Discussion Paper

on the technical causes of Container Loss at Sea and suitable countermeasures

The facts speak for themselves. Container vessels, which are currently operating at 100 % capacity, sometimes lose considerable amounts of their deck cargo in bad weather in the North Pacific. This represents an existential threat to the crew and the ship and is not acceptable under any circumstances. Furthermore, goods to a value of several hundreds of millions of euros were destroyed in the six months of the winter of 2020/21. As if that were not enough, these goods additionally harbor a considerable potential for marine pollution and thus become a problem twice over.

The Loss Prevention Transport working group at GDV has therefore investigated and discussed the possible causes of these incidents, and has looked into how the transport of containers on large container vessels can again be done safely even when the ships are sailing at high capacity and in bad weather.

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Container Loss at Sea

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1 Introduction

Over the past years, container vessels have reached a size that takes little account of the ability of experience in design, construction and operation to keep pace. This has become particularly evident in recent times, as container vessels are in high demand and are operating at capacities that have not been seen for 10 years and reports of container losses at sea are increasing dramatically.

The seakeeping characteristics of large container vessels are heavily influenced by their design, which gives them a high basic level of stability in order to safely carry the huge quantities and weights of deck cargo. If vessels of this kind are not used to capacity in respect of the weight they are able to carry, they can be regarded as 'excessively stable' and are susceptible to strong rolling motion in heavy seas. Such movement becomes particularly dangerous during synchronous rolling and, due to the narrow underwater shape of these vessels, during parametric rolling. Both of these types of behavior, however, are outside the design conditions for the cargo securing systems developed by the classification societies and for which they are responsible. The fitting of anti-roll tanks as a means of improving seakeeping is not mandated.

- Other factors that contribute to the loss of containers at sea include:
- the enormous windage area of the high stacks of containers on deck,
- the possibility of incorrect stowage of excessively heavy containers, despite the prescribed weight declaration,
- sometimes inadequate securing of heavy cargo in containers,
- structural and functional defects in the containers themselves as a result of rough handling.

These causes and possible countermeasures are discussed below.

2 The development of container vessels

Although initial designs for container vessels were still heavily influenced by the shapes and sizes of general cargo ships, a separate type of vessel soon evolved. Technical solutions to the initial problems of longitudinal strength were found and the vessels gradually became larger. The turn of the millennium saw an urgent race for increased capacity. The vessels became faster and, above all, larger. The high speeds did not make economic sense, but the size of the vessels appeared to offer potential economic advantages. Whereas in the 1980s 10.5 seamen were needed to transport 1000 TEU by sea, today the largest container vessels require only 0.875 crew members per 1000 TEU. This represents an improvement by a factor of 12. As container vessels developed, very close attention was paid to damage stability, but handling in heavy seas and the ever increasing acceleration forces resulting from rolling and pitching and the forces acting on the cargo securing systems were probably neglected by all key institutions due to the sheer size of the vessels.

A comparison with the bulk carriers and tankers of the 1970s and 1980s comes to mind. Untreated ballast water tanks literally broke the backs of innumerable such vessels as a result of internal corrosion. More than 120 bulk carriers were lost, in some cases with all hands. As a result, the IMO pressed for significant structural improvements and the establishment of the "Memoranda of Understanding", e.g. the Paris MoU and Tokyo MoU. The "Port State Controls" (PSCs) introduced as a consequence are now a crucial element in respect of the safety of vessels and the monitoring of vessel safety. This raises the question of whether cargo securing regulations for container vessels will in future need to be reviewed and if necessary adapted in much the same way.

3 Economic considerations

Predatory competition is raging in the container shipping sector. Economies of scale generate savings that are immediately passed on to customers. Ever larger container vessels mean ever greater capacity. As a result, there was for years an oversupply of shipping space, and the laws of supply and demand meant that this put pressure on rates. In order to meet schedules, ships sailed at capacities of 80 % or less. At such capacities, the cargo securing systems were not stretched to their limits. At present, however, the economy is in a strong recovery phase. Vessels are operating at 100 % capacity, pushing the mechanical capacity of the cargo securing systems to their limits and occasionally beyond.

4 Developments in stability

The stability of a vessel describes its ability to right itself after its lateral equilibrium has been disturbed. Where there is plenty of stability, the vessel quickly rights itself, and this is referred to as a "stiff" vessel. If there is little stability, it is referred to as a "tender" vessel. A healthy compromise between the two is ideal for people, the vessel and the cargo. Back when container vessels still had to fit through the old Panama Canal locks, their beam was limited to 32 meters. Due to the height of the deck cargo, these relatively narrow vessels often needed a lot of ballast water to achieve sufficient stability. As a rule, these vessels were rather tender and had pleasant seakeeping characteristics. Capsizes due to inadequate stability only occurred with small container vessels as a result of blatant stowage errors.

Nowadays, the largest container vessels are almost twice as wide, measuring up to 61 meters. Since the beam of a vessel has a disproportionately positive effect on stability, today's vessels very often have a problem with excessive stability. This then causes the vessel to behave like a roly-poly toy in a swell, causing rapid rolling motions. This has two serious consequences: Firstly, with fast rolling motions, the acceleration at the return points is higher, leading to greater inertial forces, especially acting on the deck cargo. Secondly, short rolling periods are fundamentally aligned more frequently with the excitation periods due to the swell, which leads to larger rolling angles as a result of resonance-like behavior and the consequent amplification of the proper motion of the vessel. At present, it seems that the extent to which such borderline situations are still covered by the design conditions framework has not been adequately clarified in the field of shipbuilding.

5 Synchronous rolling

Beam seas striking a vessel cause rolling motions around its longitudinal axis. If these excitations coincide approximately or even exactly with the natural rolling period of the vessel, this is referred to as synchronous rolling. In such cases, the rolling angles of the vessel continue to build up to extreme values of up to 30° - 40°. The irregularity of the swell means that this resonance usually falls out of sync again after a short time; the rolling motions subside and the buildup starts again. The MSC Zoe incident has been attributed to such synchronous rolling. If vessels such as the MSC Zoe are sailing in traffic separation zones, masters have virtually no means such as a change of course at their disposal to eliminate the conditions of a constant angle of incidence of waves on the hull that lead to synchronous rolling.

6 Parametric rolling

This phenomenon has been known for decades. The vessels most at risk are those with a narrow underwater hull fore and aft and a heavily flared hull shape. This holds especially for large container vessels. Parametric rolling does not occur in beam seas, but in head and following seas, particularly in force 8 headwinds, with wave lengths of the order of the vessel's length. In this case, the excitation for heavy rolling does not come directly from the waves, but from the periodic fluctuations of the vessel stability "parameter" between the two states 'center of vessel on the wave crest' (low stability) and 'vessel in the wave trough' (high stability). What is so insidious about this is that steering into the seas at low speed used to be considered a proven method of surviving dangerous phases of storms and is still employed successfully on vessels with less radical hull shapes.

Large and even medium-sized container vessels fall outside the scope of experience in this respect. The onset of parametric rolling often comes unexpectedly to the master in what appears to be a safe situation. Nowadays, classification societies provide masters with special charts that allow them to more easily recognize the conditions for parametric rolling and mitigate the danger by, for example, changing course and speed. But it is not always easy to assess the swell and sea state in stormy conditions.

7 The classification societies

The classification societies' technical regulations for the design and testing of container securing systems assume a defined set of basic conditions. Known as "defined design conditions", these allow for the vessel to be fully loaded with the container weights gradually changing in a vertical direction in a carefully applied system and with an upward limit on stability. Alternatively, the current stowage scenarios are assessed and checked using the lashing calculators available on board. Synchronous and parametric rolling are not part of these basic conditions, but rather of the "off design conditions", alongside collisions, stranding or sailing in a tropical hurricane.

By definition, these "off design conditions" should and must be dealt with by good seamanship. But significant cargo losses over the winter of 2020/21, along with comparable earlier incidents, have shown that this is clearly not possible. The boundary between "normal" seakeeping and synchronous or parametric rolling is somewhat fluid if one takes into account the fact that, as a result of slot chartering and the sequence in which ports are visited, vessels must inevitably also be underway with partial or residual cargoes, which results in high levels of stability with large and ultra-large container vessels. It may therefore be necessary to revise the basic conditions for the design of container securing systems for specific types of vessels.

8 Anti-roll tanks

Anti-roll tanks can be used to damp roll oscillation in ships. These tanks come in active and passive forms. Actively controlled tanks consist of tanks arranged at the sides of the vessel that are connected to each other. Computer-controlled valves delay the flow of ballast water back and forth in such a way that it effectively damps the vessel's rolling oscillation by phase shifting. Passive anti-roll tanks consist of a ballast water tank arranged athwartships, in which constructional features delay the flow of water back and forth, with the result that the phase shift that damps rolling is also achieved. The quantity of water in the tank can be controlled to enable the effect of the water to be adapted to different stability conditions of the vessel. Installation of such tanks has not yet been recommended, and it is certainly not mandatory. A few shipowners do so voluntarily.

9 Higher wind loads

No other type of vessel carries anywhere near as much cargo on deck as container vessels, which carry up to 60% of their cargo on deck. Ultra large container carriers (ULCCs) have up to 11 layers of containers on deck, which corresponds to a lateral windage area of cargo larger than a football pitch. The wind forces from the tall towers of containers have to be transmitted downward into the body of the vessel through the stacks. But with increasing height comes increasing leverage. These wind loads are indeed part of the design conditions. However, it is reasonable to raise concerns as to whether all aerodynamic effects have been identified for large container vessels of the dimensions mentioned above.

10 Cargo securing systems

The load securing systems are of particular importance when the loads on deck are so high. Originally, containers were transported on deck in four to five layers, and the containers were connected to each other with mechanical twistlocks. Additional securing was provided by lashing rods, which were attached either laterally or crosswise in front of and behind the container stack. Lashing rods that are attached crosswise also have the important task of absorbing the enormous racking forces in the lower container layers. These lashing rods were usually hooked onto the bottom corner fittings of the container in the second or third layer and pre-tensioned with turnbuckles. This securing method was appropriate to the dimensions involved. As the size of the ships increased, ever more layers were carried on deck, and so the securing systems had to "grow" accordingly. To ensure that the lashing rods have an adequate securing effect in container towers of up to 12 layers, lashing scaffolds are now built between the container bays, enabling the fifth and sometimes even the sixth and seventh layers to be secured using rods. The twistlocks were also modified as a result of the considerable working height above deck. Semi-automatic and fully automatic twistlocks were developed that could be inserted and removed while the container was still at the pier. The designation “twistlock” is misleading for the latest developments, as they no longer have any rotating parts. After some problems with cargo securing (often at the stern) arose in the Bay of Biscay, among other places, lashing systems were reviewed and in some cases adapted. Even today, individual shipowners continue to push ahead with the further development of lashing systems. The pull-out forces of locks are being significantly increased.

One gets the impression that the systematic development of securing systems has simply been neglected, or has at least only been pursued half-heartedly. Work on the deficiencies that exist is being done, but there is no comprehensive and coherent approach to dimensioning the securing systems in such a way that they meet the high stability requirements of today’s large container vessels.

11 Verified gross mass (VGM)

SOLAS requires that a verified gross mass (VGM) must be declared for all containers presented for transport. Knowing the correct weights of the containers is essential for securing the cargo on board. The position of each container in the individual stacks on board and the combination of the stacks taken together (“towers”) are subject to weight limitations around which the cargo securing systems and the maximum point loads at the foundations (tank decks / hatches) are dimensioned. On deck, unlike in the hold, there are no cell guides, and the forces required to secure the cargo have to be provided by the twistlocks and lashing rods alone. This means that the weights of the containers stacked on deck must decrease towards the top, and as a rule, only empty containers are permitted to occupy the top positions.

If the VGM of the containers is not correct, it is possible that the securing system may become overloaded and fail even as a result of a single container that is too heavy and stowed in the wrong position. As the vessel rolls, the now loose stack of containers leans against the neighboring stacks, which are unable to withstand this additional load. There too, the cargo securing system fails. This domino effect can no longer be stopped, resulting in the loss of many containers from a bay. Such a loss of cargo usually occurs on one side, and the vessel will now roll around a new center of gravity (point of equilibrium). This means that the rolling oscillations to the other side will increase, which can lead to further cargo losses.

Although SOLAS requires that a VGM has to be declared, there are no effective checking mechanisms in place. It can therefore be assumed that cargo loss from container ships will continue to result from incorrect weights and/or incorrect stowage.

12 Stowing and stuffing containers

When calculating the cargo securing systems on container vessels, it is assumed that the weights of the containers are static. In other words, the cargo in the containers must not move. Annex 7 of the CTU Code provides good guidance on this subject, and there is plenty of technical literature on the Internet on how to stow and secure cargo properly (http://www.containerhandbuch.del). However, we can see that the quality of container stowage and stuffing is tending to decline as a result of a mixture of ignorance, economic pressures and indifference. Loss events reveal glaring deficiencies in securing with sometimes catastrophic consequences. If cargo is not perfectly secured in a container, it can break loose and move around freely in the container. This moving mass now acts in the same way as the pendulum movement of a wrecking ball on the securing measures for this one container, and hence on the vessel’s entire cargo securing system along the lines of the “domino effect” described above.

13 Already damaged containers

The quality of the containers themselves has steadily declined in recent decades. This is partly due to rough, or even reckless, handling as they are used to carry such cargo as scrap metal, logs, steel coils and Flexitanks, as well as to reduced maintenance outlay on the part of the owners. Damage to the floor structure and side walls is commonplace. Corner fittings sometimes show excessive tolerances after years of rough use, and many a container owner has reduced the thickness of the steel plate of the side walls to the point where there is no safety margin left. The structure of the lower containers must support the entire deck cargo. Lashing and securing systems are calculated on the basis of units that conform to standards. It is legitimate to ask to what extent this reflects real-life practice.

14 Conclusion and demands

In conclusion, it is possible to say that economic pressures have had an excessively negative qualitative impact on a number of individual factors relevant to the loss of containers from seagoing vessels. The stowage and securing of containers, VGM, the quality of the containers themselves, the high, perhaps excessive stability of the wide ULCCs, and the considerable wind loads have resulted in the vessels' securing systems becoming overloaded. If specific conditions, such as those exemplified by parametric and synchronous rolling, cannot be compensated for by cargo securing systems because they are "off design" conditions, there must either be ways to avoid these conditions or they must simply not arise.

It is necessary for either technical modifications such as anti-roll tanks to be installed or the quantity of deck cargo to be reduced by an appropriate amount, because when the ships were not operating at 100 % capacity, such situations occurred only extremely rarely or not at all. Simply carrying on in the same way until the economic upturn subsides and the problems seem to disappear of their own accord cannot be a way out, because the next economic boom may be just around the corner.

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