IDENTIFICATION OF MOISTURE CONTENT IN THE CLASSIFICATION OF SOLID BULK CARGO OF NICKEL ORE THAT HAS THE POTENTIAL TO LIQUIFY WHILE IN THE CARGO HOLD OF A MERCHANT SHIP

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Abstract
Iron ore has long been used for industrial steelmaking. Several countries have very large reserves of this commodity, such as Brazil and Australia, which export 70% of their total exports and are the two countries with the highest export value, followed by other countries such as South Africa, Chile, Canada, and the United States with an estimated 33%. Most iron ore is transported by Capesize ships > 80,000 DWT, and even for oceangoing transportation, it can be much larger, reaching 165,000 DWT with a ship length exceeding 350 meters with a draft of over 20 meters. Solid bulk cargo of nickel ore poses a risk in transportation because it can melt (liquefy) during the journey, reducing the stability of the ship, thus endangering the safety of the ship. Solid bulk cargo of nickel ore is classified as cargo group A, which is that it may liquefy if shipped at a moisture content (MC) exceeding the Transportable Moisture Limit (TML). The liquefaction of nickel ore cargo has caused the capsizing of several ships and reduced safety in transportation. To overcome the risk of liquefaction in solid bulk Nickel ore cargo before the start of loading, a laboratory moisture content test must be carried out so that the cargo is safe before being loaded. The purpose of this study is to analyze the moisture content in solid bulk Nickel ore cargo that is at risk of liquefaction and can disrupt the stability of the ship. If the Moisture Content in a Group A cargo exceeds the Transportable Moisture Limit, then the cargo can be declared unsafe to be loaded onto the ship. Therefore, the Moisture Content of the cargo must be reduced to less than the specified Transportable Moisture Limit.

Keywords: Nickel solid bulk cargo, Liquefaction, Ship stability

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1. Introduction

The risk of liquefaction of nickel ore cargoes from Indonesia and the Philippines has long been a major issue requiring constant vigilance and review by shipowners and charterers. Referring to reports of maritime accidents in October and November 2010 where three bulk carriers, namely MV 'Jian Fu Star', 'Nasco Diamond' and 'Hong Wei' sank while transporting nickel ore from Indonesian ports for export abroad where dozens of crew members were reported to have died with the cause of the shipwreck still undetermined, however nickel ore like fine iron ore and many other concentrates, is a cargo that can liquefy if the moisture content of the cargo exceeds the Transportable Moisture (TML) threshold during loading. The occurrence of liquefaction of bulk cargo can result in loss of ship stability which in turn can endanger the condition of the ship during navigation. The recent tragedy of MV Emerald Star in October 2017 once again demonstrated the importance of strict compliance with the IMSBC Code (2016) and other relevant international conventions, as well as the sinking of MV Nur Allya on August 21, 2019, is a testament to the fact that Nickel ore is the most dangerous cargo if handled improperly. Under the IMSBC Code (2016 edition), solid bulk cargoes can be classified into three categories and among these, group A cargoes are those that may liquefy if shipped at a Moisture Content (MC) exceeding their Transportable Moisture Limit (TML). By its nature, nickel ore is a cargo that may liquefy if the MC of the material exceeds its TML. Thus, nickel ore falls under Group A cargo under the IMSBC Code (2016 Edition).

Nickel ore cargo has sufficient moisture and naturally absorbs water. Continuous vibrations of the ship during sea voyages can cause cargo containing high moisture content and TML to become unstable, which can cause changes in the cargo structure, from a solid to a liquid state. This will cause instability on the ship, resulting in listing or even capsizing. Ship motion can cause the cargo to shift sufficiently to capsize. Cargo shift can be divided into two types: shear failure or liquefaction consequences. Cargo trimming according to the code of conduct can prevent shear failure. Cargo shift caused by liquefaction can occur when the moisture content exceeds the TML (Roni, 2023; Fierdaus et al., 2024).

Some cargoes are susceptible to moisture transfer and can develop a dangerous wet base even if the average moisture content is less than the TML. Although the surface of the cargo may appear dry, undetected liquefaction can occur, resulting in cargo shifting. Liquefied ore cargoes will only be accepted for loading when the actual moisture content of the cargo is less than its TML. To address the risk of liquefaction in iron ore solid bulk cargoes, laboratory moisture testing must be conducted before loading to ensure the cargo is safe before loading. This laboratory testing includes MC and TML moisture testing on samples of nickel ore solid bulk cargoes. The purpose of this study is to analyze the moisture content in nickel ore solid bulk cargoes that are at risk of liquefaction and thus disrupt ship stability, and how to manage moisture in nickel ore solid bulk cargoes.

The transportation of solid bulk cargoes is an important part of the shipping industry, especially for mining commodities such as nickel ore. Based on the provisions of the International Maritime Organization (IMO) through the International Maritime Solid Bulk Cargoes Code (IMSBC Code), solid bulk cargoes are classified into three groups based on their level of danger, where Group A is cargo that has the potential to liquefaction if its moisture content exceeds the Transportable Moisture Limit (TML). Nickel ore is included in Group A because it contains fine particles and a certain moisture content which, when subjected to vibration and compaction during shipping, can increase the water pressure between particles, thereby reducing shear strength and changing the nature of the cargo from a solid to a liquid. This condition risks causing cargo shift, listing, and even capsizing. Therefore, before loading, a moisture content (Moisture Content/MC) test is mandatory to ensure the value is below the TML, which is determined based on the Flow Moisture Point (FMP) through an internationally recognized test method. The challenges are further complicated when loading is carried out from remote ports with limited facilities, conventional loading and unloading methods are still used, independent laboratories are limited, the physical properties of nickel ore are not homogeneous, and transhipment practices can potentially cause changes in water content due to weather exposure. These conditions increase the risk of inconsistencies between TML and

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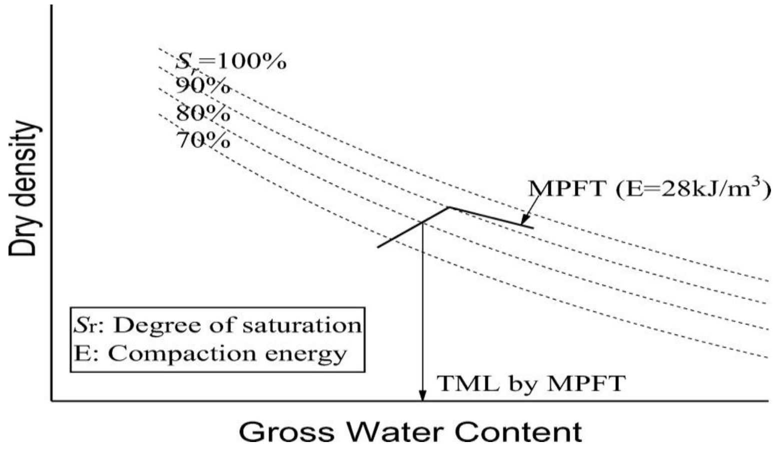
MC data and increase the potential for liquefaction, which endangers the safety of the vessel and its crew.



2. Method

This study uses qualitative descriptive research, namely with the aim of describing the conditions observed in the field more specifically, transparently and in-depth. Data collection techniques are observation, interviews, documentation and literature studies. The purpose of this study is to systematically describe the analysis of water content in solid bulk cargo of Nickel Ore which is at risk of melting and thus disrupting the stability of the ship, as well as how to manage moisture in solid bulk cargo of Nickel Ore. This research was carried out when the author attended training and practice on Solid Bulk Cargoes Testing and Training Facility (SBC-TTF) AMSAT and Seminar on Handling Solid Bulk Cargoes on Bulk Carriers Which Are High Risk for Shipping Safety held by the Djadajat Maritime Academy Jakarta.

3. Results and Discussion

The IMSBC Code requires that the shipper provide certification to the master confirming the TML and the actual moisture content of the cargo before loading. Cargo cannot be considered safe for transportation if the moisture content is not less than the transportable moisture limit. If the moisture content is equal to or exceeds the TML, the cargo must be declared unsafe. Certification provided to the master must not be more than seven days old, the cargo moisture test must be renewed, and the cargo can only be loaded if the new certification, approved by the competent authority, states that the moisture content is below the TML.

Moisture Content (MC) testing is performed in a laboratory by placing a weighed sample in an oven at 105 degrees Celsius until a constant mass is reached. The dry sample weight is then measured.

The way to calculate Moisture Content (MC) is: MC (wt%) = (wet weight - dry weight) / wet weight x 100%. Transportable Moisture Limit (TML) testing methods that are often used are the Flow Table Test, Penetration Test and Proctor-Faberberg Test. Each method has its own advantages, the choice of testing method must be determined by on-site practice or by the appropriate authority. Determination of TML = 0.9 x FMP

Flow Moisture Point (FMP) is the point at which a granular bulk material becomes liquid. FMP is measured in percent and is the maximum moisture content at which a cargo sample will begin to flow.

If the analysis results show that the Moisture Content (MC) of the bulk Nickel ore cargo exceeds the Transportable Moisture Limit (TML), then the cargo can be declared unsafe to be loaded on a ship. The Moisture Content of the cargo must first be reduced to a level lower than the specified Transportable Limit Content (TML). Reducing the water content can be done by drying in the sun, drying with an oven, and so on.

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The International Solid Bulk Cargo Code (IMSBC) was issued based on SOLAS 1974 and its protocols. The Code establishes internationally agreed conditions for the safe stowage and shipment of solid bulk cargoes, including liquefiable cargoes, such as nickel ore. Cargoes not specifically listed are covered by Section 1.3 of the Code. The Code became internationally mandatory on 1 January 2011.

Regulation VI/2, SOLAS 1974 requires the Shipper to provide the Master or his representative with all relevant information regarding the cargo sufficient before loading to enable such precautions as may be necessary for the proper stowage and safe carriage of the cargo.

A simple test to determine the transportable moisture limit in the field is the Can Test, which is recommended by the IMSBC Code 2011. The Can Test is performed by randomly taking samples from the barge and placing them in a container (a 0.5 liter can/iron cup) until full. The container is then thumped 25 times at a height of 20 cm. The sample will be level in the container. If it is dry and free of water, the sample is considered good and may be loaded.

Moisture management for Group A cargo requires shippers to develop moisture management procedures to ensure the cargo moisture is below the TML and remains below the TML during loading. This includes sampling, moisture content determination, methods for estimating moisture increases during rain, control measures during rain, and methods for determining changes in the cargo moisture content from measured representative samples.

The methods to reduce the liquefaction of group A cargo are to avoid cargo that is susceptible to liquefaction from the cargo space, partition the cargo space with a resistant structure, appropriate drainage techniques, and deep foundation aspects.

Scientifically, the requirement to certify the TML and actual water content before loading reflects the application of the precautionary principle in shipping risk management. The phenomenon of liquefaction in solid bulk cargo, particularly nickel ore, is closely related to the concepts of soil mechanics regarding pore water pressure and effective stress (Yanuar, 2024). When a ship experiences vibrations and dynamic movements during shipping, fine particles in the cargo experience compaction, reducing the volume of intergranular voids and increasing pore water pressure. This increase in pressure reduces the internal shear forces between particles, causing the material to lose strength and behave like a fluid (Ranakulslam et al., 2022). In this context, setting the TML at 0.9 × FMP represents a safety factor to anticipate variations in material heterogeneity, sampling inaccuracies, and changes in water content due to weather exposure.

From a technical-operational perspective, the accuracy of Moisture Content (MC) and Flow Moisture Point (FMP) testing is crucial for the validity of the certification granted to the captain (Dara & Melysa, 2023). Unrepresentative sampling can result in biased MC values, particularly in stockpiles exposed to rain or with an inhomogeneous grain size distribution (Setiani et al., 2026). Therefore, sampling procedures must adhere to international standards, including the random and proportional determination of sampling points. Test methods such as the Flow Table Test or the Proctor-Fagerberg Test not only measure moisture content but also simulate dynamic conditions that mimic ship vibrations, thus providing an empirical picture of potential changes in material behavior during voyage. Thus, laboratory testing is not merely an administrative formality but a scientific instrument for predicting cargo stability under real-world operational conditions.

Furthermore, Group A cargo moisture management should be viewed as an integrated control system encompassing technical, administrative, and field supervision aspects. Rain control, stockpile protection with adequate cover, timing of testing and loading, and periodic evaluations during the loading process are all part of ongoing risk mitigation. The master's role under SOLAS provisions is not only to receive documents but also to exercise professional judgment (master's overriding authority) if there is any doubt about the validity of the data submitted. With this approach, compliance with the IMSBC Code not only fulfills international regulatory obligations but also directly contributes to the prevention of ship accidents due to cargo shifting and liquefaction, which can potentially cause loss of life, ship damage, and environmental impacts.

4. Conclusions and Suggestions

Solid bulk cargo of nickel ore poses a high risk in maritime transportation due to its potential for liquefaction during shipping, which can reduce ship stability and endanger shipping safety. According to the International Maritime Organization (IMO) regulations, the International Maritime Solid Bulk Cargoes Code (IMSBC Code), nickel ore is classified as a Group A cargo, meaning it can liquefy if shipped with a moisture content (MC) exceeding the Transportable Moisture Limit (TML). Therefore, laboratory testing is mandatory before loading begins to ensure the cargo's moisture content is below the TML to ensure it is safe for transport. If the test results indicate that the Moisture Content exceeds the TML, the cargo is declared unfit for loading and must be reduced to below the specified TML. In practice, the loading process of Group A solid bulk cargo must be accompanied by strict moisture management procedures to ensure the moisture content remains below the TML, both before and during loading. In addition, the captain or his representative is obliged to monitor the entire series of loading operations from start to finish, and loading may not be carried out if all the required written cargo information has not been received and agreed upon by all related parties.

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