CARGO LIQUEFACTION AND DANGERS TO SHIPS

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This paper was first published at TransNav 2014 Conference, Barcelona

ABSTRACT

Bulk carriers are ship types designed to carry dry cargo in bulk form. Especially concentrate cargoes, such as iron ore and nickel ore, affect ship stability negatively. International Maritime Solid Bulk Cargoes Code (IMSBC Code) divide bulk cargoes into three categories. First category is cargoes which may liquefy. Cargo liquefaction is a serious problem for solid bulk cargo carriers. Liquefaction problems cause loss of lives, total loss of ships and a high cost of insurance. M/V Mega Tars, M/V Sea Prospect, M/V Jian Fu Star, M/V Nasco Diamond , M/V Hong Wei and lastly M/V Vinalines Queen are all totally lost ships with 94 lives lost during 1988-2005. Besides loss of lives and total loss of ships; near miss accidents, cargo and ship structural damage often occur due to cargo liquefaction. During voyages; motion of ships especially rolling, engine and deck equipment vibration, cause cargo liquefaction due to the moisture content of the cargo. In this paper the author investigates the reasons for total loss of bulk carriers and their cargo, the reason for loss of stability due to cargo liquefaction and the Master and crew responsibilities for loading and during the voyage under the IMSBC Code and SOLAS 74 Regulations

Keyword: Bulk Carrier, Cargo Liquefaction, Loading, SOLAS 74.

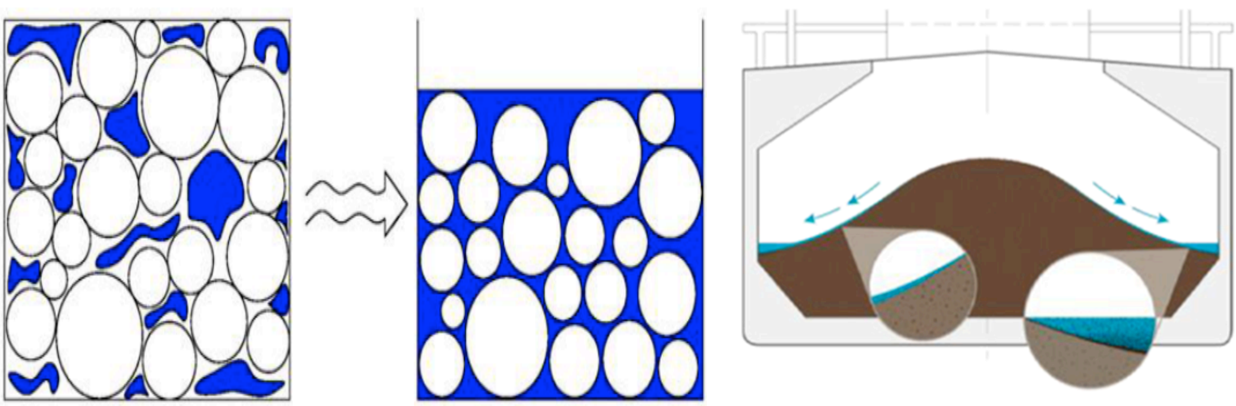
1. INTRODUCTION

The International Maritime Solid Bulk Cargoes (IMSBC) Code; defines solid bulk cargo as any material, other than liquid or gas, consisting of a combination of particles, granules or larger pieces of material, generally uniform in composition, which is loaded directly into the cargo spaces of a ship without any intermediate form of containment [1]. International Convention for the Safety of Life at Sea, 1974 (SOLAS) Chapter IX; defines a bulk carrier as, a ship which is constructed generally with a single deck, topside tanks and hopper side tanks in cargo spaces, which is intended primarily to carry dry cargo in bulk, and includes such ship types as ore carriers and combination carriers [2]. According to Maritime Safety Committee 70/4/Add.1; a bulk carrier is a ship designed, constructed and/or used for the carriage of solid bulk cargo [2]. Most popular bulk cargoes in world trade are iron ore, coal, grain, bauxite/alumina, petroleum coke, steel, ores, cement, sugar, quarts, salt, fertilizers, sulphur, scrap, aggregates and forestry products [3]. Much demand for bulk carrier trade exists, the biggest drawback is carrying solid bulk cargoes that involve serious risks. These risks include reduced ship stability, and even capsizing, due to cargo liquefaction; fire or explosion due to chemical hazards; and damage to ship structures due to poor loading procedures [4]. According to the International Association of Classification Societies Class (IACS) research shows that insufficient loading plans and improper handling of heavy and high density cargo during loading and unloading causes dangerous situations for ship structures and creates excessive stress [5]. Poor ship to shore communication, ignoring and deviating from loading plans, inadequate pre-loading plans, improper load distribution between holds, asymmetric load and ballast distribution, overloading by high capacity systems, partially filled holds and ballast tanks, physical and structural damage during discharging can also cause fatal structural damage to ship's hull [5]. The main legislation for safe carriage of solid bulk cargoes is the International Maritime Solid Bulk Cargoes (IMSBC) Code, which became mandatory on January 1, 2011, under the SOLAS Convention [4]. The primary aim of the IMSBC Code is to facilitate the safe stowage and shipment of solid bulk cargoes and to give detailed information about the intended solid bulk cargo to the ship and give instructions about the dangers and risks of particular cargoes [6]. The IMSBC Code categorizes cargoes into three groups. Group A - cargoes which may liquefy, Group B - cargoes which possess a chemical hazard which could give rise to a dangerous situation on a ship, and Group C - cargoes which are neither liable to liquefy (Group A) nor posses chemical hazards (Group B) [4]. The goal of this study is to make seafarers aware, especially the master, about cargo liquefaction and try to highlight the risks of cargo liquefaction as an overview.

2. CARGO LIQUEFACTION

The general definition of liquefaction is the process of converting a substance from its solid or gas state into its liquid state. In more scientific terms, in its solid state the particles of a concentrate are held together by friction [7]. Certain cargoes, particularly nickel ore and iron ore fines, initially look dry and their characteristics are solid during loading on the ship. But during the voyage, concentrate cargoes like nickel ore or iron ore fines are exposed to agitation under certain conditions including ship's rolling, wave impact and engine vibration which results in compaction of the cargo [8]. Due to sufficient moisture in the cargo, external agitation can increase water pressure inherent within the concentrate, pushing particles apart as shown in the figure 1. The material suddenly starts transition, friction is lost and the cargo begins to behave like a liquid with free surface effect and creates a sudden and major stability problems for the vessel [7]. The cargo starts to shift in one direction with the ship's rolling and does not return to the centre. Further rolling causes listing. This situation may lead to loss of ship stability and potentially capsizing [9].

Fig 1: Liquefaction as a result of cargo compaction. [8]



The main reason for cargo liquefaction starts with most mine locations being very far from the loading/port facilities. Also, very rudimentary and limited loading equipment and methods take time to load the cargo on board. Cargo is stockpiled, uncovered, on the beach. Rain and monsoon conditions cause the moisture levels in the cargo to increase but this cannot be visibly seen [10]. Due to remoteness of the mines, it is hard for independent surveyors/experts to take samples of the cargo to be loaded [11].

Fig 2: Iron ore fines before and after liquefaction [12]

2.1 ACCIDENTS and TOTAL LOSS DUE TO CARGO LIQUEFACTION

There have been a series of total losses and serious incidents caused by cargo liquefaction. This may result in serious stability problems as loss of lives and total loses of ship, see table-1.

Table 1: Accidents due to cargo liquefaction [7]

Vessel	**Vessel Details**	**Date**	**Loss of Life**	**Voyage**
Mega Taurus	1988	16/12/1988	20	Hinatuan Mine (Philippines) – Japan
Oriental Angel	1990	09/06/1990	-	New Caledonia (capsized at anchorage)
Jag Raghul	2005	Dec-07	-	Tanjung Buli (Indonesia) – Ukraine (nr miss)
Asian Forest	2007	17/07/2009	-	Sank In The Arabian Sea 8 Miles Southwest Of Mangalore, India
Jian Fu Star	1983	27/10/2010	12	Sank In The South China Sea 90 Miles Southwest Of Cape Eluanbi, Taiwan

Nasco Diamond	2009	10/11/2010	20	Developed list to port, took water and sank In The Pacific Ocean.
Hong Wei	2001	03/12/2010	10	Capsized and sank in the South China Sea.
Vinalines Queen	2005	25/12/2011	22	Developed 18 degree list and eventually sank In the Philippine Sea.
Trans Summer	2014	05/02/2014	-	Sunk off coast of Hong Kong
Grand Fortune	2014	04/04/2014	13	Sunk off southern coast of South Korea

M/V Jian Fu Star, M/V Nasco Diamond and M/V Hong Wei sank and totally forty four seafarers loss their lives. Their cargoes were nickel ore; the ships were sailing from Indonesia to China [13]. The cause of the sinking has not yet been definitively known but nickel ore is known to suffer the risk of liquefaction, if the moisture content of the cargo exceeds the transportable moisture limit (TML) when loaded. It is very possible that all three vessels capsized and were lost as a result of cargo liquefaction [13]. In 2009, two bulk carriers, The Asian Forest and the Black Rose sank while carrying iron ore fines during the monsoon season. The Indian Director General of Shipping investigated the sinking, and concluded that the reason was liquefaction as a consequence of excessive moisture in the cargo [14].

One of the main causes of the casualties and near misses is poor compliance of some shippers with the testing and certification requirements concerning the moisture test of cargoes that are required under SOLAS and the IMSBC Code [8]. If the cargo is loaded and the moisture content is in excess of its transportable moisture limit, the cargo reaches its flow moisture point and turns into a fluid state. Liquefaction which reduces a ship's positive stability and metacentric height (GM) may cause possible loss of the ship [14].

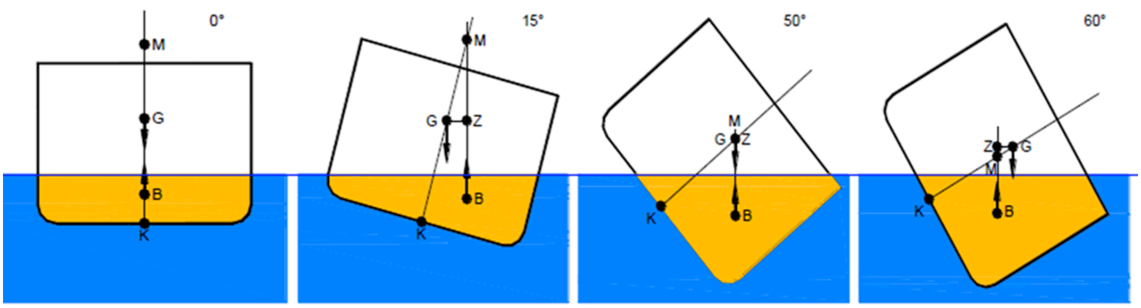


Fig 3: Liquefaction effect on ship stability [15].

3. INTERNATIONAL REGULATIONS, RESPONSIBILITES and TESTS for AVOIDING CARGO LIQUEFACTION

3.1 DEFINITIONS

The definition of flow moisture point is the maximum water content, expressed as a percentage, at which a sample of cargo will begin to lose shear strength. The moisture content of a cargo beyond the flow moisture point (FMP) may liquefy [16]. According to IMSBC Code definition, *transportable moisture limit (TML)* of a cargo which may liquefy means the maximum moisture content of the cargo which is considered safe for carriage in ships. The transportable moisture limit is determined by the test procedures, approved by a competent authority [6].

3.2 SHIPPER and MASTER RESPONSIBILITIES

According to IMSBC Code, Regulation 4; the shipper has to provide the master, or his representative, with appropriate information about the cargo. The shipper should provide adequate and appropriate information in advance. By providing this information, the ship will be able to take any necessary precautions for proper stowage and safe carriage of the cargo onboard. This information should be presented to the Master prior to loading and confirmed by officially prepared documents [6]. .

The most important subject for the ship operators and master is actual TML value determined by laboratory. SOLAS requires that the average moisture content of a Group A cargo in any cargo space must not be higher than the TML [16]. To find the TML using the Flow Table Test, FMP should be determined by laboratory tests. Loading a cargo above, at or near its FMP represents an unacceptably high risk for vessels. The cargo is safe to load when moisture content of the cargo sampled is below the TML [16].

The master should ensure that moisture content of the cargo is not more than the TML. As per the IMSBC Code, a certificate of moisture content must be declared by the shipper to the master. The interval between testing moisture content and loading current moisture content should not be more than seven days [9].

Masters and officers should check and inspect the cargo moisture content visually before commencement of loading by undertaking a visual inspection of the cargo before loading. If the Master believes in the necessity, additional testing should be done to determine moisture content [9]. If there is any doubt about the validity of the signed certificate of average moisture content, or the cargo moisture content has excessively high moisture, the master should stop or refuse to load the cargo until he is satisfied that the cargo is safe for carriage. Also, an independent surveyor should take samples of the cargo for testing the true moisture content [9].

Fig 4: Flow Table Test [9].

4. CONCLUSION

The improper loading of solid bulk cargoes, cargo liquefaction effects and inadequate communication between the shipper and the Master, are resulting in a number of accidents. The Master must always monitor the weather conditions before loading commences for iron ore, nickel ore and other concentrate cargoes. The master should not forget he has an overriding authority under SOLAS. If he is not satisfied with the safety of the cargo, he should refuse the cargo and stop loading if any risk exists. SOLAS and IMDG Code have very strict rules for avoiding cargo liquefaction. The transportable moisture limit that IMSBC Code specifies, must be known before cargo loading commences and should be certificated by an appropriate laboratory. Familiarity of IMSBC Code and SOLAS regulations is required of bulk carrier crews. Qualified and experienced ship's crews are essential for solid bulk cargo carriers to prevent loss of life and total ship loses.

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