Carriage of Direct Reduced Iron (DRI)

Contents

Carriage of Direct Reduced Iron (DRI)

Introduction

Direct reduced iron (DRI) is produced by passing hot reducing gases such as hydrogen and carbon monoxide over iron ore (oxide), which is usually in the form of pellets or lumps. Although the process is conducted at high temperature, this is still substantially below the melting point of iron. This means that the lumps and pellets retain their original shape, but are considerably lighter owing to the removal of oxygen from the ore. Therefore, the pellets and lumps have a very porous structure, which makes the material extremely reactive and prone to re-oxidation on contact with air and moisture.

This briefing highlights the issues, and problems, with the carriage of DRI.

DRI and its derivatives

Initially, most DRI was shipped in the form of pellets. This form was found to be most at risk of heating (see below) and methods of treating DRI were tried in order to reduce the danger.

Passivated pellets

These are ordinary DRI pellets coated with a substance which is intended to protect the iron from air and moisture. Producers in different countries use different forms of coating, some of which are more effective and durable than others. However, no coating renders the DRI entirely safe. The coating can chip off and it will break down over time.

Cold moulded briquettes

These are DRI pellets which have been compressed into the shape of a cake of soap, the intention being to reduce the accessible surface area of the pellets in order to reduce the area available for reacting with air and moisture. The briquettes can also be passivated. The problem with this cargo is that the briquettes are relatively fragile as they are compressed when cool. They can fracture during normal cargo operations, which increases the amount of surface area available for reaction with air and moisture and the cargo becomes dangerous in a similar way to pellets.

Hot moulded briquettes or hot briquetted iron (HBI)

The pellets and lumps can be compressed at temperatures exceeding 650°C to form coherent briquettes that are less porous than the original materials. As such, the briquettes are less fragile and, therefore, less prone to breaking up during cargo handling and have less surface area available for oxidation. They can also be passivated. This is possibly one of the safer forms of DRI but, even so, is still prone to heating and giving off hydrogen in certain conditions.

DRI fines

The DRI production process (and the hot-briquetting process if HBI is being produced) generates copious quantities of dust or ‘fines’.

These fines are usually stored separately from the finished DRI or HBI product, but, as they have commercial value for steel making, there is a market for shipping them. Fines are not normally compressed into large cohesive briquettes and remain porous like DRI pellets. As fines they also exhibit an extended surface area. Consequently they can exhibit self-heating qualities. They may have also generated hydrogen in sufficient quantities to form explosive atmospheres, even in holds that have been subject to natural ventilation through conventional cargo hold vents, or hatch cover openings.

Carriage of Direct Reduced Iron (DRI)

Hazards of DRI and derivatives

The principal hazards of all cargoes of DRI and its derivatives are twofold.

Reaction with air

Firstly, they will react with the oxygen present in the air, thereby producing heat. This effect can run away in spectacular fashion, leading to auto-oxidation (burning) of the iron, in which the stow becomes incandescent as the temperatures approach 1,000^{o}C. This tendency is successfully prevented in most practical applications by densifying the DRI pellets at temperatures exceeding 650^{o}C to produce HBI.

Whereas self-heating is dangerous and alarming, it is a gradual and progressive event that can often be diagnosed early, affording masters time to obtain advice from ashore and institute suitable safety measures.

Reaction with moisture

The second hazard is again related to the reactivity of iron, this time with moisture or water. The result is the generation of hydrogen gas, which is explosive over a very wide range of concentrations and, in practical situations, displays an alarming readiness to be ignited. Explosions of hydrogen in air are extremely violent and rapid and an unfortunate master has no time in which to react to an explosion.

Misleading descriptions of DRI

Shippers may offer a material for bulk shipment that is clearly a DRI product, but is claimed to be safe for bulk carriage by sea without the usual precautions. This particularly applies to DRI fines.

The most common device is to call the fines ‘HBI Fines’ or ‘Metallic HBI Fines’ and thereby claim the relaxation in precautions afforded to HBI. Fines have also been described as ‘Iron Remet Fines’, the term ‘remet’ probably being a shortening of the word ‘remetalised’, signifying it is metallic rather than the ore.

Despite the foregoing, not all cargoes with ‘DRI’ in the description are hazardous. For example, Members have been offered cargoes described as ‘direct reduced iron ore’. By referring to the typical material composition supplied by the shippers, it could be seen that this was indeed iron ore that was destined for the direct reduction process, and therefore a cargo that posed no special hazards. However, this is difficult for a master to determine and expert advice should always be sought by the Member.

Regulatory Developments

Following a number of investigations into accidents associated with the carriage of DRI, the International Maritime Organization (IMO) has recently revised the relevant schedules to be included in the new International Maritime Solid Bulk Cargo (IMSBC) Code, which will replace the BC Code. The IMSBC Code was adopted at the IMO Maritime Safety Committee (MSC) meeting in November 2008 for voluntary implementation by member States from January 2009 and mandatory application from 1 January 2011.The IMSBC Code was finally published during September 2009.

Safe carriage of DRI

The common factor to both hazards mentioned above is the oxygen present in the atmosphere. It is clear that the exclusion of oxygen, or its reduction to a suitably low level, will eliminate the possibilities of self-heating or of a hydrogen explosion occurring. It follows that carrying a cargo of DRI or its derivatives under an inert gas blanket, and maintaining that blanket throughout the voyage, is an acceptable method to carry the product safely. The IMSBC Code recommends that both DRI (B) and DRI (C) cargoes are carried under an inert blanket.

Summary of IMSBC Code Schedules for DRI and its Derivatives

The following summary has been produced to assist Members in their decision making process and for their general information. Should a vessel be fixed to load a DRI or related cargo Members should, of course, refer to and comply with the more detailed advice contained within the IMSBC Code. We strongly recommend that DRI cargoes and their derivatives are carried strictly in accordance with the requirements of the IMSBC Code.

All Types of DRI

- Fines are now defined as particles up to 6.35mm (¼") in size.
- Cargo spaces shall be clean, dry and free from salt and residues of previous cargoes. Wooden fixtures and combustible materials shall be removed.
- The carrier's representative is to have reasonable access to stockpiles and loading installations for inspection.
- Prior to loading, the shipper shall provide the Master with a certificate issued by a competent person stating the cargo is suitable for shipment and that it conforms with the requirements of the Code in terms of particle size, moisture content and temperature.
- A similar certificate shall be provided after loading relating to the whole consignment.
- The shipper shall provide comprehensive information on the cargo and safety procedures to be followed in the event of an emergency.
- No cargo shall be loaded or transferred during precipitation and non-working hatches shall be kept closed.
- The cargo shall not be accepted when its temperature is in excess of 65^{o}C, or its moisture content exceeds the permitted value, or if the quantity of fines exceeds the permitted value, where appropriate.
- The cargo temperatures shall be monitored during loading and recorded in a log.
- The cargo shall be trimmed in accordance with the relevant provisions of the Code.
- Adjacent tanks other than double bottom tanks shall be kept empty during the voyage.
- Weather tightness shall be maintained throughout the voyage.
- The bilge wells shall be clean and dry and protected from ingress of cargo.
- Precautions shall be taken to protect personnel, equipment etc. from the dust of the cargo.
- During handling of the cargo, "NO SMOKING" signs shall be posted and no naked lights or other ignition sources permitted.
- Suitable precautions shall be taken before entering cargo spaces, which be depleted of oxygen and/or contain a flammable atmosphere.
- The ship shall be provided with a detector suitable for measuring hydrogen in an oxygen depleted atmosphere and for use in a flammable atmosphere.
- Cargo temperatures and hydrogen concentrations in hold atmospheres shall be measured at regular intervals during the voyage.
- If the hydrogen concentration exceeds 1% or the cargo temperature exceeds 65^{o}C, appropriate safety precautions shall be taken. If in doubt, expert advice shall be sought.
- Bilge wells shall be checked regularly for the presence of water.
- All records of temperature, hydrogen and oxygen measurements, where appropriate, are to be retained on board for 2 years.
- The hydrogen concentration shall be measured in the holds prior to opening the hatch covers.

DRI (A), Briquettes, hot-moulded

- The moisture content shall be less than 1%.
- The cargo shall comprise essentially whole briquettes and the addition of fines shall be prohibited.
- Fines shall comprise no more than 5% by weight.

- Weather deck closures and hatch covers shall be inspected and tested to ensure integrity and weather tightness.
- Surface ventilation only shall be conducted as necessary and air shall not be directed into the body of the cargo. When mechanical ventilation is used, the fans shall be certified as explosion-proof and shall prevent spark generation. Wire mesh guards shall be fitted over inlet and outlet ventilation openings, and the escaping gases shall be unable to enter living quarters.
- During discharge, the application of a fine spray of fresh water is permitted only when the cargo is to be stored in an open area.

DRI (B), Lumps, pellets, cold-moulded briquettes

- The average particle size shall be from 6.35mm to 25mm, with fines no more than 5% by weight.
- The shippers' certificate shall state the date of manufacture for each lot of cargo.
- The certificate issued after loading shall confirm that the moisture content has not exceeded the permitted value.
- The cargo shall be certified as having been aged for at least 3 days, or treated so as to achieve the same reduction in activity.
- The cargo shall be kept dry at all times. Any cargo that has been wetted, or known to have been wetted, shall not be loaded.
- Loading conveyors shall be dry.
- Prior to loading, an ultrasonic test or another equivalent method with a suitable instrument shall be conducted to ensure weather tightness of the hatch covers and closing arrangements.
- The moisture content shall less than 0.3% by weight and shall be monitored during loading.
- Any cargo that has already been loaded into a cargo space and which subsequently becomes wetted, or in which reactions have started, shall be discharged without delay.
- The breakage of briquettes and lumps shall be minimised and the addition of fines shall be prohibited.
- Carriage is only permitted under an inert gas blanket.
- Prior to loading, provision shall be made to introduce a dry inert gas at tank top level. Nitrogen is preferred. All vents and openings shall be sealed to prevent the loss of the inert atmosphere.
- On completion of loading of a cargo space it shall be immediately closed and sufficient inert gas introduced to achieve an oxygen concentration of less than 5% throughout the cargo space.
- The ship shall be provided with the means of reliably measuring the temperatures at several points within the stow, and determining the concentrations of hydrogen and oxygen in the cargo space atmosphere on voyage whilst minimizing the loss of the inert atmosphere.
- The oxygen concentration shall be maintained at less than 5% throughout duration of voyage. The ship shall be provided with the means to ensure that this requirement can be achieved throughout the voyage. Consideration shall be given to topping up with additional supplies of inert gas: the ship's fixed CO_2 fire-fighting system shall not be used for this purpose.
- The ship shall not sail until the master and a competent person recognised by the national administration of the port of loading are satisfied that:
    - All loaded cargo spaces are correctly sealed and inerted;
    - The cargo temperatures have stabilised at all measuring points and are less than 65^{o}C; and
    - The concentration of hydrogen in the free space has stabilised and is less than 0.2% by volume (i.e. 5% LEL).
- The cargo spaces shall remain tightly sealed and the inert condition maintained throughout the voyage.
- The ship shall be provided with a detector suitable for measuring oxygen in a flammable atmosphere.
- Oxygen concentrations shall be measured at regular intervals during the voyage.
- During precipitation, all cargo discharge operations shall be suspended and holds containing cargo shall be closed.

DRI (C), By products, Fines

- The average particle size shall be less than 6.35mm, and there shall be no particles greater than 12mm in size.

- "The reactivity of this cargo is extremely difficult to assess due to the nature of the material that can be included in the category. A worst-case scenario should therefore be assumed at all times."
- The cargo shall be kept within the permissible moisture content at all times.
- The carriage requirements are identical to those for DRI (B), including the 0.3% limit on moisture, with the following exceptions:
    - The shippers' certificate does not need to state the date of manufacture of each lot of cargo;
    - The cargo shall be certified as having been aged for 30 days.
    - Any cargo that has already been loaded and which subsequently is exposed to additional fresh water or seawater over its natural moisture content and becomes wetted, or in which reactions have started and its temperature has exceeded 120 ^{o}C, shall be discharged without delay.

Acknowledgements

The Association is very grateful to Dr Alan Mitcheson, Dr J H Burgoyne & Partners LLP, for providing articles for North of England's Signals newsletter on which this briefing is based, and for providing further assistance with the briefing. The Association is also very grateful to Cliff Mullins, Minton, Treharne & Davies Ltd, for providing assistance with the briefing.

Dr J H Burgoyne & Partners LLP
Burgoyne House
Chantry Drive
Ilkley
West Yorkshire
LS29 9HU
UK

Telephone: +44 (0) 1943 609251

Website: www.burgoynes.com

Minton, Treharne & Davies Ltd
Bankside House
107-112 Leadenhall Street
London
EC3A 4DJ
UK

Telephone: +44 (0) 20 7626 8626

Website: www.minton.co.uk