Cargoes: Cargo damage, Cargo handling and storage on ships and in international ports

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Sveučilište u Zadru

Pomorski odjel - Nautički odsjek
Preddiplomski sveučilišni studij Nautike i tehnologije pomorskog prometa
(jednopredmetni- izvanredni)

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Izjava o akademskoj čestitosti

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Sadržaj mojega rada u potpunosti odgovara sadržaju obranjenoga i nakon obrane uređenoga rada.

Zadar, 10. veljače 2017.

Contents

1. Introduction

Food and raw materials have been transported across the seas and rivers for hundreds of years. Ship was recognized as the most efficient means of transport, as it is today. Merchant shipping developed due to uneven distribution of natural resources and growing demand on goods. Since industrial revolution and improvement of living standards, the number of different types of cargo in organized commodity exchange have been rising. Dozens of different kinds of goods in this moment are being transported across the seas. Each type of cargo has unique storage requirements and has to be handled with appropriate care. Both, shipper and buyer expect the goods to be transported without any damage and in short period of time. To achieve this goal, specialized ships, terminals and handling equipment have been developed to provide most efficient transport, handling and storage of cargo.

The intention of this paper is to provide information on handling, storage and damage to different types of cargoes. The paper is divided into four chapters, each covering a single group of cargo. It includes: grain cargo, refrigerated cargo, containerized cargo and crude oil. Wide span of damages, handling procedures and storage arrangements of these groups of cargo are presented.

2. Containerized cargo

General cargo used to be dominant in sea trade, but since 1970's, containerized consignments have been growing in popularity. Today's image of any large port proves that unitized cargo is omnipresent. A Shipping container is designed for intermodal transport. There is less time needed for handling of cargo, and ship's turnaround time is therefore reduced [1]. **"**For the shipper, the shipowner's customer, the advantages were even more significant. The attraction of the customer towards a system which conveyed cargo from door to door with minimal risk of damage or loss has proved to be the real driving force behind containerization. Consequently, containers today are to be found in considerable numbers all over the globe, even in countries where the landside infrastructure is clearly inadequate or where stevedoring charges are still modest**"** [2]

The standard twenty foot equivalent unit measures 6.058 × 2.438 × 2.591 meters. All kinds of goods are shipped in this box shaped unit, although forty foot equivalent unit is dominant in sea trade today. It includes food stuff, beverages, electronics, machines, clothes and all other kinds of products, semi products and raw materials. Cargoes which are extremely heavy, fragile or obnoxious are shipped in special containers. They are designed to meet special requirements of all kinds of cargo. Here are some of the most common types of specialized containers:

- Open top container
- Half height
- Platform
- Flat track
- Reefer
- Tank container
- Open sided container
- Side door container
- Coil carrier
- Dry bulk
- Ventilated
- Fan box

Picture 1. Tank container

Goods which are shipped in containers are still packed the same way as they used to be when shipped as break bulk. It means: wooden boxes, cartons, plywood boxes, steel drums, fiber board drums, bales, bundles, textile bags, sacks, paper bags [1]. **"**Cargo in a container very often has the same requirements and same characteristics as a cargo loaded into a locker, tween deck or hold of a ship. For this reason many of the remarks on general stowage apply equally well to containers.**"** [2]

2.1 Storage on ships

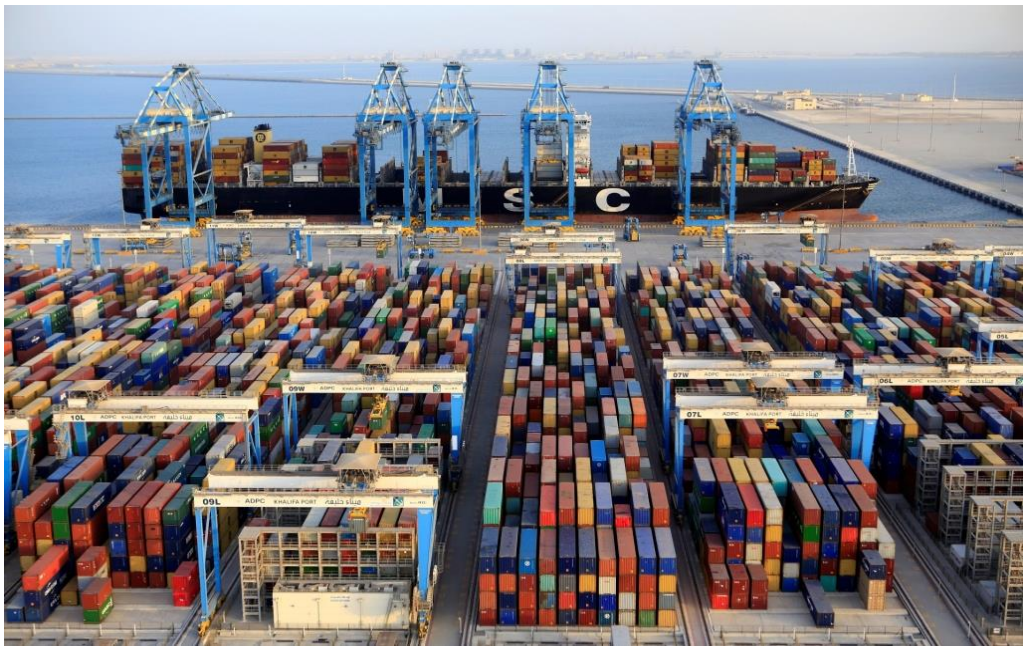
Most of the containers are stored on appropriate container vessels. These have specialized holds and securing points, and are aimed to provide fast loading, unloading and securing of containers. Holds are covered by hatch covers which are made of steel. They provide certain weather protection to units stored in the holds and serve as a base for those stacked on deck. Modern ships can facilitate up to 6 ties in hold and 10 on deck. Another key feature of container vessels are vertical steel structures mounted on sides of the holds. They guide the containers and provide side to side support to units stacked in holds. Containers stacked on the deck are secured by twist locks, turnbuckles and lashing rods. The twist lock is a semi-automatic mechanism which must be inserted into the bottom corners of the unit which is going to be loaded. When it is lowered onto the one already stacked, temporary connection is created.

Picture 2. Container vessel

The structure of a container can stand static load of 6 fully loaded units. Twistlocks are used to connect them. The bond must be as strong as the container structure is. Because of dynamic forces which appear in rough seas, lashing rods are used in conjunction with lashing bridges. Lashing bridges are raised structures which enable higher container loads. Stevedores carry out the work of securing the cargo which is lifted on or off by container gantry crane.

Containers are stacked according to the plan made out by shore based planners. They are stacked so that ones which need to be discharged first, can be reached first. The weight of container is also taken into consideration. Those carrying heavy loads will not be stacked on top, but empty ones instead. Containers are stowed in bays, rows, and tiers [1].

2.2 Storage of containers in a port



Picture 3. Khalifa port container terminal

Containers are stored on open stockyard. It is basically a large flat asphalted area placed right next to the water front. Containers are stored in stacks, one on top of the other. Container yard is intersected with system of roads designed for movement of cargo handling vehicles. In between the roads containers are stacked in specific pattern. They can be perpendicular, parallel or at forty- five degrees to the waterfront. Each row can be up to 4 containers wide and 6 containers tall. This depends on the turnaround of the cargo in the port and handling equipment used in a specific port. Refrigerated containers are stored in special area of a terminal which is provided with power supply for these units [3].

2.3 Cargo handling gear

Container gantry crane – It is a large dockside gantry crane specifically designed to load and unload container vessels. It is rail mounted structure capable of traversing entire quay length. They are equipped with spreader, which is a device used to hook the container.

Transport vehicles- there are many types of vehicles used for this purpose. Among most popular are: multi trailer system and automated guided vehicles. Straddle carriers are also used extensively, as they are able to pick and leave the cargo by themselves. These are becoming more and more automated.

Reach stacker- This is one of most versatile vehicle used on container terminals. It is used to transport units at short distances and to pile them. It can handle both empty and loaded containers.

Rail mounted gantries or rubber tyred gantries – These are cranes specially designed to stack and reclaim containers from the yard. They can be manned or automated guided [3].

2.4 Damage to cargo

2.4.1 Stuffing of container

Cargoes of uneven shapes and different chemical characteristics are shipped in containers. They travel great distances, often exposed to temperature extremes and experience mechanical stresses. Package and cargo itself can be damaged due to stresses during transportation. In order to prevent this, container must be properly secured and handled with care, when on board. However, gentle handling and proper handling can not prevent damage to cargo if it is not stuffed properly. This must be made so that weight is uniformly spread. Individual items must be secured by using lashing gear. If it is stuffed with large amounts of packaged cargo it should be stuffed in the way to avoid any movements, and void spaces filled with dunnage [1].

Picture 4. Poor cargo securing

Dunnage is a term used for materials which are not firmly attached to the cargo transport unit, the cargo or its package and are used to protect the load. This includes: wooden dunnage, beams, planks, boards, wedges, plywood, hardboards, walking boards, mats, paper, sailcloth, canvas, tarpaulins, plastic and metal sheets, spray covers, cardboard, paperboard, packing paper, oiled paper, inflatable bags… It is used to prevent movement of the cargo, to separate different types of goods and provide protection to the package as well [2].

2.4.2 *Mechanical damage*

Uncontrolled cargo movement inside of the unit can make entire load to start shifting from side to side of container, thus gaining home grown acceleration. This may cause the damage to the entire load. Containers are often ripped apart with their content spread all over the place. Even cargo that is firmly secured can be damaged. Acceleration forces make the cargo heavier. It becomes pressed against the lashing or bracing and becomes dented or punctured. Damaged container or package can cause spillage or leaking which may contaminate other cargoes carried in the same unit. In order to prevent this kind of damage to cargo, goods must be separated with adequate materials, and stowed according to good practice [1].

2.4.3 *Sweating*

Sweat water can occur as a result of container sweat or cargo sweat. The roof is most susceptible to formation of water droplets. It can cause wet damage to cargo or its package, thus completely damaging it, or lessening its value. Top dunnage must be used to absorb sweat dripping from the roof [1].

2.4.5 *Heat damage*

As the cargo may be exposed to extreme temperatures on its voyage, it is likely to experience high temperatures from the sun radiation. Some commodities can be affected and therefore their quality changed. This is mostly the case with beverages such as wine or beer. Heat can also cause mechanical damage. For example, beer bottles can brake due to increase of inside pressure and cause leakage. If flammable cargo is carried, heat can trigger chemical process which may cause fire [1].

2.4.6 *Chafing*

Not only bad weather and violent movement of vessel causes mechanical damage. Pulsating movement of the vessel or truck can be taken up by packages which are not properly stowed. This causes them to rub one against other or against any sharp corners. Cartons can rub against each other, thus removing a thin layer of carton. The value of consignment may be reduced this way. If, for example, insulated cables are carried, and insulation coating is affected, it could lead to heavy claims [2].

2.4.7 *Loss of cargo*

Cargo stored in container can become lost due to damage of the unit. The ones stowed on deck may experience breaking wave impact. The magnitude of this event makes it impossible to secure the load. Entire containers may break apart, and the content lost at sea. Due to extreme movement of the ship lashing gear may fail, and containers become lost. According to World Shipping Council surveys, in period from 2008 to 2013, it is estimated that there were 546 containers lost at sea each year, not counting catastrophic events [1].

Picture 5. Cargo damaged by breaking wave impact

3. Refrigerated cargoes

Certain commodities such as fresh or half processed food are easily perishable, and require specific temperature and atmosphere conditions. There are two types of cargo shipped in refrigerated state: live and dead cargoes.

Dead cargoes are transported as frozen in order to prevent them from deteriorating. This can be caused by bacteria or enzyme activity. Commodities of this group are: meat, fish, dairy products, half processed food… The temperature at which these are transported vary between -8°C and -30°C, depending on the enzyme content.

Live commodities can be both, frozen or cooled. These are kept at specific temperature to slow down their ripening process, inhibit bacterial or mold growth. Some of the cargoes transported as cooled are: eggs, tropical fruit, vegetable, flowers and other agricultural products. Although ripening process is slowed down, thanks to low temperature, these still respire and this calls for the use of ventilation. In order to protect the cargo from temperature shocks and to enable fast transport, terminals and ships are oriented to speed [4].

3.1 Storage on ships

Refrigerated cargoes used to be transported exclusively as break bulk cargo in specialized refrigerated ships. This type of vessel is characterized with insulated walls and refrigerating equipment. It is provided with multiple decks and locker spaces which allow it to carry cargoes of different requirements. It is designed to carry palletized cargo which can be loaded trough the hatch openings or trough the doors on the ship's side. With the development in container technology and introduction of refrigerated containers, more cargo is transported this way. Nowadays, refrigerated containers are mostly handled by liner container vessels. Liner container vessels carry refrigerated units at the aft, where power supply connections are readily available.

Modern frigo ships also offer accommodation for containers, as they are easier to handle and offer uninterrupted cold chain from producer to consumer. These can be designed to carry palletized cargo in the hold, and containers on deck, or as exclusively container carrying vessels. There are two general types of refrigerated ships:

- Ships for frozen goods
- Ships for cooled cargoes

The difference between these two is in their equipment. Ships for cooled cargoes, in addition to refrigeration equipment, are also fitted with ventilation units. They are also provided with double skinned flooring which allows air circulation. Within this group, banana vessels are most specialized. These are fast ships, usually painted white and equipped with doubled refrigerating equipment, for safety [4].

Picture 6. Reefer vessel

3.2 Cargo handling

Most of the frigo ships are equipped with their own derricks for handling both, palletized and containerized cargo. It is lifted from the shore into the hold trough the hatch. Forklifts are used to carry the pallets from the warehouse and to load them into the pallet cave. This is a metal frame with the capacity up to 8 pallets, hanged on ship's or shore crane. Once the cargo is lifted in to the hold, jacks and forklifts are used to stow it. Some ships are designed to receive and discharge the pallets using just forklifts. They enter and leave the hold trough the gates on ships side Containers can also be handled by ship's own or shore based mobile cranes. Refrigerated containers shipped on larger liner container vessels are handled using container gantry cranes [4].

Picture 7. Loading palletized cargo

3.3 Storage in port

Refrigerated cargoes are stored in special cold storage warehouses placed only few meters from the berth. It is placed this way in order to reduce the temperature shock to the cargo while being transported from the ship into the port storage facility. The warehouse is provided with loading docks for refrigerated trucks as well. This way cold chain is preserved from a producer to a customer. All openings and walls are designed to provide optimum insulation level. They are provided with separate storage spaces for all types of cargo. So, they offer space for chilled, cooled and goods which undergo ripening process [4].

3.4 Damage to cargo

3.4.1 *Too high temperature*

Of all the cargo shipped in cooled or frozen state, tropical fruit appears to be the most sensitive toward temperature. It is picked in unripe condition and during transportation and storage in a port warehouse, it undergoes the process of slow ripening. Insufficient cooling can cause it to enter climacteric. If this happens, irreversible process of ripening starts and entire batch of cargo can overripe during the transportation. Insufficiently low temperatures

can also cause growth of naturally present mold, yeast, and bacteria on all sorts of cargo, from meat and dairy products, to fruit and vegetables.

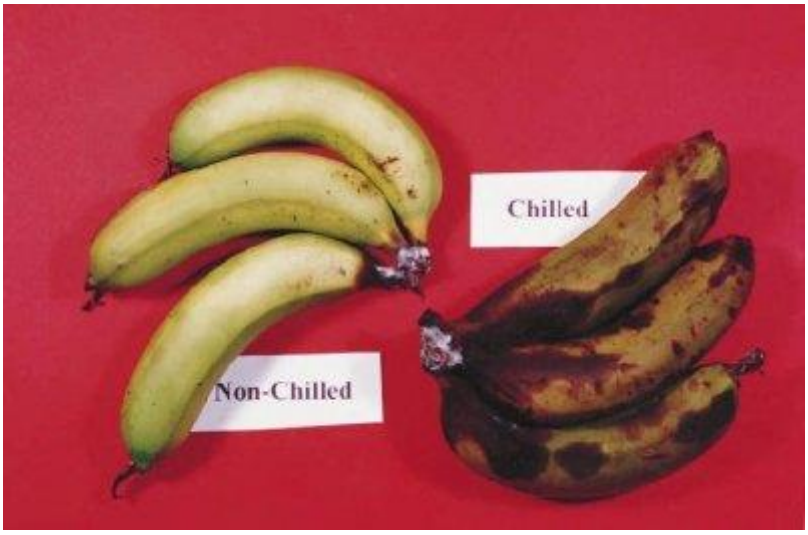
Bacteria, found on dead commodities, requires temperatures of above -8°C to be active and make harm to the cargo. The enzymes found in frozen commodities are active at the temperature above -62 °C .Satisfactory suppression of activity is achieved at the value of -18°C. Each type of cargo has its optimum storage temperature, and if this is not respected, deterioration or over ripening will start. This can be caused by human error or equipment failure [5].

3.4.2 *Fluctuation of the temperature*

Frozen cargoes require storage at constant temperature. When being handled in the port and on the ship, it is prone to partial defrosting which can occur due to temperature fluctuation, even if temperature is below 0°C. This can be caused by the malfunction of refrigerating equipment or by human error. When the cargo is exposed to lower temperatures again, large crystals form inside the tissue and break cell walls. This causes the goods such as meat or fish to lose its quality [5].

3.4.3 *Too low temperature*

Fresh fruit and vegetables require storage of temperatures between 0°C to +15°C, depending on the type of cargo. Commodities which are not sensitive to low temperatures are carried at values of around 0°C. It must be kept in mind that most fruit and vegetable are consisted mainly of water, and if chilled, they may be damaged irreversibly. Tropical and subtropical fruit is sensitive to low temperatures, and require higher values than most other fruit. Bananas are considered to be the most sensitive to low temperatures. A drop in temperature of just 0.2°C can cause chilling injury. Skin becomes grey and the fruit can not ripen any longer [5].



Picture 8. Chilling injury

3.4.4 *Tainting*

Prior to stowing of the cargo, the storage space should be checked for cleanliness. Food is susceptible to strange smells thus cargo spaces should be free of any. It does not matter if the smells are pleasant or obnoxious, they should be eliminated, as the smell is closely associated with the taste [2]. Mechanical and ozone treatment are undertaken to neutralize any smells [6].

3.4.5 *Damage caused by inadequate ventilation*

Live cargoes respire. The product of this process is water, heat, CO2 gas and ethylene, which can have negative effect on cargo if found at certain amounts. Ethylene is the compound produced by ripening fruit. It acts as a trigger to further ripening process. Holds must be ventilated, in order to remove this hormone from the surrounding. Bananas are highly susceptible to this hormone and therefore require up to 90 changes of air per hour. If ventilation fails, over ripening will occur. Carbon dioxide is normally found in the atmosphere. It naturally affects the intensity of fruit respiration. If live cargoes are exposed to higher levels of carbon dioxide they will ripen much slower [2]. This effect of carbon dioxide is used to significantly prolong the storage life of certain cargoes. If bananas are exposed to optimum levels of carbon dioxide their green-life will be prolonged, but if the concentration is too high, abnormal ripening will occur. While pulp continues to ripen, skin of the fruit stays green. This is known as green-ripening [7].

4. Grain cargo

Grain cargo is mostly transported as bulk cargo, but it can be transported in containers or in bags, as break bulk. The most common sorts of cereals are: rice, wheat, corn, oats, barley, millet, sorghum and rye. Oil seeds and processed seeds of added value are also transported as bulk. The by-product of processed seeds is often has the used as a fodder. A good example is corn gluten feed pellets or dry distiller's grains. Among most popular oil seeds are soya beans which are used for production of oil. Still, the most popular seed worldwide is wheat [2].

4.1 Storage on ship

4.1.1 *Hold design*

Ship's holds are divided by bulkheads, they are structural elements which give her hull transversal stiffness and divide it into watertight compartments. The most popular is corrugated design of bulkhead. In port and starboard bottom corners of each hold, there are hopper tanks, which are used as ballast tanks. They are covered with hopper plating which forms sloped smooth surface. This feature helps discharging of the cargo, as it centers it underneath the hatch opening. Sloped surfaces are also provided in forward and aft bottom corners by bulkhead stools. Upper corners are also fitted with hopper tanks called "wing tanks". These are used for ballast water, but their primary function is to prevent movement of cargo. When the grain is loaded, it tends to form a pile. Wing tanks reduce the need for trimming of the cargo, as the grain fills all parts of the hold, while being loaded. Grain cargo must be filled to the top of the hold, as it tends to settle during transportation by 5-6%. If holds are not filled entirely, ship's stability could be jeopardized [2].

Picture 9. Hold on dry bulk vessel

4.1.2 *Hold cleaning*

Cleaning of the hold is the first step to be taken prior to loading of grain cargo. Holds must be subjected to a survey by an approved independent surveyor in order to be grain clean. The type of cargo previously carried determines the process and equipment to be used for cleaning. Excess cargo residue must be hand swept. After this has been done, holds are washed with high pressure hold cleaning gun, a portable unit operated by a couple of seaman. Some ships are equipped with fixed cleaning gun, but the principle is the same. Washing is done by means of salt water, which in case of oily residue left by bituminous coal, is supplemented with marine safe degreasing compound. Rusty parts of the ship's hold and paint chippings must be removed and painted. Painting is done if there is sufficient time for the paint to cure until next loading. Otherwise, it could pose a threat for taint contamination. The final step of hold cleaning is rinsing with fresh water [8].

4.2 Storage in port

Silo is the facility made for storage of grains in the port. It is a tall structure usually around 50 meter high, with capacity up to 100 000 tons in ports with large amount of grain trade. There are three types of silo:

- Silo with one or two shallow compartments of large base area
- Silo with many smaller chambers for storing many different types of grain
- Silo with multiple stores

Grain is stored at optimum atmospheric conditions, which can be altered by using appropriate equipment. Cargo is discharged from the silo by gravity. It can be loaded onto bulk carrier or can be automatically bagged at the base of the structure and forwarded as general cargo [9].

4.3 Cargo handling

Grain cargo is loaded by ship loaders, which are metal structures equipped with the system of belts or chain conveyors. This system enables movement of the cargo trough the structure into the loading spout. Slewing, pendulum, and hoisting motion of the spout, as well as the travelling motion of entire tower, enable it to reach entire width and length of the ship's holds. Dust is generated in the loading spout, because of friction between accelerated grain and the spout. This is the reason why dust suppressing units are fitted at the end of the pipe. When completing the holds, it is essential to direct the spout so that all corners of the hold are completely full. It is also good practice to let some time for the grain to settle and refill afterwards. This is important from stability point of view, as the cargo would start shifting if not loaded to the top.

Picture 10. Grain loading

Unloading of grain can be done by means of mechanical or vacuum systems. Grabs or bucket elevators represent the group of mechanical systems. Those are machines of great efficiency which can exceed 600 t/h. During the unloading process, dust is created, and when completing the hold, an assistance of front loaders is required in order to unload last bits of cargo. Both of these disadvantages are the reason why vacuum unloaders are extensively used nowadays. Vacuum system provides dust free operation with less need for front loaders, as all

corners of the hold are easily accessible by flexible hose. This system, however is not cheap to run. It consumes up to four times more energy than mechanical systems do, but offer up to 1000t/h capacity in return [4].

4.4 Damages

4.4.1 *Moisture damage*

After the grain has been harvested, it contains high percentage of moisture, and therefore must be dried before shipment. For approximately two months period from the harvest, it undergoes process of post ripening. Water is constantly being expelled in this period, and grains should not be shipped yet. Moisture content of the grain should be below 14% in order to be "dry for shipment". Freshly harvested grain is likely to create damp atmosphere inside the hold. It is important to understand that the loaded cargo space contains grain and 30-40% interstitial air. It quickly becomes saturated with the moisture drawn from the seeds. When the ship enters colder climate regions, the temperature of the periphery layer of cargo is lowered. This is where the moisture which is generated in the deeper regions of the hold is constantly deposited. It is called cargo sweat at the periphery. Condensation can also occur on the inner side of the hold walls, and underneath of the hatch cover. It is called ship's sweat. It is caused by drop of the temperature of the ship's steel work. This part of the hold is not easily accessible, and can form some rust areas. As the drops of water form and drop on top of the cargo, it becomes soaked wet and can easily form suitable substrate for growth of mold. Cargo can become contaminated with the rust this way, too. To prevent this from happening, cargo space must be ventilated when conditions allow it.

When introducing air into the hold, it is important not to cause grater damage. The temperature of the introduced air must be lower than the temperature of the steel work, cargo and interstitial air. Introduction of additional condensate is prevented this way. The problem which can be caused by introduction of cool air is rapid cooling of top of the cargo caused by direct contact with the cool air and by evaporation of the moisture from top layer. This results in drop of the dew point of top layer below dew point of warm and saturated air from underneath. Rising, saturated air condenses underneath this layer and creates wet cake of cargo [10].

If the moisture of the grain exceeds 15%, it is likely to germinate, and when the moisture of grain is 17% it starts to swell. The increase of the grain moisture content can be caused by

introduction of water by the ventilation or by direct contact of the cargo with water. Swelling of the grain due to ingress of sea water can cause structural damage to the ship. Grain damaged by sea water becomes bitter and is no longer suitable for milling into flour [11].

Picture 11. Moisture migration

4.4.2 *Microbiological activity*

Self- heating of organic matter is number one hazard when dealing with grain cargo. Single consignment of cargo often consists of numerous different batches of grain with different properties. Localized damp areas may be formed this way. The fungi and yeast, naturally found on kernel surface, start to consume organic material when temperature and humidity levels are suitable. The respiratory activity of growing fungi and yeast releases water, heat and CO2 gas. Damp clusters of grain start to form, and intense heat cooks the cargo. If plausible, effected areas should be separated from unaffected cargo and destroyed. This is necessary, because certain fungi contain powerful neurotoxin and therefore grain is no longer compatible for human or animal consumption [10].

4.4.3 *Pest infestation*

Heat can also be generated by pests. In case of wheat, black weevil is the most common. The by-product of weevil larvae respiratory activity is heat. Temperature rises and cooks the grain as well as the beetles. The mix of dead bodies and cooked grain becomes media for mites, molds and bacteria. Grain deteriorates and becomes smelly. Heated and moist air rises upwards and creates columns of caked grain [10].

5. Crude oil

Crude oil, also known as mineral oil, is a liquid to semi-liquid substance found deep underneath the earth's surface. It is a mixture of various hydrocarbons and impurities such as metals, sulfur compounds and water. Crude oil is nonflammable liquid which emit flammable vapor. Volatility is a term used to describe the tendency of liquids to produce vapor. The volatility of oil is indicated by the vapor pressure it can create. Freshly extracted oil is highly volatile and as such can not be safely shipped or transported via pipeline. It is therefore stabilized first, by in the process during which vapor pressure of oil is reduced.
Crude oil is not used raw, it is separated into various customer products in refining process. Some of those fractions are: gasoline, kerosene, diesel fuel [12]…

5.1 Storage of oil in port

Liquid bulk terminal is equipped with storage facilities, piping and dedicated cargo handling equipment. Crude oil is stored in steel tanks specifically designed to store this type of cargo. Those are cylindrical structures made of steel plating. They are equipped with cargo mixing and heating equipment which reduce sludge accumulation and prevent the oil from solidifying. The technology of oil tanks is improving, ever since they were first introduced. For some time, fixed roof tanks were the only ones used. The problem with crude oil, as well as with other petroleum products, is volatile organic compounds [13]. Cancerogenic and flammable compounds are emitted by petroleum products and represent a threat to the entire ecosystem [14]. This is the reason why tank farms are placed away from residential areas. Fixed roof tanks are not designed to suppress emissions, and engineers came up with different design. The main characteristic of new design is the floating roof. The floating plate floats on the top of the oil and there is no free space for vapors. This design suppresses the emissions by 90% in relation to fixed roof solution [13].

Picture 12. Tank farm

5.2 Storage on ships

Storage space on tanker is divided into smaller sections. Longitudinal and transversal bulkheads represent barriers between each compartment. Smaller vessels are fitted with single longitudinal bulkhead, while larger ones have two. Thus, three tanks are formed across transversal section of the ship - one center tank and two wing tanks. Nowadays, tankers are constructed as double hullers. This feature protects the cargo from leaking in case of slow speed grounding, or collision [15]. It is estimated that 90 % of spillage in 1970's would be prevented if those were double, instead of single hullers. Modern terminals are also fitted with vapor recovery system. Its purpose is to recover any remaining vapors released from the storage tanks or those displaced from the ship's tanks during loading operations. This system improves the quality of the air at the terminal, and reduces cargo losses due to evaporation [16].

5.2.1 *Heating of cargo*

Crude oil tends to solidify if let at room temperature. In order to make it pumpable, it has to be in liquid state. This is why oil tankers are fitted with heating equipment. Normally, the temperature of received cargo is the one desired to be maintained until discharge. Upper and lower limit temperature should not be exceeded, as this could have effect on consistency of cargo and its quality. Every oil carrier is equipped with heating equipment. It can be: steam heater, oil heater or deck heaters. First two solutions use stainless steel coil, placed at the bottom of each hold. Hot media (low pressure steam or oil) circulates trough the system of

coils. Deck heaters are less popular system. Pumps are used to circulate the cargo trough heat exchangers placed on the deck [12].

Picture 13. Steam heating coils

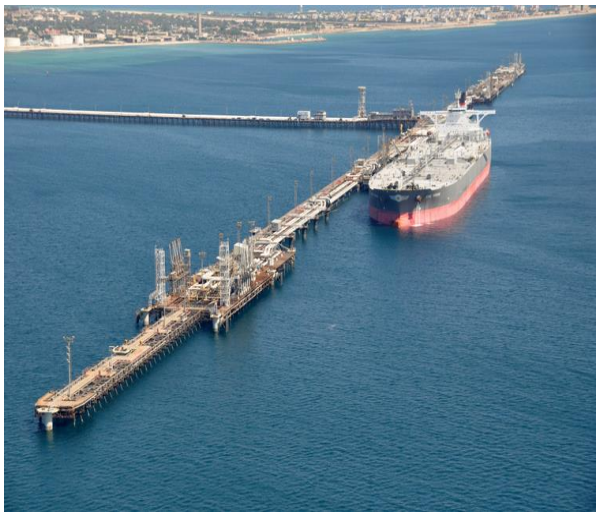
5.2.2 *Inert gas system*

Crude oil produces significant amounts of flammable gases. If proper mix of vapor and oxygen meet the source of the heat, it will explode. In history of oil tankers, explosions and fire happened many times, resulting in environmental and human suffer. Oil tankers are fitted with inert gas system. Inert gas is the air mixture which contains 5% or less of oxygen. It can be collected from the ship's boiler exhaust or produced in nitrogen generator. At the oxygen content of 10% in ship's hold, atmosphere does not support combustion. In practice, concentration of oxygen in the hold is kept between 3-5%. During loaded voyage, inert gas system does not work most of the time. Ullage space has too high concentration of flammable vapors and therefore does not support combustion. Tank must have positive pressure to prevent external air intruding into the tank. The functioning of inert gas system is of crucial importance while the ship is being unloaded [12].

5.3 Handling of cargo

5.3.1 *Types of terminals*

As ships became larger in size, port infrastructure struggled to keep the step. The length of the dock and the depth of the sea in the port were limiting factors for accommodating large vessels. This is why some smaller ports are equipped with offshore terminals. Those are made as mooring buoys. They are connected to the tank farm at the shore by means of submerged pipes. Once the vessel is moored to the buoy, flexible cargo hose is connected to the ship's manifold. At the conventional quay, peer or jetty, shore pipe lines connected to the ship's manifold using loading arms of flexible cargo hoses. Loading arms are essentially telescopic steel pipes with swivel joints. They are designed to tolerate slight ship movement during cargo handling operation [17].



Picture 14. Jetty

Picture 15. Single buoy mooring

5.3.2 *Loading*

When the loading arm or cargo hose is connected, and after going trough necessary preparation, the Chief Officer contacts the terminal to start delivering cargo. Oil is delivered in small rate at first, to check if all the connections and valves are properly secured. Any kind of leakage should be detected in this phase. After this, cargo is delivered at steady rate. Tanks are filled until topping off ullage is reached. The rate of delivery is lowered in this moment by opening next tank to be loaded or by contacting the terminal to reduce the rate of delivery. One tank serves as a backup tank, where the cargo is to be directed in case of overflow or any

other problematic situation such as jammed valve. During loading, vent valves are opened. Air displaced from the tanks is released trough the Mast riser, or sent ashore via vapor collection piping for processing. This method is known as closed loading operation [18].

Picture 16. Marine loading arm

5.3.2 *Unloading*

Unloading of cargo is done by means of ship's pumps. Centrifugal pumps are most commonly used on oil tankers. Forward tanks are usually discharged first to increase stern trim. This helps to drain the tanks. During discharge, tanks are washed by using crude oil washing procedure. Sludge, which would otherwise remain on girders and tank walls is washed off. When the tank is emptied to a certain level, main pumps can not be used any longer. Stripping pumps are employed to suck all remaining cargo [19].

5.4 Cargo damage

Loss of cargo due to oil spillage is considered more of the environmental problem than just financial loss. It is estimated that in the last 64 years, 5.5 million cubic meters of crude oil were spilled into the sea due to tanker accidents. Those happened during deep sea voyage, in restricted waters, during loading and unloading. There are numerous different causes of spillage. Some of them are: grounding, collision, equipment failure, fire, and unknown

reasons. 56 percent of all spillage happened during 1970's, and number of accidents as well as quantities of spilled oil are constantly decreasing [16].

Loss of cargo due to evaporation is even more significant, and results in every day losses. It is estimated that in fixed roof tanks with capacity of 21 700 tons of crude oil, approximately 96 tons of cargo are lost due to evaporation. In tanks with floating roof, this value is much lower, about 2 tons per year [14]. When crude oil is being shipped, increased temperature of ship's deck causes the increase of vapor emissions. Sometimes, deck is sprayed with sea water to reduce losses [17].

6. Conclusion

The principles of handling and storage of different types of cargo are determined according to their characteristics and requirements of trade. Ships and storage spaces in ports are designed to ensure economic use of storage space and to comply with specific cargo requirements. Personnel employed in cargo handling and storage is required to have good knowledge of cargo characteristics, its liability to damage and hazards of handling. Their actions have direct impact on the safety of the handling procedure and the final quality of the cargo. It may be the case that the damage is localized to small portion of the consignment and represents just the financial loss to the owner of the cargo. However, the effect of damage can be much more serious. Lives and properties may be lost and environment effected. Those are the reasons why cargo must be properly stowed, handled and taken care for during the voyage.

7. Glossary

Batch- količina

Belt conveyor- transportna traka

Break bulk cargo- generalni teret

Bulkhead- pregrada

Cell guides- vodilice

Chafing- šteta od trenja

Chain conveyor- lančani prijenosnik

Claim- tužba, reklamacija

Collision- sudar

Commodity- roba

Container gantry crane- mosna dizalica

Contaminate- kontaminirati

Crude oil- sirova nafta

Crude oil washing- pranje sirivom naftom

Customer- kupac

Dairy product- mliječni proizvod

Damage- šteta

Deck- paluba

Deterioration- kvarenje

Dunnage- zaštitni materijal

Equipment- oprema

Eradicate- iskorijeniti, ukloniti

Forklift- viličar

Grain cargo- žitarice

Grounding- nasukanje

Handling- ukrcaj, rukovanje

Hatch cover- poklopac grotla

Hold- brodsko skladište

Inert gas- inertni plin

Insulation- izolacija

Interstitial- međuprostorni

Jack- paletar

Loading arm- ukrcajna ruka

Merchant ship- trgovački brod

Mites- gnjide

Mold- plijesan

Obnoxious- neugodan

Package- pakiranje

Pattern- uzorak

Perishable- kvarljivo

Port side- lijeva strana

Reach stacker- auto dizalica

Refrigerated cargo- rashlađeni teret

Residential- stambeno, naseljeno

Saturated- zasićeno

Seaman- mornar

Shipper- otpremnik

Silo- silos

Solidify- očvrsnuti

Sorghum- sirak

Spout- cijev

Stack- složiti

Starboard side- desna strana

Stevedore- lučki radnik

Storage- skladištenje, skladište

Stowage- slaganje

Straddle carrier- kontejnerski prijenosnik

Stuffing- punjenje

Submerged- uronjeno

Sweating- znojenje

Taint- kaljanje

Tarpaulin- cerada

Transportation- transport

Turnbuckle- zatezač

Tween deck- međupalublje

Ullage- slobodni prostor tanka (2%)

Volatile- isparljiv

Wharf- lučka obala

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8.1 Pictures

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9. Sažetak

Tereti: štete na teretima, rukovanje teretom i skladištenje na brodovima i u internacionalnim lukama

Ovaj rad bavi se teretima u pomorskom prometu, njihovim skladištenjem, rukovanjem te štetama tijekom transporta. U rad su uključeni: kontejneri, rashlađeni tereti, žitarice te sirova nafta. Svaka vrsta tereta odlikuje se posebnim karakteristikama koje diktiraju dizajn skladišnih prostora te prekrcajne opreme. Opisani su načini ukrcaja i iskrcaja terete te posebnosti brodova, lučkih skladišnih prostora te opreme za rukovanje teretom. Postoje različite vrste šteta na teretima. Objašnjene su posebnosti ovih tereta, mehanizmi nastanka te posljedice šteta.

Ključne riječi: cargo damage, cargo handling, cargo storage, ship, port, container, grain, refrigerated cargo, crude oil

10. Summary

Cargoes: Cargo damage, Cargo handling and storage on ships and in international ports

This paper discusses cargoes in maritime transport, the way they are stored, handled and the way they can be damaged during transport. It includes: containerized cargo, refrigerated cargoes, grain cargo and crude oil. Each type of cargo has unique characteristics which dictate the design of storage spaces and cargo handling equipment to be used. It describes the process of cargo loading and unloading. There are different types of damages. It explains the characteristics of these cargoes, causes and outcome of damages.

Key words: cargo damage, cargo handling, cargo storage, ship, port, container, grain, refrigerated cargo, crude oil