Damage Stability and Decision Support

How can we be better prepared and what questions do the teaching face?

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ABSTRACT

In the case of a "damage situation" adequacy of ship stability can become questionable. In a situation like that it is important that the Master of the ship makes the right decisions. The first moments can often be very crucial for the development of the damage and thus the whole situation. This paper discusses the design of a damage stability education and presents examples of decision support systems which also were worked with during a research project called "Damage Stability Control in the education of Master Class 1 in the merchant fleet, with or without Safety and Cargo System".

Keywords: *Education stability, damage stability, decision support*

1. INTRODUCTION

Good stability is fundamental for ships at sea. Intact stability is a delicate balance between the requirement to keep the ship upright in rough weather and the need to achieve comfortable rolling periods creating reasonable rolling accelerations. To accomplish good stability the master of the ship needs basic knowledge of ship stability and an onboard system for ballasting the ship for different loading situations.

How to achieve good stability in intact conditions and handling loading conditions is well covered in the basic education and training of master mariners in the maritime schools.

How to handle a damage situation after an accident is not as obvious. The literature about damage stability is not as vast and easy to get hold of as the literature concerning intact stability. One reason for this could be the fact that different ships differ a lot in their behaviour due to different internal design. A ships behaviour after an accident is to be considered as dynamic and is not always so easy to predict. This means that the behaviour of a damaged ship depends on different factors, which can change over time, and each of them can have an effect on the ship stability. Examples of factors affecting a damage situation are: load condition, wind and wave situation, the size and position of the damage and how the ship is internally designed.

In some cases the safety limit of good stability can be small, a slight shift of the cargo may worsen the condition and in rough sea the situation can become very hazardous. In such situations a correct action of the master can make the difference between survival and non-survival.

There are accidents like for instance the Zenobia 1980 and the Jan Heweliusz 1993 where knowledge, awareness and operational guidance could have changed the outcome. In a recent Swedish research project where a RoRo ship is redesigned to survive large damages (the DESSO project) it has been reported “that ’bad management’ in most cases is starting the cause of the events …’bad management’ is also the reason for the continuing or worsening the events” (Ulfvarson, Karlsson, 2005). In the present paper an example of education concerning damage stability is presented. This could very well be used as a part of crisis management education and could be in line with the statement that “water intrusion and fire are important to consider as the most effective areas for improvement of safety” (Ulfvarson, Karlsson, 2005) at least for RoRo-passenger ships.

2. PROBLEM

Luckily the majority of the active Master Mariners will never find themselves in a position were they would require the knowledge of how to operate the ship in a damaged situation. Never the less some Masters will be put in that position and one of the main questions during this work was how to create an education that would give Master Mariners a better understanding of the phenomena affecting a damage situation. As mentioned, the situation is affected by several factors. Some examples are; wind and wave conditions, the size and position of the damage, the type of ship for instance “tankers” or “RoPax ferries”, the ship watertight integrity and how well the procedures that exist are followed. Further the situation is dynamic which means that it can develop differently depending on what kind of actions and decisions are taken. During the research project: “Damage Stability Control in the education of Master Mariners with or without Safety and Cargo System” some of these questions were raised. The main goal of the project was to develop a new education and discuss a decision support called Safety and Cargo System (SCS) which exists in a prototype form. In order to be able to develop the education mainly three questions were focused:

What is reasonable and appropriate to learn in the area of damage stability?

How is the new education to be designed?

How ought the interface of a decision support system to be designed to really support?

3. DECISION SUPPORT

To make a decision in a damage situation on a ship some information is needed. Decision aid could be useful as “the stability books are not useful for quick decisions in cases of emergencies” (Ulfvarson, Karlsson, 2005). The use of technology has developed and today there are a lot of different equipment that can measure, evaluate and give information about different status of the surroundings (like the wave radar) or status of the ship (for instance measurement of strains of the hull). How this new equipment could be used is for example discussed by Steen (2002) who states that “Combining and sharing out information between different systems will give new possibilities”. In the present paper a decision support system called Damage Information and Procedures (DIP) will be presented. The DIP-system is based on paper charts and do not require any high technology or computer which makes it robust for the educated user. The DIP-system it today already incorporated and used on several ships. Another system called Safety and Cargo System (SCS) will also be presented. The system is new and do only exist as a prototype. The SCS-system relies on a computer and software and combines different information sources, its implications on decisions will be discussed. These two systems have the same objective, to support and aid quality in the decisions to be made and could of course also be combined and would in that case offer redundancy of the support.

3.1 Damage Information and Procedures (DIP)

The Damage Information and Procedures is a decision aid consisting of a plan on a paper chart. The system is developed by Lars Peter Rosander, a Captain who thought that there was a lack of information of how to handle a damage situation. The system is based on the design plans of a ship and a DIP-chart has to be developed for every ship individually. According to Lars Peter Rosander the best result is achieved if the chart is developed together with the crew of a ship. One reason for this is because the crew can give information about the routes and under what restrictions the ship is usually operated. The DIP-chart is developed so that the user after an accident quickly should be able to evaluate the status of the ship and which status is the most probable in the future. With this information available it is easier to take decisions about what actions that should be taken in order to minimize the risk of damage development into unwanted status. The input, information needed for the system, is the approximate location and size of the damage. With this information the user can navigate through different stages that are visually described with different colors and an approximation of the stability curve (GZ-curve) is representing each status to give a quick overview. Examples of DIP-charts are shown in figure 1.

In the examples different damages, which are numbered, and their position can be seen at the upper two pictures. At the lower picture a GZ-curve representing the damage can be seen as well as recommended actions described in a box below the GZ-curve.

With basic knowledge of stability a user can easily be taught how to use the system. This way of working is not new, there are similarities behind the DIP and the stability instructions for fishing vessels described by Johnsson who states that “it is important to make the figures believable to the crews”. This could further be strengthened by Ulfvarson & Karlsson who writes that “It would improve safety if the stability book included pages more user-friendly for the officers on the bridge”.

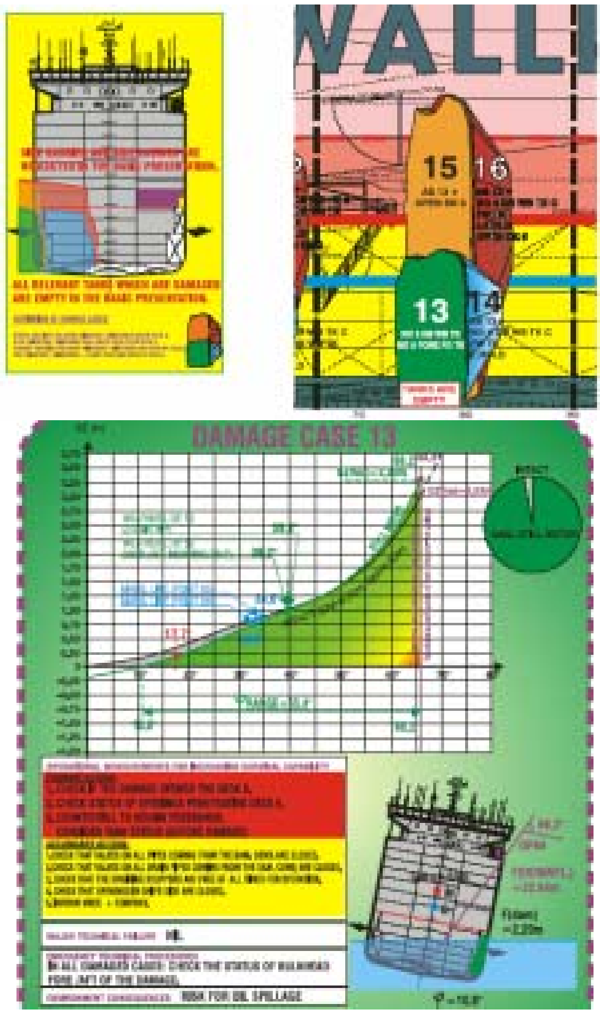

Figure 1 Drafts of a DIP-chart.

3.2 Safety and Cargo System (SCS)

The work with the SCS was started in 2002 and the system exists in a prototype form on a RoPax vessel. This Vessel Ms Skåne is operating the route between Trelleborg (Sweden) and Rostock (Germany) on daily basis. The SCS is based on a system with different gauges or sensors, an overview is shown in figure 2. The information from these gauges is fed into a computer where registration and evaluation is carried out. From a central point at the ship, for instance the bridge, this information can be reached and used. The idea behind the SCS is to combine it with a loading control computer and it could thus be used in daily routines, like loading, as well as in a critical situation.

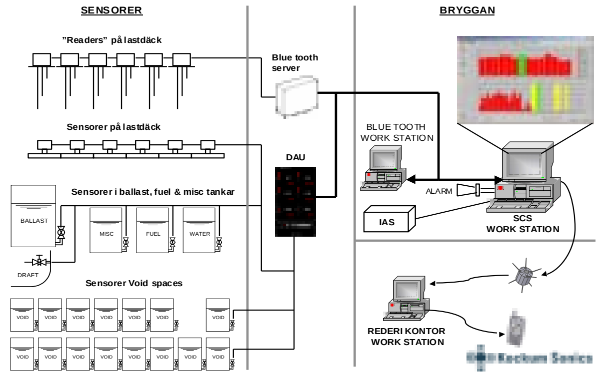

Figure 2 Schedule of how the gauges (sensors) in the SCS-system are connected to the computer and displayed.

The SCS mainly consists of three types gauges (sensors). There are water gauges put everywhere on the ship, cargo spaces as well as void spaces. This provides the computer with information about which spaces are flooded in a damage situation. During the first test the cargo on the ship was marked with microchips with information about the cargo, for example weight and what it consists of and its location. This information was transmitted with radio waves to a receiver and further on to the previous mentioned computer. This could for example give information about a sudden cargo shift. The third gauge is a gyro giving information about the ship roll (heel) and pitch.

Together with information about the ship the computer can provide information about the stability of the ship in intact as well as in damaged condition. In the vision of the system the thought was to combine the previous mentioned data with a weather module and instantly present updated dynamic information about the ship. Example of how the display is designed today can be seen in figure 3.

Based on the thought of having continuous updated information of the ship available there were, through a computer and a data base, to be served recommendations of what to do in a damage situation. These recommendations, which can be seen in the middle of figure 3, were to be presented as two different types of actions. The first is called “recommended action” which for example could consist of which tank of ballast water to fill or empty. The other type of action is called “banned actions” which for example could be which course to avoid or which tanks to not fill or empty.

Another example of information that is to be provided is the current situation of the stability and the expected final position. This information can be seen in figure 3 as the two columns, one on the left hand side of the display and one on the right hand side. These columns are also marked with different colors that are indicated with a black line in the center. Green color, on top, indicates that everything is in order, the stability is still good. Yellow, in the middle, indicates that there is risk at hand and red color, at the bottom, indicates that it is appropriate to order abandoning the ship.

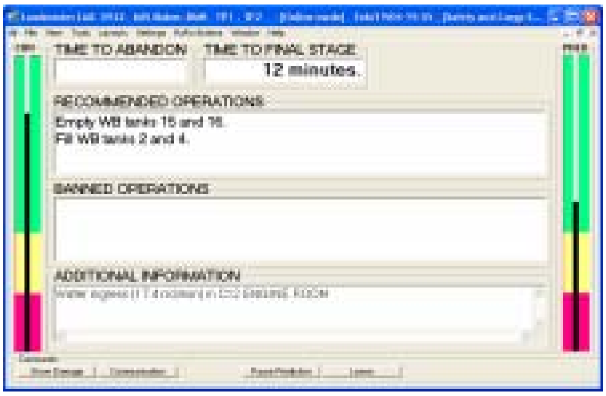

Figure 3 Example of information displayed by the SCS.

There have been some delays in the development of the prototype and today the system can only provide information about the static stability of a ship.

4. METHOD

The method used to develop an education in damage stability control was a combination of literature studies (References under BOOK REFERNCES) and interviews with teachers and Master Mariners. The interviews were semi structured which means that the interviewer is prepared with the main questions but leave some place for the interviewed person to evolve the answers to questions them selves. The interviews were conducted at Chalmers University of Technology. The work resulted in a course plan which was tested on a reference group consisting of teachers and master mariners and finally on a group of 16 students of a class of Master Mariners in the 3rd year of their education.

5. RESULTS AND CONCLUSIONS

The results from the literature studies and the interviews are here presented together.

5.1 What is Appropriate to Learn

Damage stability is a problem that easily can grow and become very big. There are many questions to be answered in a damage situation which can vary a lot and be very complex depending of factors like for example: the ship design, weather, type and amount of cargo. It is difficult to specify actions that are obvious and "correct" or best and that generally will solve all problems. What may be a good decision in one situation, like compensation with ballast water, may not be a good decision in another situation, for example when there is a high likelihood of free water surface. Some examples of important questions are: should we compensate a list with ballast water, can we safely maneuver this ship around, is it possible to get of a grounded situation or is it better to stay on the ground. It is not fair to expect a student to become an expert in this area after one course in damage stability. A realistic aim of a course in damage stability is rather to provide a good learning situation where the students could be given the opportunity and the tools to understand some general problems. One way of reaching this is to highlight some basic factors and how they affect a damage situation. Since a damage situation often is very specific the recommended way of learning what to do is to have discussions based on cases and to evaluate affecting phenomena like wind and wave conditions and how the ship is likely to respond to damage in a specific part of the ship and what consequences this may cause. These cases could be based on previous accidents. Identified chain breakers of accident events could be discussed. Earlier scientific studies concerning behavior of damaged ships, flooding and its intermediate stages could also be highlighted and discussed [Schreuder, Spanos, De Kat, Ikeda, Palazzi and Vassalos].

A desirable aim is to achieve a growing self confidence, for the student, to understand problems in a damage situation and to promote a problem solving oriented thinking. Given the experience that the knowledge of theories of stability decreases, when they are not actively used, the aim was to design an education that is both practical and theoretical and that focuses on understanding phenomena and problem solving. This is believed to create a deep understanding with a practical orientation of what to do.

5.2 Design of the Education

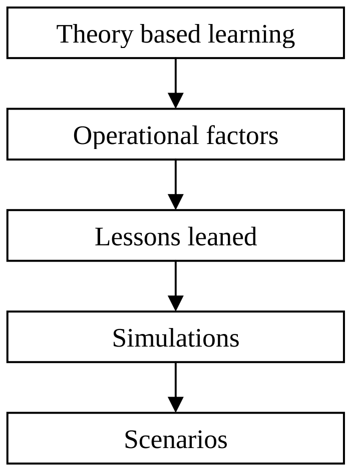

Figure 4 Different blocks in the education of damage stability.

In the striving of achieving and supporting the aims of the course in damage stability the following design of the course is put forward. The different parts are presented in five groups consisting of: theory based learning, operational factors, lessons learned, simulations and scenarios. How these blocks are linked is shown in figure 4. The different lectures within the groups, presented below picture 4, are marked with Italic.

Theory based learning The basics of ship stability are repeated to get all the students "up to date" and to teach the *basic terminology*. After that some theoretical perspective of the *effects of damage and leaking* like for example "loss of buoyancy" or "added mass" are discussed and practiced. This is followed by the *regulations of SOLAS* in order to better understand the constructions and what the rules recommend and allow considering ship stability.

Operational factors Some basic understanding of *human factors* ought to be discussed. How do humans react to stress and what are we supposed to expect from our selves and others? This part is important for understanding the situation and the stress that naturally could be expected. Afterwards follows demonstrations of the *decision aids SCS and DIP*. This is done to give an overview and presentation of existing technique considering decision support. This part also gives a better understanding for the phenomena affecting and problems like for example what kind of information is needed and how to get a hold of it. It is easy to imagine that without gauges, sensors or video cameras one has to send a messenger instead and that would most likely take more time, which in it self is very valuable.

Lessons learned This part of the education focus at earlier accidents and "*lessons learned"*. Previous accidents like for instance Karelia 1986 (sunk at Gotska Sandön, Swedish water) and Vinca Gorthon 1988 (sunk in the North Sea) is presented and discussed. Previous research in the area like for instance the work with "chain-breaker" also ought to be highlighted and discussed. When dealing with earlier accident focus is put on factors that made the specific situation hazardous. One ought to be restrictive and careful to not "over-generalize" from earlier accidents.

Simulations After the theoretical start the students get to practice with tools that exist in the problem area. It could be done through charts like the DIP or computer interactive tools like SCS and Load master. Although the SCS is not developed as planned, the prototype based on the program Loadmaster is used today.

The intention with this part of the education is to practice problem solving based on some of the theory given before in combination with a more reality based approach of a damage situation. It is important that the students get the opportunity to practice with the tools in a "trial and error" mode to become comfortable with both the problems and the tools that could be used for solving them. In figure 5 a ship with different damages is shown. The damaged area is marked with red (black) colour. By having to deal with different damages on the same ship the students get feedback on their hypothesis and get the opportunity to deal with problems giving different outcomes, like for instance loss of cargo or loss of propulsion, which drastically can affect the situation.

Scenarios As the last part of the education *scenarios* are used. These *scenarios* differ from the *simulation* in the aspect of that the decisions made should be motivated and not have the character of "trial and error". The scenarios can show how well the students have understood the basic factors and the phenomena related to the area. One important part of the scenario is to let the students solve the problem without charts and computer aid first. After that they get to use the Loadmaster and get feedback on their ideas of ship behaviour and the actions that they would like to take.

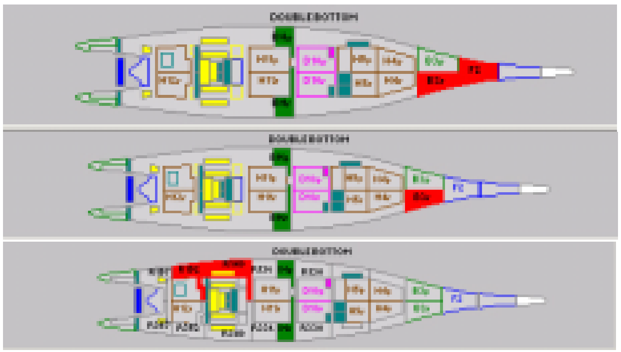

Figure 5 Examples of different damages, marked red, presented in the SCS.

5.3 Education Evaluation

The results from the evaluation of the test class were positive. The main part of the class was very positive to the education and reported that the material gave the expected support to be able to work towards the objectives. The students liked the problem solving orientation and comments implied that the students would like to have more of the computer experiments and more of the computer aided exercises. The students further reported that the material in the course contained a reasonable level of material due to the time of the course. Comments also indicated that the students thought that the course ought to be implemented in the ordinary mariner education program.

6. DECISION SUPPORT DESIGN

Although the technique is evolving quickly it is important to adapt it to the specific work situation in a proper way. There are examples of technique implemented without respect to the needed education or the understanding of how it will effect the working situation.

One example of the impact of new technique is when electronic navigation charts were tested in a simulator and the Master Mariners in the test group tended to develop new behavior that could have the negative effect on safety related to regulations of how to navigate to avoid other ships. There is also research showing that the human being is remarkable at adapting to technology. Based on that, it ought to be natural to strive for making systems that support the humans instead of humans adapting to systems. It is proposed that new technology ought to be carefully evaluated before put into use. A decision aid ought to provide information in a way that feels natural to the user and that is recognized in performing the task. It is further good if the system could be adapted after the users' potential. There have been examples of radar displays that show as much information as possible without the possibility of reducing the amount of information on the display.

This could cause too much information at one occasion although some of the information very well could be important in a later or different situation. In this case it would be good if the system could be adapted to the user.

How to adapt a product to the end-user is not a new problem and today there are even recommendations for how to evaluate and test products early in the manufacturing process to be able to cut costs. Further the user must know the system boundaries, for example what data the system relies on and what the system can perform. The boundaries also ought to be well adjusted to the task.

Parts of the research of decision making have worked on how human machine interaction ought to be designed to really be helpful. One example of a theory which could be helpful was presented at a conference of decision making by Woods. He emphasizes the role of two functions, one called *coordination* and it represents the ability to coordinate and synchronize activity across agents. One example of this could be the possibility to counter fill a ballast tank through the SCS. The other function is called *resilience* and it represents the ability to anticipate and adapt to potential surprise and error. This could be exemplified by the information given by the SCS regarding current state and expected final state. Woods further describes 5 sub-functions that when correctly supported will achieve *coordination* and *resilience*. Maybe this system could serve as foundation for further development and evaluation of decision support.

7. DISCUSSION AND FUTURE WORK

This paper presents some problems arising in education of ship crews on the subject of management of crises such as loss of stability after flooding. Focus was put on how to create a situation that could stimulate the students to learn about damage stability and basic phenomena affecting a damage situation. This is done by a combination of theoretical and practical problem solving. After the first course and some reflection the course designer had drawn some conclusions or “lessons learned”. More time in the simulation-phase was asked for. More effort could be put in making scenarios and practices more similar to real accidents. Further the thought of making the knowledge more durable, compared to the basic stability theory, with the combination of theoretical and practical problem solving with a more “hands on” direction could be evaluated. How to teach damage stability is still considered by the authors a challenge due to the basic pedagogical facts of how to educate for durable effects. One way of solving this question and perhaps practically the best is to recommend repeated training.

In the future more research could be done in the area of decision making on a ship bridge. This would give more answers to what equipment is used and needed. This would also give a good base for the continuation of developing decision support and other equipment meant to be used on a ship bridge. For example questions of single person decision, group decisions or other organizational aspects of work on a ship bridge in a damage situation could be investigated.

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