 7 with the maximum KG (equivalent to minimum GM), required in different situations. Its parameters and variables can be grouped as convenient. This information can simplify the process of reaching conclusions and taking decisions by including new data. However, the problem of its complexity in use remains.

- MAXIMUM KG - DAMAGE STABILITY -								
	TRIM =	0,00	DEN =	0,80				
		MIDDLE DRAUGHT						
	FLOODING CONDITION	**4,0**	**4,5**	**5,0**	**5,5**	**6,0**	**6,5**	**7,0**
EP1E	Engine room flood.(pt) - empty side H.F.O storage tanks.	7,12	6,87	6,71	6,59	6,30	6,04	5,78
EP1F	Engine room flood.(pt) - full side H.F.O. storage tanks.	6,86	6,76	6,70	6,63	6,31	6,42	6,17
ES1E	Engine room flood.(sb) - empty side H.F.O. storage tanks.	7,12	6,87	6,71	6,54	6,25	5,99	5,71
ES1F	Engine room flood.(sb) - full side H.F.O. storage tanks.	6,95	6,84	6,71	6,43	6,32	6,43	6,19
1E1F	Empty cargo tanks-full side tank damage BKH.127/137 (fr.115-FO)	7,12	6,87	6,71	6,63	6,51	6,35	6,15
2E1F	Empty cargo tanks-full side tank damage BKH.106/115 (fr.94-127)	6,84	6,54	6,36	6,24	6,17	6,11	6,00
4E1F	Empty cargo tanks-full side tank damage BKH. 94 (fr.80-106)	6,82	6,59	6,39	6,27	6,16	6,08	5,99
5E1F	Empty cargo tanks-full side tank damage BKH. 74/80 (fr.61-94)	6,74	6,46	6,28	6,18	6,06	5,96	5,86
7E1F	Empty cargo tanks-full side tank damage BKH. 61 (fr.49-74)	6,71	6,85	6,62	6,47	6,34	6,18	6,00
8E1F	Empty cargo tanks-full side tank damage BKH. 49 (fr.37-61)	7,12	6,87	6,71	6,63	6,45	6,23	6,02
1P11	Cargo tank 25%-empty side tank damage BKH.127/137 (fr.115-FO)	7,12	6,87	6,71	6,57	6,39	6,19	5,86
2P11	Cargo tank 25%-empty side tank damage BKH.106/115 (fr.94-127)	6,17	6,02	5,94	5,91	5,87	5,69	5,27
4P11	Cargo tank 25%-empty side tank damage BKH. 94 (fr.80-106)	6,26	6,08	5,97	5,89	5,81	5,77	5,53
5P11	Cargo tank 25%-empty side tank damage BKH. 74/80 (fr.61-94)	6,17	5,97	5,86	5,80	5,71	5,62	5,51
7P11	Cargo tank 25%-empty side tank damage BKH. 61 (fr.49-74)	6,19	6,02	5,91	5,82	5,74	5,66	5,52
8P11	Cargo tank 25%-empty side tank damage BKH. 49 (fr.37-61)	6,74	6,51	6,37	6,31	6,25	6,05	5,84
1P12	Cargo tank 50%-empty side tank damage BKH.127/137 (fr.115-FO)	7,12	6,87	6,71	6,61	6,42	6,25	5,98
2P12	Cargo tank 50%-empty side tank damage BKH.106/115 (fr.94-127)	6,45	6,22	6,10	6,04	6,00	5,95	5,71
4P12	Cargo tank 50%-empty side tank damage BKH. 94 (fr.80-106)	6,54	6,30	6,15	6,06	5,98	5,91	5,76
5P12	Cargo tank 50%-empty side tank damage BKH. 74/80 (fr.61-94)	6,50	6,26	6,08	6,00	5,90	5,80	5,72
7P12	Cargo tank 50%-empty side tank damage BKH. 61 (fr.49-74)	6,42	6,22	6,04	5,97	5,88	5,78	5,67

Figure 7

It is our belief that the best procedure to enable the Captain to take correct decisions would be to have on board a load calculator capable of calculating the conditions after any case of damage. At present, it is not mandatory to have this instrument on board and, nevertheless, it is required to have a load calculator with capacity to assess the structural strength of the vessel. Furthermore, often, even if the vessel has a system capable of calculating the after damage stability, some Administrations do not accept it as a predictive method.

Given the complexity and broad spectrum of existing possibilities, fitting on board a system capable of calculating situations after damages should be mandatory. Evidently, the rules defining the conditions of this system have to be developed, and they should reduce to a minimum the possible objections to the system. Specifically, rules should be developed on:

- Hardware: capable of guaranteeing the correct use of the system under any condition (redundancy in different spaces, accelerations, lists, power supply sources, …)

- Software: a verified and verifiable system. That is to say, the calculation procedures should have been verified and the results checked to ascertain that they are correct and correspond to the actual situation. Even more, it must be possible to check in actual time, that the stability and its correction, in order to guarantee its correct performance during its entire life.

Lastly, it should be pointed out that having a system capable of calculating the after damage stability, does not preclude the need of carrying out the calculations described in this work. These calculations are most necessary to study exhaustively all the load possibilities of the vessel. Careful analysis of the results would make possible to draft a Manual of Advise to the Captain that would allow loading the vessel in the best way to guarantee its survival in case of damage. There are other conditions imposed when planning the cargo distribution (compatibility, segregations, …) which are carefully followed. However, the criteria that would increase capability of survival after damage are seldom taken into consideration. In most cases, this is due to lack of the pertinent information. With the previous information the Captain would be better able to plan loading the cargo in a safer way.

The improvement in the Captain's position concerning the possibilities of survival after damage is hardly quantifiable, since cases of damage and emergency cannot be expected to conform to what is foreseen. However, with the "classic" documents, determining the possibilities of survival after damage of the vessel would take at least half an hour of concentrated calculations, and in a half hour, some of his options might disappear. This alone, without considering that at the time of an emergency the Captain's attention is probably called upon to solve more than one problem, demonstrates how difficult handling this documentation is. With a load calculator to allow more suitable cargo distribution and the adequate software to consider after damage cases, it would take barely a minute, allowing the Captain to consider his different options while these are still viable or feasible. Although this is not strictly quantitative, Captains and ship owners surely will appreciate the improvement of their situation in case of emergency.