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The Study of Dangers Related to the Ship's Stability during Container Loading and Discharging in Ports and its Solutions

Behzad Roshani[1]
Master of Science, Maritime Transportation, Amirkabir University of Technology, Tehran, Iran

Abstract

One of the greatest technological changes and developments in international transportation is the foundation and prevalence of containers in this area. Nowadays, operators of transportation and trade use containers because of their high strength, the ability to store them on top of each other on the ship, its water proof material, no need for a covered storage room, the fact that it can easily and quickly be loaded onto a ship, truck, or train, fast transportation, minimum cargo damage during cargo operation & transportation, its security against thieves, they are reusable, packages can be sorted like trays, and they can be used on refrigerated ships since each container has a set of goods with a packing list and the accumulation of these goods in one large package decreases the number of packing lists and at the same time decreases the number of customs documents. Considering this topic, the dangers related to the ship's stability while loading and discharging containers in ports will be reviewed and solutions will be brought up. The results of this study can help port and ship workers decrease these dangers while loading and discharging containers in ports.

Keywords: Risk Management, Container ship, Container Depot, Container ship Risk, Bay Plan, Stowage plan

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[1] *Corresponding author's email: b.roshani@aut.ac.ir*

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Introduction

Familiarity and knowledge of containers and its different types in marine transport has made transportation operators try their best to make sure their goods reach their destination quicker and in one piece. Container shipment makes international transport easier, decreases the amount of compensation for broken or stolen insured goods, decreases packaging costs, inclusive transport of insured goods in one container considering its capacity, the ability to deliver goods from the producer to the user, and creates an increase in the speed of loading and discharging.

Due to its strategic benefits and importance, marine transport and especially container transport is one of the most important methods of the transportation of goods. Considering the appearance of great changes in marine transport and terminal, container transport can create a decrease in the amount of operations and time spent moving goods in ports. One of the great technological changes and developments in international transport is the appearance and prevalence of containers in this area. Due to their specific benefits, these changes quickly spread throughout countries all over the world. This is why nowadays container transport has had a considerable increase in comparison to other transport methods. International transport's tendency towards container transport shows that according to the aforementioned points, container transport must be further developed. In acceptance of these, changes and modern technology will basically have negative effects which will plague the national economy and also the maritime industry. Since all countries are generally under pressure from their partners in trade, disregard of technological changes will have a negative outcome on trade between developing countries. However, in accepting these changes and using modern technology an important issue is reviewing the danger related to the ship's stability during the discharging and loading of containers in ports.

In this study, the researcher aims to review the safety measures related to preventing danger in the ships' stability while loading and unloading in ports and it can result in preserving the safety of a container ship at sea since a safe loading and discharging at a port and safely preserving a ships' stability towards the end of a mission, means that the ship will be stable at sea.

Literature Review

Form 1970 s, the problems related to container stowage planning has been studied by researchers and shipping lines. The most research is about on the container loading and discharging problems. The size of the demand space for the container stowage planning problems depends on the ship capacity and the shipping request at each port.

By the way with refer to review of recent researches we can understand that most of research looking to find a way to reduce risk of dangers related to the ship's stability during container loading and discharging in ports.

In one of research the author has introduced one module which is developed to improve the stability of a stowage plan automatically by a heuristic algorithm.

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In other research effect of wave will effect on GM during vessel riding to waves' cross or falling waves' through.

In generally we can see all research wanted to reduce risk of dangers related to the ship's stability during container loading and discharging in.

Research Questions

1. What endangers ships at Port, during loading & discharging of containers?
2. What solutions when facing the dangers of container discharging and loading?

Significance of the Study

One of the main goals of this research is to study and review of dangers during the loading and discharging of container ships and finding a safe method to prevent this danger in ports.

Method of research

Researcher used two methods - researcher's experiences and Library study–approach for this study. This study is a field and library study and the instrumentation was notes from books and documents (All books and documents are referred below) analyzes by the author according to his experiences on container vessel about 18 years. . It is predicted that considering the results of this study, would decrease the amount of danger related to discharging and loading container ships, with considering the mentioned method, data collection is based on taking notes from books and documents including the researcher's direct experiences during his service on container vessel in various ports.

Review of Related Literature

It had been estimated that the cost of building a container ship is much more expensive than other transport ships but considering their economic benefit, investors have focused on this type of ship. It must be mentioned that this ship has lower port costs than other ships and if we consider the lowest amount of human resources, we will realize that development in this industry has great benefits. Container ships have seen a great amount of transformations over the past half-a-century in a way so that nowadays insurers and operators of marine transport face the third generation of these floaters which not only have every type of facility, but also extraordinarily flexible. Nowadays, there is an increase in the capacity of ships, trucks, and cars, and other types of vehicles besides accepting different types of containers in different shapes and sizes.

Nowadays, ports face an increasing growth in container transport all over the world as an answer to our needs. It has been predicted that in Northern Europe between 2001 and 2015 transport will see an increase from 6.72 million TEU to 17.1 million TEU. Due to economic standards container ships have had an increase of 8000 TEU to 140770 TEU from 2001 to 2011 considering their size and handling ability. All in all, ports must work with larger ships. Considering these changes, container terminals were built and ever since their establishment, they have played an important role in transport services.

The most important features of container terminals are their storage and the transfer of large amounts of containers from and to ships. One of the most important effective factors in these container terminals activities is time because it is a competitive factor between terminals. Some practical explanations can be seen below.

Large ships tend to pass several ports. A delay in one port can lead to a delay in the next port. Besides this, ports have a limited jetty. Therefore, during rush hour ships must wait for a while to berth and this is one of the reasons for a delay when reaching the next port. Thus, waiting in one port can result in a delay in reaching the next port.

The outcome of a ship deeply depends on the time it spends at sea and the waiting time at a port (Saffarzadeh 2012: A).

Considering their size, container ships are divided into three groups:

Trans-Atlantic Liners: This group contains the largest ships with a capacity over 14500 TEU and the amount of mooring and division is up to 2 to 3 times each trip. About 50 to 60 per cent of its goods must be evacuated in one to berthing.

Ocean Liners: These ships have a capacity between 4000 to 8000 TEU. These ships can travel on for a long period of time.

Feeder Ships: These ships somehow support the mother dock of which only small ships are able to link smaller ports together and can support smaller ports linked with mother docks. These ships have a capacity of 3000 to 4000 TEU.

One of the benefits of containers is door to door delivery. The owners of the goods can be confident that whatever is in the container will not be touched until the destination. Even though it is possible that the container will be replaced several times during the trip, the resistant body will preserve what is in the container. Without a container, the goods will be in danger of being damaged throughout the many discharging and loading.

Containers can be stored on top of each other for several stories without putting any pressure on the goods. The structure of a container is resistant against rain and sea water and does not need a roof. Containers have propagated multifaceted transport in trade now more than ever because they can easily be transported with different types of vehicles. The presence of facilities in different corners of the containers helps workers lift them with the right equipment and there will be a decreased need for human resources. These facilities have helped decrease the amount of wasted time to secure a container.

The equipment needed to secure a container, contrary to general goods, can be used multiple times and for a long period of time. Containers have created the invention and use of cellular ships. The cells have been made out of four layers of steel which has

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covered four corners of the container and prevents them from moving to the movement of the sea.

Practical Container Standards

Container standards are not just limited to their size but their practical standards are also involved. These standards include the maximum gross weight, the strength of containers under other containers, the ability to pick up these containers, resistance against shape change, the strength of the containers' walls, roof, and floor, and their water resistance.

The first practical standard of containers is their maximum gross weight or rating. The maximum weight that an ISO 1 container with the weight of the goods it contains is meant by this. The maximum weight of the container with its goods cannot pass this number. The second practical standard is the weight that container can carry. Containers are stacked on top of each other and it's made so it supports both its own weight and the weight of the containers on top of it. The ability to pick up containers is the third practical standard of containers. Containers are lifted by corner fittings. Therefore, it is important that these fittings can tolerate the weight of the container and its goods. Therefore, the convention for safe containers has designed a test to lift containers. The maximum gross rate is raised to twice its legal weight and they are lifted by corner fittings and they are left up in the air for 5 minutes, and the container must not face a permanent shape change.

The Use of Archimede's Law in Ships

A ship is like a closed iron box in which the following factors can be explained:

As long as the ship's weight is less than the volume of the transferred water, the ship will remain afloat. The amount of water withdrawal that will allow the ship to remain afloat makes the volume of the transferred water equal to the weight of the ship.

Mass of Vessels' Water Volume

The weight of any vessel times its volume mass as a result of its mass is equal to the weight of that entity divided by its volume mass. The following formula has been explained about vessels:

$$\text{The mass of transferred water} = \frac{\mathit{The\ weight\ of\ transferred\ water}}{\mathit{Water\ volume\ mass}}$$

The Center of Gravity

The center of gravity is the point in which an entity or a page is in balance with. In other words, the geometrical center of flat shapes or a point which gravity horizontally affects is the center of gravity.

Computing the Ship's Center of Buoyancy

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The Ship's Center of Buoyancy is a part located underwater.

Up to now we have become familiar with the center of gravity of flat shapes but the Ship's Center of Buoyancy can only be computed when we know of its distance from two known sources of the ship. The Center of Buoyancy is usually determined by a KB. Considering the definition of a buoyancy center, if the underwater section of a ship becomes in contact with water and is vertically divided by an equal distance, by using the Simpson formulas the buoyancy center of a ship can be estimated. To estimate the distance of a buoyancy center from the keel, this section can be divided into equal horizontal pages and it can be estimated using the Simpson formulas.

Loading Capacity of a Ship

The subtraction of the amount of heavy ship from the light ship is called the loading capacity of a ship.

Draft

The vertical distance between the keel and pipe is called the draft of a ship. The draft has been engraved on the two sides of the stem, midsection, and stern of the ship. The stern of the ship and stem are always engraved together and if both drafts are the same, the ship is called an even keel and if the draft of the stern is more than the draft of the stem it is called trim by stern and if it is the opposite, it is called trim by head. The mean draft the sum of half the amount of the stem draft and stern draft put together. The legal size of a ship outside water is the distance of the joining point of the deck and structure of the ship with the Plimsoll Mark disk center but in a normal situation it is the distance of the joining point of the deck and structure of the ship until the pipe.

The Ship's Center of Gravity

The G point is a point on which all the weight of the ship affects vertically. A ship is like an empty box which has had some added weight or has lifted some weight and whenever there is a change in the amount of weight the center of gravity also changes. The changing of the center of gravity can be estimated and is extraordinarily important in computing the ships' stability. The width and length of the ship's Vertical & Longitudinal center of gravity will be discussed separately. The vertical of gravity of a ship will always be thought to be along the dividing line of a ship unless the ship leans on the side that holds the center of gravity and in this situation we say that the ship is listed.

KG: The vertical distance of the center of gravity from the keel of the ship. In all ship Plans the keel is shown with a K and the gravity center is shown with a G and the distance between these two is called the KG (Derret, 1990).

KG of a Light Ship

The height of a gravity center of a ship from keel which has not yet been loaded with goods and is in light movement is called the KG of a light ship.

To calculate the KG of a light ship, the builders can use some special formulas or use the inclining experiment method.

Stability in Ships

In normal ships the gravity center is always higher than the buoyancy center of a boat or it can be said that KG>KB. Gravity vertically comes downwards from the gravity center and on the contrary, buoyancy gravity vertically affects the buoyancy center upwards.

It was seen here that an entity's balance which leans on one side depends on the status of the gravity center as long as the gravity center and reliance point are not along the same line the entity will lean more or return to their previous state. This principal is the same for ships. If we consider of the buoyancy center of a ship instead of the reliance point the B point and the G point must be along a vertical line until the ship is balanced. During the loading or discharging of a ship, enough attention must be paid so that during the entire process of loading and unloading, the ship is in its normal state and is not listing towards any specific direction. In this situation, we say that the G point and B point are along the same line and if after loading the weight of the goods and newfound energy make the ship list toward any direction; this new situation will be the new balanced state of the ship. The status of a balance ship is divided into sustained balance, unsustainable balance, and apathetic balance.

A- Stable equilibrium- A ship is said to be in stable equilibrium if, when inclined, she tends to return to the initial position. For this to occur the centre of gravity must be below the metacenter, that is, the ship must have positive initial metacentric height.

In smaller angles, GM is a positive amount.

For each listing angle, the GZ is in the lyses of the ship.

B- Unstable equilibrium- When a ship which is inclined to a small angle tends to heel over still further, she is said to be in unstable equilibrium. For this to occur the ship must have a negative GM. Note how G is above M.

In smaller angles, GM is a negative amount.

For each listing angle, the GZ is in the upper head of the ship. A ship having a very small negative initial metacentric height GM need not necessarily capsize. This point will be examined and explained later. This situation produces an angle of loll.

C- Neutral equilibrium - When G coincides with M, the ship is said to be in neutral equilibrium, and if inclined to a small angle she will tend to remain at that angle of heel until another external force is applied. The ship has zero GM. Note that KG _ KM. (Derret, 1990).

Correcting unstable and neutral equilibrium

When a ship in unstable or neutral equilibrium is to be made stable, the effective center of gravity of the ship should be lowered. To do this one or more of the following methods may be employed:

1. Weights already in the ship may be lowered.

2. Weights may be loaded below the center of gravity of the ship.

3. Weights may be discharged from positions above the center of gravity.

4. Free surfaces within the ship may be removed (Derret, 1990).

Change of the Draft as a Result of a Change in the Trim

When a trim changes as a result of loading or unloading as a result of an increase in draft on one side the draft on the other side will decrease. A mathematic addition of the changes of the draft on both sides of the ship is called a change of trim. A change of draft as a result of a change of trim depends on the position of the F point. For example, when the F point is exactly in the middle of the mid line of the ship, on one side the draft change will be half of the trim change and the same happens on the other side.

Minimum number of factors needed for a marina with safety tips for a ship:

Criteria of Stability:

Extract from the Load Line Rule (1968)

The area under the curve of Righting Levers shall not be less than:

0.055 metre-radians up to an angle of heel of 30˚

0.09 metre-radians up to an angle of heel of 40˚

0.03 metre-radians between the angles of heel of 30˚ and 40˚

The Righting Lever shall be at least 0.20 metre at an angle of heel equal to or greater than 30˚

The maximum Righting Lever shall occur at an angle of heel not less than 30˚

The Initial Transverse Metacentric Height (GM) shall not be less than 0.15 metre (Derret, 1990).

Mandatory Points about Preserving a Ship's Stability

The primary GM for ships that load and unload on normal liners must not be lower than 0.15 meters. Ships that carry timbers can be at least 0.05 GM meters. The maximum GZ must not be in angles less than 30 degrees and the amount of GZ must not be less than 0.2. The transfixed area between the static balance curve and X line must not be less that the following amounts: 0.055 radians per meter in angles up to 30 degrees, 0.09 radians per meter in angles up to 40 degrees, or until the deck comes into contact with water (Derret, 1990).

Use of the Maximum Torque in the Loading Capacity

This is a simple method in calculating the GM of a ship:

The torque in the loading capacity is the total amount of cargo in the keel of the ship (Goods, fuel, water, staples, and anything else that may be seen in the cargo.)

The amount of torque around the keel is equal to the amount of torque in a light ship.

List: 'G', the centroid of the loaded weight, has *moved off the center line* due to a shift of cargo or bilging effects, say to the port side.

GM is positive, i.e. 'G' is below 'M'. In fact GM will *increase* at the angle of list compared to GM when the ship is upright. The ship is in *stable equilibrium*. In still water conditions the ship will remain at this *fixed* angle of heel. She will list to one side only, i.e. the same side as movement of weight. In heavy weather conditions the ship will roll about this angle of list, say 3° P, but will not stop at 3° S. See comment below. To bring the ship back to upright, load weight on the other side of the ship, for example if she lists 3° P add weight onto starboard side of ship. (Derret, 1990)

Angle of loll: If a ship is in a balanced position and has a negative primary GM, the ship usually becomes lopsided. If it becomes even more lopsided and it becomes askew, we call this the angle of loll. In this position, the ship does not become capsized but this is one of the most dangerous positions for a ship.

In this situation, the ship is extremely vulnerable and doing anything wrong or not doing the right thing to fix this mistake is make put lives in danger and damage the ship.

Forces Exerted on the Ship's Structure

If a ship is moving, there are many forces that are being exerted on it and these forces can be divided into two general groups:

This first group consists of the general forces that are exerted on the different parts and main structure of the ship.

The second group consists of forces that only affect a specific point or area of a ship. Due to this, in the design and building of a ship in order for the ship to tolerate the exerted forces extreme accuracy must be taken into account to eliminate or decrease the effects. Otherwise, the speed of these forces will affect it and will cause a twist in the shape and in the end it will destroy the structure of the ship.

Hogging and sagging are two of the main forces on the general body and structure of the ship. If these forces are completely obvious and strong, they will curve and dent the length of a ship. These forces can come along in two ways: first of all, when the ship is moving and moves on waves and also when heavy cargo is loaded onto the ship in a nonstandard way.

Reasons for Pressure on a Ship

When a ship is moving along, it is under the pressure of many types of forces and it can be damaged. These forces can be divided into two groups: the weight of the ship which goes downwards and the pressure of the water which moves upwards.

Dynamic forces: Forces that can be seen when a ship is moving.

In general, the movement of a ship can be attractive and tricky but studies on it are extremely complicated. Nobody can predict the movement of a ship when it faces pressure from winds or water or how it will behave when faced with some specific type of wave. Following the safety points in the design of a ship so it can resist these pressures is very difficult.

These forces can be exerted onto the ship in two ways:

General forces: Consists of forces that can be exerted onto the entire ship.

Local forces: Consists of force that is exerted onto a specific point or area of a ship.

General Forces are as follows:

A- Lengthy forces in static water: Even though the pressure from a buoyancy mass which moves upwards from the water is equal to the weight of the ship but distributing the pressure from the weight and the pressure from the buoyancy mass along the length of the ship is not the same. Therefore distributing uneven weight or pressure along the ship creates bending or augmentative pressure outside the neutral axis or line.

B- Lengthy pressures on tensional movement: This force creates sagging and hogging on the ship.

C- Parallel forces: Pressure as a result of uneven distribution of weight or buoyancy mass might cause parallel forces. The most parallel force can be seen on the neutral line. These pressures can happen horizontally or vertically.

D- Changes in the parallel section: This happens as a result of twists in the width of the structure especially when it is empty.

E- Water pressure: The effect of water pressure is horizontal. When waters deepen, it increases. Water pressure makes the sides of the ship and their ends curl up internally.

As was mentioned before, local pressure is a type of pressure that affects a specific point or part of a ship and some examples are:

A- Pounding pressure,

B- Panting pressure,

C- Pressure as a result of extra weight or the cargo.

Preserving the Balance of a Ship

To preserve the balance of a ship which is a buoyancy device, its gravity center must be held low. When an entity's gravity center is low, it tends to straighten after listing to one side.

To better understand this, think of a heavy entity we have used to lower the gravity center of a bottle. This bottle will not flip in water. To preserve the balance of a ship, heavy containers are put on the bottom, light containers on the top, and empty containers are put on the top of the light containers. Other than distributing the vertical weight which was previously mentioned, we must also pay attention to distributing the weight horizontally. In the loading of a ship, we must pay attention to the fact that distributing the weight equally will stop the ship from tipping over. The vertical and horizontal distribution of weight is not just for the end of the mission, it must be observed during the entire loading and discharging period. Therefore, loading and discharging must not be concentrated on one part of the ship for a long time. Ships which have ballast tanks on its sides and two ends can stop the ship from tipping over by taking in water from the sea. A ship's inclination in its width due to uneven weight is called list and due to the length of the ship is called trim.

The Process of Discharging and Loading

This process is as follows:

Before the ship reaches the destination, the EDI file is sent to the port. In the EDI file, information related to the container which consists of the number, container type, the status and if it has dangerous cargo, the type of cargo and where it is going to evacuate the cargo, and the most important point is that they show the status of the ship on the ship and all of these factors can be seen on the computer monitor by Load Master.

The EDI file sent by the ship and the previous ports are compared with each other by the destination port and any differences are immediately fixed via email. Considering the number of discharging and loading, in the EDI file the number of tractors and gantry cranes are prepared by the port so the discharging and loading process can take place immediately and as soon as possible in the destination port.

During the voyage and before the ship reaches the first port, the Operation manager sends container allocation considering the conditions and number of containers in each port to each port and vessel so the ports can reserve spots on the ships considering their reserved space. Considering port law and order, allocated time to reserve space in a port is 24 hours to one hour prior to loading.

Before the ship reaches the destination port, on behalf of the liner's representative the final reservations are sent to the ship so the first officer can prepare the bay plan under the Master's supervision. It must be mentioned that the information that is sent is an estimated amount and the first officer must prepare the bay plan according to the estimated weight and aforementioned factors including overweight, overside, oversize, overheight, or the type and class of dangerous cargo, and type of containers.

Results and Discussions

Effective Factors in the Ship's Stability During Port Operations

According to the researcher, factors which can put a ship's stability in danger are:

-Negative GM

During port operations, if these things are carried out without the knowledge of the first officer:

Loading heavy containers on the on top of the light ones,

Transferring the ship's fuel,

Keeping the ballast tanks half empty or empty,

or actions such as these, positive GM can be changed into negative GM.

If a ship has negative GM, it list towards one side. This happens as a result of factors in and out of the ship. If this happens, then the listing continues and the center of buoyancy goes under the gravity center. Therefore, negative GM turns into zero GM and as a result the GZ will become zero too and the ship will go into Neutral condition and it will stay in this mode. To solve this problem we must first make sure that the main reason was not uneven loading on the two sides on the longitudinal center line of the ship and it was due to negative GM. Then we must start filling the half empty or empty tanks on the side of the ship that is listing and then we must fill in the tanks on the other side of the ship. At this will increase the angle in which the ship is listing but then because of the increase in GM, this angle will decrease (Derret, 1990).

There are other elements which can create negative GM as well such as unforeseen increase or decrease in the number of containers during the loading process or not observing the discharging and loading sequence which was prepared by the chief officer. In ports this sequence is prepared according to the amount of cargo.

Another reason is loading heavy containers on top of the light ones. This mostly happens in ports in which they do not pay attention to the weight of the containers when loading (like Iran's ports). Luckily, this rarely happens in developed countries.

List and Container Sinking

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Another element that challenges the balance of ships is list which is a result of discharging and loading via cranes.

Basically, loading has to start from the sea to the middle of the ship towards the quay and for discharging it is the opposite.

Extreme list of the ship towards the quay can damage the cranes in the quay. Another problem that can be seen fatigue of the Lashing equipment of containers (cone, turning buckle, lashing bar, and twist lock) must be randomly inspected by a workshop verified by the competence workshop to make sure they are intact. However, many ship owners delegate inspections to the ship personnel and they mostly just visually check the supplies. If these problems can be seen, they are taken out and disused or they change that part with a twist lock but small cracks cannot be seen with the naked eye. Damaged parts cannot hold these heavy containers during list therefore there is a probability that the containers might fall down and this creates a sudden movement against the direction of the list and this in itself can cause the fall of the containers on other side. As a result of sinking containers, problems such as negative GM or SF or BM can be seen.

SF and BM during Port Operations:

During port operations the SF and BM must be at limited levels. The first officer must check these levels at specific times and if they are higher than the allowed amount, they can be lowered by filling and emptying local tanks that have high amounts of SF and BM. Sometimes, because of a decrease or increase in the number of containers at a specific place the SF or BM increase to a level higher than the legal domain. At first we can lower these amounts by filling in and emptying balance tanks and if this amount does not decrease, we must change the location or loading of the containers on the ship.

An Abnormal Increase in Trim

An abnormal increase in trim is another reason we have problem in the balance of a ship. It affects the fuel tanks the most. When it is an extremely high amount, the fuel in the ship's fuel tanks moves towards the back of the tanks and if the mass of fuel inside the tank is more than 95%, the fuel can exit from the ventilators. This can create pollution in the deck and sea. To prevent this from happening, when bunkering, 90 to 95% of the tank is filled up.

Windage Area

In container ships, because 5 to 9 tiers are built on the storage doors and deck a high wall is built. During gales, this wall creates a resistance against the strong wind. Pressure from the wind puts a lot of pressure on the ship. Sometimes, list is seen in both mild and serious forms contrary to the direction of the wind. If the amount of list is more than allowed and it creates problems while loading, operations must be stopped until the winds are slower or stop. It must be mentioned that high amounts of list in windy weather could create one of the aforementioned situations.

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