Review of the Ship Accidents Investigations Presented at the STAB Works/Conferences

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ABSTRACT

The safety of seafarers and passengers and the protection of the marine environment can be enhanced by timely and accurate reports identifying the circumstances and causes of marine casualties and incidents. These reports can lead to greater awareness of casualty causation and result in remedial measures for the purpose of enhancing safety of life at sea and protection of the marine environment. This "review paper" collects several contributions presented through the years in different STAB events.

KEYWORDS

Ship accidents; stability; ship behaviour.

INTRODUCTION

As it is mentioned by IMO, Resolution A849(20), the safety of seafarers and passengers and the protection of the marine environment can be enhanced by timely and accurate reports identifying the circumstances and causes of marine casualties and incidents.

The investigation and proper analysis of marine casualties and incidents can lead to greater awareness of casualty causation and result in remedial measures for the purpose of enhancing safety of life at sea and protection of the marine environment.

This Resolution introduces the "Code for the investigation of marine casualties and incidents". This Code recognizes that under IMO conventions each flag State has a duty to conduct an investigation into any casualty occurring to any its ships when judges that such an investigation may assist in determining what changes in the present regulations may be desirable or if such casualty has produced a major deleterious effect upon the environment.

Through the diverse Proceedings of the STAB Conferences/Workshops, many papers dealing with ship accidents, mainly related with stability, have been presented. Although they are not "official reports" can shed light about the cause of the incident and increase the knowledge about the ship safety.

Many of these contributions are presented in this "review paper".

STAB 1975 (Glasgow)

Tanker, EDITH TERKOL

A small Danish tanker, “EDITH TERKOL” (Kure, 1975), having GZ-curves complying with the IMO recommendations capsized in the Baltic Sea near the Swedish island of Goland. She was on a ballast journey and steamed south in a stern quartering sea. In between she rolled rather heavily and suddenly she capsized. The weather had strength of Beaufort 6-7. Only two persons survived.

After model tests and different numerical considerations the final hypothesis concludes that the ship was rolling moderately in stern quartering seas. The GZ-curve was varying as the waves overtook the ship in a non-harmonic way causing the particular motion from one side to the other which should end up as the ship’s ultimate half roll to have much reduced righting levers. This caused a continuous lagging of the roll motion behind the sway and yaw motion. The lagging disturbed the balance between the large wave exciting moment and the large sway acceleration moment existing in the harmonic motion, where they almost completely cancelled each other out. The new resultant of these two, outweighs the remaining righting levers and accelerates the roll motion into capsize.

STAB 1982 (Tokyo)

Hotel Platform “Alexander L. Kielland”

The “ALEXANDER L. KIELLAND” was originally built as a drilling rig, but had always served as an accommodation platform for the Ekofish field in the North Sea. There had been four modifications in which new containers were mounted on the deck, forward of the drilling tower.

It was a pentagone type platform. The buoyancy came from five individual columns/pontoons supported by a system of bracings. The lower horizontal bracings were free-flooded, the other ones were watertight.

On the 27th of March 1980 at about 6.30 p.m. one of the supporting columns broke off when the platform was in service. The failure started with a fatigue crack in bracing D-6, the five other bracings connecting column D to the platform subsequently failed from overloading, resulting in a total loss of column D. The platform almost immediately heeled over to an angle of 30-35 degrees. From this position it continued slowly to heel and sink, until it capsized after about 20 minutes. Out of the 212 men onboard, 123 lost their lives.

Columns C and E were submerged, and it is thought that down flooding took place through the doors and ventilators of these columns. However, considering the rapidity with which the platform capsized, there is also a possibility that flooding took place through openings caused by structural damage. This income of water would imply that half of the deck space would be filled by then.

The paper on the capsizing of this platform (Rusaas, 1982), dealt with some aspects and circumstances of the described accident.

It was assumed that the mooring system delayed the capsizing only for a few minutes and that it was not possible to prevent the capsizing by a redistribution of ballast because the power supply failed when the platform heeled over.

The calculations showed that the platform capsized due to progressive flooding in the deck structure. The capsizing occurred when the filling reached about 75-80% of the available space.

It was also suggested in that study that semi-submersibles should have a reserve of buoyancy in the deck, since the calculations made after the capsizing showed that without buoyancy in the deck structure, the platform would capsize at any loss in the supporting system.

STAB 1986 (Gdansk, Poland)

Large Stern Trawler

On 6th January 1982, a large stern trawler of 549 gross tonnage, similar to the "GAUL", capsized and founded during hauling a net in the Bering Sea. Out of 33 crews on board, 32 members lost their lives and only third officer was saved by her friend ship.

The vessel had two decks between which there was a large fish processing factory, and there were two openings called garbage shoots on the sides in the factory. There was no testimony concerning whether those garbage shoots were closed or left open.

Model experiments on ship motions in her various intact and flooded conditions were explained in the paper presented (Kan, 1986). These experiments did not show any evidence of poor seakeeping. Measurements of intact stability showed a good agreement with the calculation which met the criteria with a substantial margin. Stabilities with the free water in the factory and in process of flooding trough the garbage shoots were also measured, and besides capsizing tests of the initially heeled model with open garbage shoots were performed. From these results and other examinations, including the testimony of the survivor, it was concluded that the capsizing had been caused by water flooding through the unclosed garbage shoots into the factory and then, probably into the fish hold.

"RF2" rescue vessel

The self-righting ability of the almost new-built rescue vessel RF2 was analysed in the presented paper (Guldhammer, 1986). This boat capsized in Skagerak in 1981, with the loss of 6 men. Investigation proved that the stability was substantially less than desired. However, the accident was explained as being due to bad circumstances.

The vessel left station at Hirstshals to search for survivors from a cutter. Before "RF2" managed to terminate action and return safely to the harbour, she was struck just outside the harbour by a breaking wave, lifted on the wave crest only to fall down in the trough at the same time heeling 90º to the port side. The vessel was not able to right her-self, and some seconds later turned upside down.

When the vessel was turned to even keel, it was discovered that the entire top of the wheel house was torn away and the two windows in the port side plus a few more blown in. The hull, however, was almost intact.

The appearance of an amateur film from the self-righting test renewed the investigations. The analysis of this film concluded that the test as in fact carried out was no proof of stability.

STAB 1994 (Florida, EEUU)

RO-Ro ships in waves

The paper presented in 1994 (Jiambo, 1994) provided a compilation of some of the most significant capsizing accidents performed by Ro-Ro ships during the decades of the 80s and 90s in Europe.

Among these we can find the "ZENOBIA", she which capsized in 1980 as a consequence of load shifting onboard caused by an uncontrollable manoeuvre motion.

The "HERALD OF FREE ENTERPRISE", which capsized outside the port of Zeebrugge (Belgium) on her route to Dover in 1987, over 180 human lives were lost. The reason for the capsize was that the ferry was trimmed by bow and had the bow doors open so that the water got ingress to the car deck as the ship's speed increased.

The "VINCA GORTHON" was a Ro-Ro ship for paper product transport from Sweden to the European Continent, and she sank in 1988 due to the load shifting caused by the simultaneous effect of vertical and horizontal acceleration, and roll motion at a moderate sea.

The “JAN HEWELIUSZ” capsized under a severe storm over the Baltic sea in 1993. Fifty-five lives were lost in the accident.

The result presented in that paper is a theoretical study showing that Ro-Ro ships can be subjected to the parametrically excited roll motion not only in regular but also in irregular waves. It was also mention that the study of the dynamic stability problems of a RoRo ship in waves must consider the combination of model tests and computer-simulation.

“STARTS PRIDE II” fishing vessel

The paper on the capsizing of the fishing vessel “STRAITS PRIDE II” (Bass, 1994) analysed the importance of paravanes with regards to the stability of a ship, and considered them as an element to be taken into account during the design process. This study focused on the capsizing of this small fishing vessel, which partially lost the side paravane in the capsize, and pointed at other capsizes where the paravane was considered to be a contributing factor.

Although the results of the experiments did not show the moment generated by the single paravane as responsible for the capsizing, it was possible that it was so for the ingress of water into the fish hold, and the subsequent shift of the fish cargo. In any case, the study suggested that the cause for the capsize was a complex interaction of a number of factors associated with asymmetric roll, wind, drift, the single paravane deployment, and the movement of water and fish in the fish hold.

In this capsizing there were two factors to be taken into consideration in subsequent studies: the additional roll damping added to the vessel by the paravane, assumed as an increase of stability; and the significant modification of the roll of the vessel under certain conditions due to the paravane, considered, in this case, as a lack of stability.

It was not certain that freeing the vessel of the paravane would have saved her from capsizing, but it was clear that paravanes do affect the roll damping and therefore the dynamic stability of small fishing vessels.

STAB 1997 (Varna)

General Cargo Ship

A general cargo ship sank in front of the Catalonia Coast (Spain) after two hours of her departure, the weather conditions being excellent. The accident was investigated by both port authorities and the service company involved. Studies on ship buoyancy and stability were performed, in order to determine the causes of the capsizing, and the conditions in the moment of the loss. Those studies were analysed in the paper presented by Prof. Sagarra (Sagarra 1997). Some of the conclusions reached, pointed to the loading condition and the stability situation of the ship as the main hypothesis of the capsizing.

The information given by the port authorities revealed that the ship was overloaded at her departure, with an extra weight of 370 T, and that she arrived at the port with ballast, which made her trim aft.

Both the ballast water formerly carried and the extra weight on board made the ship leave port overloaded and she did not reach the minimum stability criteria established by the IMO. These studies showed the deficiency of stability as the main reason for the loss of the ship.

The studies concluded that the ship did not have enough reserve of stability to confront a cruise and therefore could not recover from a small heel, which made her heel over completely until she sunk.

Purse Seiner

A purse seiner capsized in beam seas, in East China in 1993. There was only one survivor and the cause and process of the capsizing are still unknown nowadays. An experimental study was carried out with a model in order to clarify whether the fishing net resulted in a shift capable of capsizing the vessel or not. (Shin, 1997)

It was known that the seiner was inclined for a few minutes before capsizing, and that condition caused shipping water to accumulate on the deck and the net on the deck to shift in the same direction. However, also to be taken into account was the fact that the net was not fixed on the deck when the storm reached the vessel and shipping spray occurred frequently on the deck and starboard deck which made the ship roll to starboard, increasing more and more the inclination. In the end, the vessel inclined more than 25 degrees to the starboard, was incapable of restoring her upright condition, and finally capsized.

The model was tested in the upright condition and two inclined positions: 5 and 10 degrees. The capsizing experiment revealed that the purse seiner did not capsize in the upright condition, and although she did in the inclined positions, it was normally due to the shipping water which had accumulated on the deck.

The testing concluded that the inclined condition caused shipping water on the deck and developed into the capsizing. There was also a possibility that a slight inclined condition due to a shift of the fishing net led to the capsizing. The purse seiner capsized easily even if the metacentric height was enough to maintain stability in the upright condition.

STAB 2000 (Launceston)

Racing Yatch "MARINE"

On December 30, 1991 the racing yacht "MARINE" capsized when sailing from Japan to Guam due to the breakage of her fin-keel at its root. Eight lives were lost in the accident.

The study presented (Kagemoto 2000) showed the results of the investigation on the possibility of the loss of the fin-keel due to severe weather conditions.

A model was constructed to measure the force and the moment acting on the fin-keel. Numerical calculations were also conducted and the results were compared with the experimental data obtained in a wave tank. The items measured in the experiments were motions of the model and the force/moment acting on the fin-keel.

A yacht is designed to possess a large restoring moment, and so its resonant period is shorter than that of conventional ships. This suggests that the roll motion is the dominant cause of the lateral force and moment on a fin-keel.

By means of the comparisons between the experimental results and the theoretical calculations on the force and the moment that will act on fin-keels, it was concluded that these could be well predicted by the theoretical calculations based on the linear potential theory. However, the predictions of the force and the moment that may have acted on the yacht at the time of her capsizing might be considered to be meaningful.

The investigation showed that it was very unlikely that the moment or the vertical force reached large enough values so as to break the fin-keel of the "MARINE" off her canoe body in the sea state as reported at the time of the accident. The results indicated that the moment should have been twice the value of the largest moment expected. This fact implied that either the fin-keel did not have the expected structural strength or she encountered certain extreme loads such as an impact load caused by breaking waves.

Coastwise chemical Tanker

A coastwise chemical tanker sailing at full ahead capsized in calm waters while turning. The paper published on this subject (Sadakane, 2000) investigated the reasons of the accident, and judged the possibility of the capsizing trough the static righting arm weakened by the free surface effect of the cargo, and the influence of the low freeboard, that could endure the external heeling moment caused by turning.

Coastwise tankers have some typical characteristics relating to the transverse stability. For example, the freeboard is very low, causing the shipping of water on the upper deck which arises the centre of gravity and alters the trim. The cargo is a liquid with free surface that moves in wide tanks. In the case that the liquid is of high density, the stability loss due to the free surface effect appears more clearly.

A proper correction for the free surface effect of the liquid cargo was not performed in the initial design stage, and the quantity of the righting arm loss was quite different by correcting the free surface effect. The liquid cargo shift occurred when the ship turned and a significant outward heel moment was generated.

The shipped water, caused not only by wind waves but also by the ship own waves, increased the trim of the ship by flowing towards the low end. The trim made the freeboard lower. The righting arm was enough until the upper deck edge immersed.

There were two possible explanations for the capsizing: either the static righting arm weakened by the free surface effect or the influence of the low freeboard could not hold the external heel moment caused by turning.

WORKSHOP 2002 (New York)

Post-Panamax Container Ship

In October, 1998 a C11 class post-panamax container ship, eastbound in the north Pacific from Kaohsiung to Seattle, was overtaken by a severe storm. She carried a deck stow of some 1300 containers. As encounter with the storm became inevitable, the master hove to ride out the rough seas and winds. About 400 containers were lost overboard and another 400 collapsed or crushed during these motions. During the period of severest motions, port and starboard rolling of as much as 35 to 40 degrees was reported simultaneously with extreme pitching.

The C11 class vessels are 262 m LBP, 40 m Beam, and 24.25 m Depth with a loaded draft of about 12.5 m. Pre-construction model testing indicated no significant rolling in head and bow quartering seas.

An extensive investigation was undertaken to determine whether head-sea parametric rolling could have been the cause of the vessel's extreme motions. This investigation, and its results were explained in the paper presented (France, 2002). Initially, computer modelling was carried out using nonlinear, time domain programs developed by the Maritime Institute of the Netherlands (MARIN) and by Science Applications International Corporation (SAIC). Both programs predicted rolling between 30 and 40 degrees for the vessel in the head seas encountered.

Vessels with flat transom sterns and significant bow flare are most prone to parametric rolling, due to the large variations in stability these vessels undergo in head and near head seas. Bow flare is also of importance due to the righting energy introduced at maximum roll angle, when ship is pitched down by the head.

It was also found that parametric rolling in head seas introduced loads into on-deck container stacks and their securing systems well in excess of those derived from classification society guidelines, or predicted though linear seakeeping analysis. The large roll amplitudes that are developed and the in-phase relationship of pitch and roll accelerations are of particular importance.

This case point out that the head-sea parametric rolling might be relatively common although otherwise unfamiliar to mariners and vessel operators.

Fishing Vessel "ARTIC ROSE"

On April 2, 2001 the 92 ft fishing vessel "*ARTIC ROSE"* disappeared in the Bering Sea, killing all fifteen men onboard. The US Coast Guard convened a Formal Marine Board of Investigation (FMBI) to determine what happened to the ship.

The Marine Safety Center (MSC) provided naval architecture supported to the FMBI throughout their investigation, which was detailed in the paper (Borlase 2002). .

According to the analysis, the most likely reason the "*ARTIC ROSE"* sank was progressive flooding from the weather deck to the processing space through an open door connecting the two areas, and the flooding then progressed to the galley, fish hold and engine room through non-watertight doors and hatches.

Water on deck often led to progressive flooding into spaces inside the fishing vessel in which watertight doors and hatches had been left open, which was precisely the scenario the author believed most likely caused the loss of the "*ARTIC ROSE"*.

In order to compute the capsize resistance of the ship, the MSC calculated the non-linear safe basin erosion for different frequencies. Using a digitized underwater hull model, the inertia, added mass, non-linear damping, and wave force terms were calculated.

The results showed the "*ARTIC ROSE"* most likely capsized between 1 minute 40 second and 2 minutes 40 seconds after progressive flooding began, due largely to the free surface effect of the water trapped inside the vessel.

STAB 2003 (Madrid)

Ro-Ro Passenger Ferry "EXPRESS SAMINA"

The Ro-Ro passenger ferry "EXPRESS SAMINA" sank at the entranceways to the port of the island of Paros in September 26, 2000. Over eighty people died in the accident. The ship collided with a rocky islet on starboard sideways. It caused damages both below and above waterline.

Immediately following the collision, water started pouring through the fin damage opening into the main engine room and progressively into the other compartments through open left watertight doors.

The objective of the investigation was to clarify the causes of the collision, the way of flooding and foundering of the ship. A series of studies were carried out to check the compliance of the ship with the relevant regulations and, as far as the ship's damage stability characteristics are concerned, it was confirmed that the ship complied with the provisions of EUROSOLAS regulatory framework.

The investigation into the sinking, and specifically the ship's damage stability behaviour were outlined in the paper (Papanikolaou, 2003).

There were two significant results of the used numerical simulation method, the flooding sequence of the compartments and the time series of the various incurred events, including ship's motion and sinking. In the simulation analysis the effect of shift of cargo was also considered, since the ship obtained large heeling angles and the not lashed cars on ship's car deck fell to the side.

The employment of a nonlinear time domain simulation method facilitated the identification of the most probable flooding scenario, the ship's heeling time history and the estimation of the time sinking. Progressive flooding through open left watertight doors was found to be the main reason for ship's sinking.

Fishing Vessel "RYUHO MARU no.5"

The Japanese offshore trawler "RYUHO MARU NO.5" capsized off the Erimo Cape of Hokkaido on September 11, 2000, while hauling a fishing net. Fourteen men out of eighteen lost their lives in the accident.

The main factors related to the accident were hauling much amount of fish on the upper deck, rough manoeuvring, shift of unlashed items on board and shift of the cod end with fish over the inner bulwark. The effects of each factor on the stability and on the heeling moment of the ship were evaluated through a parametric study described in the paper (Taguchi, 2003)

Stability calculations were carried out with trim free condition. The free surface effect in fuel oil tanks was taken into account and so the shift of the centre of gravity due to the shifting of fuel oil.

Hauling much amount of fish onboard raised the centre of gravity of the vessel and reduced the stability. This led to a reduced freeboard and a large trim by stern, therefore the flooding angle on the aft part of the hull was reduced.

The outward heeling moment by turning of the vessel was smaller than the heeling moment due to shift of the cod end, but it keeps working along the capsizing motion, so its effect becomes very large.

The accident was considered to be caused be the combination of all the mentioned factors: hauling much amount of fish, rough manoeuvring, unlashed items on deck and the shift of the cod end with fish over the inner bulwark.

WORKSHOP 2005 (Istambul)

Small size LPG tanker

A small size LPG tanker was found in a capsized position by a Danish ship near Calamata bay off the coast of Mora Peninsula in the Mediterranean Sea on March 25, 1969. Seventeen people perished in the tragic accident. A committee of experts was established to investigate the accident.

The tanker had no cargo at the time of accident, but the ballast and fore peak were full. The capsize took about two minutes without wild rolling. The roll period was claimed to be long and the roll motion was slow.

Although stability of the tanker complied with the IMO standards (based on SOLAS 1966), her stability in waves needed to be checked since it was in rough seas at the time of capsize. The IMO weather criterion was applied to the design loading conditions. When the requirements of weather criterion were compared with the results, it was seen that although all the cases met the roll area requirement, three of the cases failed to meet list angle requirement. That meant that the tanker was not fully in compliance with the IMO weather criterion.

Another aspect of the capsize was the loss of stability especially on wave crest. It was found that the stability was reduced greatly on wave crest with compared to calm water stability.

Main aims of the paper presented (Taylan, 2005), were drawing attention to technological evolution in ship science and engineering and the response of International organizations such as IMO and classification societies to this evolution.

STAB 2006 (Rio de Janeiro)

"O BAHÍA" fishing vessel

A small purse seiner capsized in June 2004 near Sisargas Islands in the North of Spain. The ship was sailing in following seas with significant wave height when she suddenly capsized and sunk without any previous distress communication. There were no survivors among the ten members of the crew.

The circumstances in which the ship was sailing were considered as dangerous according to the IMO guidelines. This and the suddenness of the capsizing clearly indicate that the accident might have been a consequence of the sea condition.

Model tests in regular and irregular waves (Maron, 2006) were carried out at CEHIPAR in wave condition similar to those known to exist at the time of the accident. A model boat was built reproducing underwater hull and also superstructure. She was provided with bulwark ports and their closures, which reproduced those in the shipwrecked vessel. The model ship was loaded to reproduce the accident's displacement, but also the longitudinal and transverse inertia, and proper GM.

At first, only irregular tests were taken. However, the initial results suggested the convenience of trying also with some specific regular waves. Therefore, the model was tested in regular wave fields with height and amplitudes with a low but appreciable probability of appearance. Only one of the tested waves resulted in the capsizing of the model. The probability of occurrence of a similar wave was about 2%.

It was concluded that the capsizing could have been the result of a loss of stability in following seas accompanied by massive water shipping on the working deck. It could be argued that the ship was not in regular waves, but the numerical simulation shows that when a big wave appears, the previous and the following waves have similar characteristics.

Cruising Yatch

On 15 September, 2003 a cruising yacht sunk in Lake Biwa in Japan. Seven of the twelve members of the crew drowned. An investigation on the accident was carried out using a model in order to identify the time-to-sink, and stability calculations, with and without water inside the yacht. The results indicated that the yacht could capsize when the wind velocity exceeded a threshold.

The yacht was rigged as sloop and has a cabin, fin keel, rudder and an outboard motor. The cabin had two openings, a companionway and a hole for ventilator on deck at bow.

At the moment of the accident, the skipper failed to helm amidships and to release the main sheet from the cleat, causing a significant roll towards port side. One adult and one child situated on the starboard-side deck dropped onto the main sail, then the rest of the crew dropped into the water and the yacht completely capsized. Shortly after, the yacht started to re-right but its stern was under water due to flooding water. Initially the water entered into the cabin through an open hatch, and finally the yacht sunk from the stern.

The loading condition at the moment of the accident reduced significantly the restoring moment because of the weight added by the crew. As a matter of fact the static stability in this condition can be regarded as insufficient (IMO). When the crew dropped into the water the static stability increased.

Once the capsizing had occurred, the roll motion immediately stopped because of large roll damping.

One significant result from the test (Umeda, 2006) was that when the wind speed was more than 10 m/s, additional heel could allow air egress, and water ingress. When the flooded water exceeded 2 m^3, the yacht could start re-right. Trim by stern could occur because of the large amount of water, and the companionway could submerge. If bow hole was open, air egress through the hole and water ingress through the companionway could result in sinking of the yacht.

Air flow required both the bow hole and the companionway to be open. In particular, in cases where the companionway was closed and the wind speed was strong enough, the model completely re-righted and sailed again. Therefore, when the wind speed increased, time-to-sink decreased.

The measured wind speed at the accident exceeded the critical wind speed for capsizing and re-righting. Under this condition the static equilibrium existed but dynamic equilibrium did not. The roll angle exceeded the angle of vanishing stability and therefore capsizing could not be avoided.

The results of the tests also showed that the relocation of the crew was not the primary cause of the accident.

Trawler MFV "GAUL"

In February 1974, the trawler MFV "GAUL" was lost in heavy seas off the North Cape of Norway. Its wreck was discovered in 1997 and she had the lids of the duff and offal chutes open. The chutes are normally positioned on the starboard side of the vessel and serve to remove waste from the factory deck. After the investigation, it was concluded that the steering nozzle was at its maximum angle and the propeller was at a high pitch setting, indicating that the vessel was manoeuvring prior to sink.

The research presented in the paper published in 2006 (van Walree 2006), focused on the results of investigations in to the dynamic stability of the Gaul in intact and partially flooded conditions. Their main objective was to asses the behaviour of the vessel in the sea state believed to be present at the time of the loss. The performance of the vessel was determined by means of model tests and numerical simulations

A series of simulations with various flooding arrangements were carried out in order to obtain a more complete insight into the performance of the trawler in the conditions of the accident. Its purpose was to assess the susceptibility of capsizing and to measure the amount of water entering through the chutes and the factory space access door. The model, which showed rather good seakeeping characteristics in relation to the heavy sea generated, did not capsize during the tests. This result concluded that the vessel was not at risk in the intact condition.

The initial results indicated that down flooding through the two chutes was substantial when the ship operated in beam to stern quartering seas and that progressive down flooding could have led to the capsizing.

Down flooding showed a threshold character, which was crossed only under particular conditions during the simulations.

Typical operability criteria based on acceleration components and roll angle were exceeded during virtually all test conditions, indicating that the performance of normal duties must have been very difficult for the crew.

Combination of heading, speed and resulting water ingress could have been threatening to the survivability of the ship.

Motor Vessel "RECHITSA"

The motor vessel "RECHITSA" tipped and sunk in November 26, 1976 at an exit to Mediterranean Sea. The vessel carried onboard a cargo of a steel rolled wire in coves, loaded by bulk in all eight cargo compartments. This is Elastically Movable Cargo. EMC, when being deformed or sprung down and aside, causes variations in the mass moment of inertia of the oscillatory system. The paper presented at this Conference (Vorobyov, 2006) analysed the stability and rolling of this vessel, loaded with elastically movable cargo.

At her departure, the vessel met the stability requirements of the Register of Shipping of the USSR. The rolled wire in coves had never been mentioned in any official normative document as a cargo which is dangerous for ship stability conditions. Thus, no resolution existed regarding special measures to be taken during the loading of a vessel with EMC.

The official investigation established that, when EMC cargo was steeped by bulk, residual deformations of compression and shifting were obtained. The properties of this type of cargo could result in significantly influence the stability of the vessel, this effect was strengthened, in the case of the accident, by the incomplete filling of the cargo compartments at loading, and the subsequent self-packing of cargo. At the moment of the accident more than 25% of the volume of total space in the upper part of the cargo compartments was empty.

The results of the analysis had proved the necessity of taking into account change of mass moment of inertia for EMC in calculations of rolling for vessel with specific cargoes of EMC type.

A vessel loaded with EMC possesses special dynamic properties to incoming waves when navigating in heavy seas. This is due to special properties of cargo, such as the fluctuation in the mass moment of inertia of a cargo that induces a parametric resonance of a vessel rolling; and appreciable changes on vertical position of the centre of gravity of the ship due to condensation and deformation of cargo.

Under the same loading and wave conditions, the solution of traditional roll equation demonstrates a normal rolling process, while specialized equation regarding EMC properties shows the capsizing of the vessel.

The results of this research indicated the vital necessity of adding to the known line of moving cargoes an additional one: elastically movable cargo. It was also remarked the necessity of supplying the navigators transporting this cargo with reliable regulating documents.

"O BAHIA", "NUEVO PILIN" and "ENRIQUE EL MORICO", small Fishing Vessels

The paper presented (Perez-Rojas, 2006) described three similar accidents involving fishing vessels occurred in the coast of Spain. These casualties were analysed in order to shed some light in this type of accident in which the stability gets a very important role.

The "O BAHIA", already commented in other paper, sank at the Sisargas Islands in June 2, 2004. It drew to death six crewmen and other four disappeared. The "ENRIQUE EL MORICO" sank due to two successive sea strokes in August 3, 2004 at the Alboran Sea. The "NUEVO PILÍN" was lost in the Cantabric Sea in November 19, 2004. Three crewmen were dead and two more disappeared.

The ship lines were very similar and a significant change on the predominant wave direction was detected in the 3 cases.

All requirements regarding the stability were accomplished by the three ships, but in some cases very slightly. The stability values were recalculated and some significant differences had been found, these discrepancies mean that some stability criteria were not fulfilled. Both critical wave length and height considered by IMO are fulfilled in the three accidents.

In order to evaluate the loss of stability on waves, some calculations were performed and the conclusion was that stability reductions due to waves were very significant. If these considerations with the waves were taken into account at the presumable accident loading and wave conditions, the likely cause for the casualties of the three ships presented in this paper could be a poor stability conditions and a very sensitive response to waves.

WORKSHOP 2007 (Hamburg)

MV "ESTONIA"

The MV "ESTONIA" sank on September 28, 1994 in the Baltic Sea on its way from Tallinn to Stockholm. At least, 852 human lives were lost in the accident.

The Joint Accident Investigation Commission (JAIC) published its report in 1997 but the discussion on the MV "ESTONIA" has not calmed down after all these years. Therefore, the Swedish Government authorized a new study in 2005. The paper described here, (Valanto,2007) gave information on the methods used in the on-going HSVA investigation and on some first preliminary results.

In this study, new ways to model the inflow-outflow from the vehicle deck have been applied, since it was believed crucial.

An evacuation analysis would help to establish as complete picture of the MV "ESTONIA" accident as possible. The software AENEAS was used for simulations with the real ship population and the newly estimated ship's list as a function of time. The differences between them were expected to be significant. This may help to develop the guidelines further. The evacuation analysis is still far from complete and was not reported further in that paper.

A new time sequence of the course of the accident was established based on the survivors' testimonies. This sequence of the ship's list was one of the crucial facts to be reproduced with the motion simulation.

It is known that the bow visor must have dropped in quite an early phase of the accident it pulled the ramp completely open. This conclusion have, however, been put into question by various interests groups working on the MV "ESTONIA". In order to throw some light on this early phase of the accident, different cases were investigated.

The accident scenario, according to the JAIC, was the one that assumes the ship navigating without the visor and with the ramp fully open.

The JAIC considered that through the open ramp enormous amount of water flowed on to the vehicle deck and the ship heeled. However, the author agreed with the possibility that the sudden heel was not a consequence of wave forces or massive ingress of water, but a consequence of the ship starting to turn to port.

A turn to port would bring the wind and the waves to the starboard side. This would have a straightening effect on the ship's list.

The water sloshing on the vehicle deck is likely to contribute to the magnitude of the sudden heeling motion. The inflow of water through the completely open bow increases due to the sudden heel.

The simulation conclusions for the sudden heel were:

- A sharp turn to port gives a plausible explanation to the sudden heeling motion of the ship reported by the survivors.
- The amount of water on the vehicle deck, appears to contribute to the magnitude of the sudden heeling motion.

The numerical computations showed how the water flowed from the open ramp to both sides of the central casing on the vehicle deck. The simulations revealed wild sloshing motion in the longitudinal direction when the ramp is fully open.

The obtained results gave an improved picture of the early phases of the accident, but they were preliminary ones. The HSVA investigation was going on.

A central point remarked in another paper on a plausible sinking scenario for the MV “ESTONIA” (Imstøl, 2007) was why the ship sunk by stern when the group of experts maintains water was up-flooding fairly far ahead.

A possible similarity between the MV “ESTONIA” and the MV “AL SALAM BOCCACCIO 98” cases was established in this new paper. For both ships, it had to be explained how the buoyancy represented by the freeboard as well as the car deck was lost.

The proposed scenario in this paper was as follows: at sometime during the evening of disaster, the pool-compartment, situated forward at the lower deck, started to leak. Flooding of the pool compartment would make the bow work harder and the pressure on the ramp would be higher than normal. As long as the trim was by stern, the ship could drain water from the car-deck by opening the rear ramp. However, sooner or later the ship would be likely to trim by head. Due to starboard heel and the gradient of the car-deck the starboard pilot door would become the lowest point of the car-deck and it would be the best option for additional drainage.

The scenario presented in the mentioned paper seemed to be in harmony with most witness observations and it should be considered plausible until it has been proven impossible by detailed simulations.

SS Fidamus ,MV Lohengrin, SS Irene Oldendorff and MV Finnbirch

The paper presented by Kluwe (Kluwe 2007) analysed a number of real capsizing accidents, which were related to poor stability in rough weather, showing that numerical simulations are suitable to identify safe and un-safe conditions clearly for specific ships.

On January 31, 1950 the 743 BRT vessel SS “FIDAMUS” capsized in heavy weather bound from Wismar to Antwerp close to Langeoog.The vessel suddenly heeled to more than 30 degrees and remained there. Water ingress then lead to capsizing within 10 minutes.

The ship did not carry ballast although this was strongly recommended in the stability booklet.

The numerical simulations carried out with the program E4-ROLLS showed that the vessel was permanently rolling with a maximum angle of 45 degrees. As the static angle of vanishing stability in still water conditions was beyond 90 degrees, it was theoretically not possible to capsize the vessel without any additional heeling moment. Also, a significant amount of water was entrapped between hatchway coming and bulwark, which produced a sufficient heeling moment to keep the ship at a steady list.

On January 14, 1950 the 955 BRT vessel MV “LOHENGRIN” capsized in heavy weather bound from Iggesund to Kiel. The waves encountered the vessel from abaft. The vessel heeled to 40-45 degrees starboard side and remained there with a steady list of the same size. The ship finally capsized one hour and a half later.

The numerical simulations clearly showed that the reason for the loss of this ship could be consistently explained by insufficient stability and a pure loss on the crest situation.

On December 31, 1951 the vessel SS “IRENE OLDENDORFF” capsized in heavy weather bound from Emden to Ystad in the Hubert Gat.

The simulation-based analysis showed that the reason for the loss of the ship could be consistently explained as an intact stability in extreme weather conditions. The loss of stability in the particular situation could be clearly related to water entrapped in the coke deck cargo, which could not drain off fast enough through the freeing ports.

On November 1, 2006 the 8500 dwt Ro-Ro ferry MV "FINNBIRCH" capsized in heavy weather in the Baltic Sea between the islands Gothland and Olland. The vessel was loaded with trailers, of which a significant amount was stowed on the top deck.

The ship was rolling significantly and heeled to about 50 degrees. The vessel remained in that intermediate equilibrium floating condition for a while until she capsized three hours later.

The official accident investigation has not been finished yet, therefore no investigation report is available so far.

The final conclusion that paper established was that the current stability criteria neither sufficient not suitable to avoid accidents related to stability alteration in waves.

"O BAHIA" and "ENRIQUE EL MORICO" small fishing vessels.

The capsizing of this two fishing vessels took place in the year 2004 in front of the Spanish coast. The investigation carried out by the CEHIPAR and the CEHINAV (Perez Rojas, 2007) was the continuation of the experiments performed in 2006 (Maron, 2006) which could not be completed because of the scale of the model.

The purpose of the experiments was to find how the mentioned ships sank and if the stability regulations for these types of vessels were appropriate. The "O BAHIA" was a purse seiner built in steel the year 1999. The "ENRIQUE EL MORICO" was a long liner built in FRP, the year 1999. Both boats are representative of the Spanish fishing vessels fleet, so, the analysis of their accidents was relevant.

Free running tests had been performed in regular waves with the models reproducing the accident´s loading condition, but within the regulation of watertightness.

It was nearly impossible to lead the models to capsizing, in spite the rough conditions studied, and the barely fulfilment of the stability criteria that these boats had at the moment of their accidents.

FINAL CONSIDERATIONS

Several papers dealing with ship accidents presented to different STAB events have been presented.

In general, there are not conclusive findings but in many cases feasible hypothesis can explain what happened.

Many situations point out that although the fulfilment of the IMO criteria was quite poor, the intact stability was enough even with extreme sea conditions. The watertighness of access, doors and openings were not kept.

The numerical calculations in the new reports can simulate adequately the capsizing scenarios. The experimental simulation is not the only way of accident investigation.

The accidents occurrence shown that the present regulations and practices can be improved

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