Leaving Certificate Engineering Prescribed Topic 2024

Design, operation and technology of container ships.

The Rethinking Engineering Education in Ireland (REEdI) project at Munster Technological University (Kerry campus) have developed this document with the aim of supporting students with their study of the special topic prescribed for the Leaving Certificate Engineering Examination in 2024.

What is REEdI?

REEdI is a project that is funded through the Higher Education Authorities Human Capital Initiative (HCI) Pillar 3 fund. The goal of REEdI is to reinvent the way that engineering education is designed and delivered in Ireland. REEdI designed the Bachelor of Engineering (Hons) in Mechanical and Manufacturing Engineering at MTU Kerry Campus (CAO Code: MT834). This agile and innovative engineering programme is the first of its kind in Ireland and the world.

REEdI Student Engineers will spend 2 years on campus in Tralee, County Kerry and then go on 2 years paid work placement at a choice of world class manufacturing companies. Our student engineers will continue their academic studies online whilst also learning on the job by putting their knowledge and skills into practice, at our partner companies.

REEdI are proud of the support structures we have in place for our student engineers. These include extra maths support, mentoring, online learning supports and access to engineers in residence (who have industry expertise and help prepare our student engineers for their work placement).

If you are interested in an exciting and varied career, a career that will make a difference, a career that will help you to become an engineer of the future, then you should consider the REEdI Engineering degree at MTU Kerry Campus (CAO Code: MT834).

What is a container ship?

A container ship is a large seafaring vessel, which has been specifically designed for the transportation of standardised containers. They are equipped with multiple levels of cargo holds, to accommodate thousands of containers stacked in a secure and efficient manner.

The world's largest container ships, often referred to as ultra-large container vessels (ULCVs) are about 400 metres long, 60 metres wide and can carry over 20,000 (twenty-foot) containers.

Stern view of *Ever Ace* in Hamburg

Container ships play a crucial role in global trade by facilitating the movement of goods between countries and continents.

The world's fleet of container ships also includes smaller feeder ships for servicing shorter costal routes.

***Karin Schepers* a feeder ship leaving Belfast**

What is a shipping container?

Shipping containers are used to store a vast array of products and materials, whilst they are transported from one location to another. There are several types of standardised shipping containers used to meet requirements of shipping different kinds of cargo. These include flat rack containers, open top containers, refrigerated containers, and tanks.

Dry storage shipping containers.

The dry storage container (as shown in the image above) is the most commonly used type of shipping container. These are rectangular metal boxes, with standardised dimensions that have been established by the International Organisation for Standardisation (ISO).

Shipping containers are described as intermodal, which means that they can be transferred between different modes of transportation, such as ships, trucks, and trains. Loading and unloading of shipping containers is carried out by specialised cranes, the process does not require manual handling of the cargo. For this reason, the containerisation of cargo revolutionised the shipping industry by simplifying and speeding up the process of transporting goods. It enabled standardised handling procedures, enhanced security, and reduced costs, making international trade more accessible and efficient.

How is the capacity of a container ship measured?

The capacity of container ships is measured in units known as TEU (twenty-foot equivalent). TEU is based on the dimensions of one standard 20-foot-long container, which measures 20 feet in length, 8 feet in width, and 8.5 feet in height (L 6.06m, W 2.44m, H 2.59m).

The TEU measurement allows for the comparison of container ship capacities and provides a simple way to quantify the volume of goods being transported. For example, a 10,000 TEU container ship can theoretically carry 10,000 standard 20-foot containers or a combination of larger (40-foot) containers that equate to the same overall volume.

DESIGN

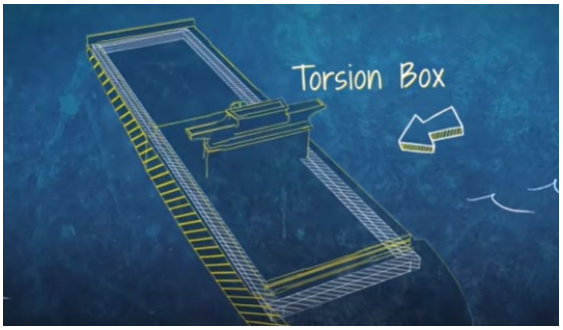
The design and shape of the hull is one of the most characteristic features of a container ship. The front of a container ship is streamlined to reduce resistance and allow the ship achieve high speed. Modern container ships have a bulbous bow. This feature modifies the way the water flows around the hull, which reduces drag and increases the ship's speed, range, fuel efficiency, and stability.

This image shows the bulbous bow of a container ship.

Most of the length of the ship's hull is rectangular. This accommodates the maximum number of containers below the deck. Container ships feature a wide and deep hull, allowing for the stacking of containers in multiple layers, both above and below the deck. The capacity of container ships is a critical factor in their design. As a result, modern container ships have become larger and more efficient over time.

Most container ships have lift-on lift off hatch covers. This means the vessel has no continuous main deck. Container ships are designed with a double hull to maintain torsional strength which is reduced by the large hatch openings. The double hull compartments are used as ballast tanks.

Another critical structural feature of container ship design is the torsion box. It is used to provide strength, rigidity, and structural integrity to the ship's hull while minimising weight. On large ships it also serves as a corridor for crew members.



A diagram showing a torsion box around the top of the hull.

What factors influence the design of a container ship?

The design of a container ship is influenced by a range of factors, which include economic, environmental, and operational considerations. The core design elements of container ships revolve around maximising cargo capacity, facilitating efficient loading and unloading processes, ensuring operational safety and fuel efficiency.

Stability

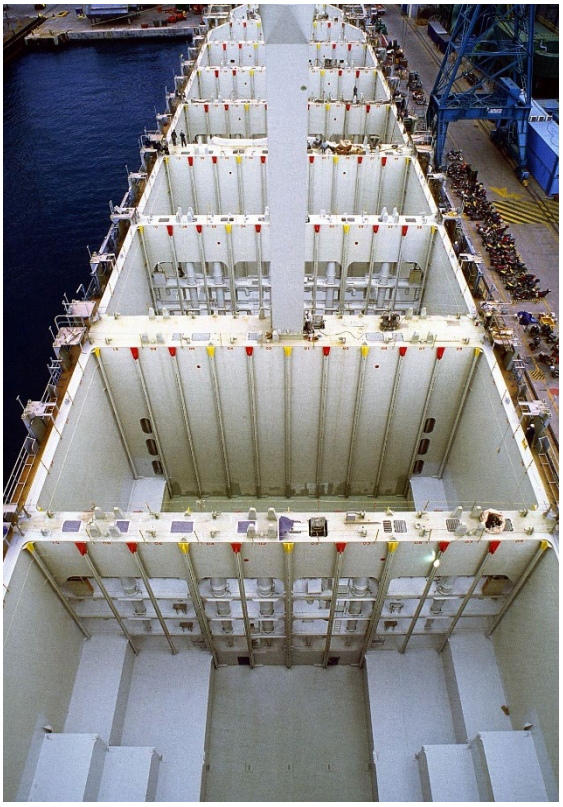
Stability is crucial for container ships, as they carry a large number of containers stacked on top of each other. Engineers must ensure that the ship's centre of gravity and metacentric height are optimised to maintain stability in

various weather conditions. A container ship's metacentric height is a critical stability parameter that indicates the ship's ability to resist rolling motions and maintain an upright position in water.

To maintain stability and proper trim, container ships use a ballast system that pumps water in and out of dedicated tanks within the vessel. Trim refers to the longitudinal balance or alignment of the vessel in the water. It specifically relates to how the ship's hull is level from bow (front) to stern (back) along its length.

When a container ship is properly trimmed, it means that the ship's hull is evenly balanced in the water, ensuring that the bow and stern are at the appropriate levels. Improper trim can affect the ship's stability, speed, fuel efficiency, and overall performance.

The hull of modern container ships is divided into cellular cargo bays, which hold the containers. Cell guides are used to securely stack and align containers vertically. The introduction of cell guides in the mid-nineties reduced the cost, as no lashing materials were required to secure the containers in the hold. This also reduced shifting of containers during transport and improved the speed of loading and unloading.



An aerial view of an empty container ship showing cell guides.

Containers on deck are secured to the hatch with lashing rods and twistlocks.

A small number of container ships are hatchless. On these ships the cell guides extend above the hold. These vessels don't require lashing rods and twistlocks.

A hatchless container ship

Manoeuvring a container ship

Container ships must be manoeuvrable to navigate in and out of ports and to avoid collisions with other ships. Engineers must consider factors such as the ship's turning radius, propeller design, and rudder size to ensure optimal manoeuvrability. The size and design of container ships are constrained by the limitations of port infrastructure, such as the depth of harbours, the height of cranes, and the width of shipping lanes, such as the Suez Canal.

The *Ever Given* blocking the Suez Canal in 2021.
Source: Rosenfeld Media via flickr

Over the past few decades, major ports around the world have been expanding and upgrading their infrastructure to accommodate larger container ships. This has included deepening channels, expanding container terminals, and investing in larger cranes and other handling equipment. As a result, the shipping industry has been able to build and operate larger vessels that can take advantage of these enhanced port facilities. While many major ports have invested in infrastructure to handle larger vessels, not all ports can accommodate the largest container ships. This limits the number of routes and destinations available to the mega ships.

Efficiency

Fuel efficiency is a critical factor in the design of container ships, as fuel costs can represent a significant portion of a shipping company's operating expenses. Designers use advanced hull designs, propulsion systems, and control systems to maximise fuel efficiency and reduce emissions. The use of high-strength steel and lightweight materials allows for larger vessels with increased structural integrity and reduced overall weight.

Regulations

Container ships are subject to a range of environmental regulations, including emissions standards and ballast water management regulations. Designers must consider these regulations when designing container ships to ensure compliance and minimise environmental impacts, such as transporting invasive species in ballast water.

Safety

Safety is a paramount concern in the design of container ships. Designers must ensure that the ship is structurally sound, that the cargo is properly secured, and that the crew and passengers are protected in case of emergencies.

A brief history of container ship design evolution

In 1956, the first container ship, the Ideal X, was launched by American businessman Malcom McLean. This ship was modified to carry standardised containers, which could be easily loaded and unloaded using cranes. This new method of cargo transport revolutionised the shipping industry, and from then on, the demand for container ships grew rapidly.

In the 1960s and 1970s, container ships became larger and more efficient. The introduction of standardised container sizes and handling equipment allowed for the construction of bigger ships that could carry more containers. The use of roll-on/roll-off ramps and container gantry cranes made

loading and unloading faster and more efficient.

In the 1980s and 1990s, container ship design focused on increasing speed and reducing fuel consumption. Advanced hull designs, such as bulbous bows, were developed to reduce drag and improve hydrodynamics. The introduction of computerised engine control systems and new propulsion technologies, such as diesel-electric engines, also improved efficiency and reduced emissions.

In the 2000s and beyond, container ship design continued to evolve with a focus on environmental sustainability. New propulsion systems, such as liquefied natural gas (LNG) engines and hybrid power systems, were introduced to reduce emissions and improve fuel efficiency. Lightweight materials, such as composites and aluminium alloys, are also used to reduce the weight of the ship and improve efficiency. Container ships have grown substantially in size, with the largest vessels now capable of carrying over 20,000 TEUs, compared to just a few thousand TEUs in the early days of containerisation.

Advancements in computational fluid dynamics (CFD) have enabled more streamlined and hydrodynamic hull designs, reducing drag and improving fuel efficiency. Modern container ships feature more efficient engines, waste heat recovery systems, and propeller designs that reduce fuel consumption and emissions.

OPERATION

Operating larger container ships can give shipping companies a competitive edge in the market, as they can offer lower freight rates and more efficient service to their customers. This can be particularly important on high-volume trade routes, such as those connecting Asia and Europe or Asia and North America.

Beyond a certain point, the benefits of larger ships may be offset by increased complexity, longer port turnaround times, and higher risks associated with accidents or operational disruptions.

Large container ships may face restrictions when transiting through certain canals, such as the Panama Canal or the Suez Canal, due to size limitations. These constraints may necessitate alternative routing or limit the full loading capacity of the vessels.

This image shows a ships tower.

The bridge is the command centre of the vessel, housing all necessary equipment for navigation, communication, and control.

There are dedicated compartments within the ship's hull, designed to hold ballast water. They are strategically placed throughout the vessel to enable precise adjustments to the ship's weight and balance. High-capacity pumps are used to transfer seawater into or out of the ballast tanks. These pumps are typically driven by electric motors and are controlled from a central control room. A network of piping, valves, and manifolds connects the ballast tanks and pumps, allowing water to be transferred between tanks or discharged overboard as required.

A centralised control system, typically located in the ship's engine control room, enables the

crew to monitor and control the ballast system's operation. This system may include sensors that measure tank levels, valves to control the flow of water, and alarms to alert the crew to any issues.

To operate the ballast system, the ship's crew follows a carefully planned ballast management plan, which considers the vessel's loading conditions, route, and regulatory requirements. The crew adds or discharges ballast water as needed to maintain stability, optimise trim, and comply with environmental regulations designed to prevent the introduction of invasive species or pollutants from one port to another.

The world's largest container ships are highly complex and require a team of specialised engineers to operate them. The number and types of engineers required may vary depending on the specific ship and its equipment, but generally, a team of at least 25 to 30 engineers is required for the largest container ships.

In addition to these specialised engineers, there may also be other personnel on board, such as oilers and fitters, who assist with the maintenance and operation of the ship's machinery. Critical tasks include checking the lashings and inspecting the containers on a regular basis. The exact number and types of personnel required will depend on the size and complexity of the ship, as well as the company's operating procedures and policies.

Loading and unloading

Container ships are loaded and unloaded using specialised cranes that are designed to handle the large and heavy containers. The cranes are typically located at ports, and they operate by lifting the containers off the ship and placing them onto trucks or trains for transport. The cranes are essential for the efficient operation of container ships, as they can handle large numbers of containers quickly and safely.

Liebherr cranes loading a container ship

Liebherr is a manufacturing company that specialises in producing ship-to-shore cranes for the shipping industry. They have a factory located in Killarney, Ireland, where they produce cranes specifically designed for loading and unloading container ships. Liebherr cranes are known for their reliability and efficiency, and they are used in ports around the world. The company's commitment to quality and innovation has made them a trusted partner in the shipping industry.

The world’s top 5 shipping companies

This list is based on the total number of vessels in their fleet.

- Maersk Line
- Mediterranean Shipping Company
- CMA CGM
- China Ocean Shipping Company
- Hapag Lloyd

TECHNOLOGY

The technology used on container ships is constantly evolving. One of the most important technological advances in recent years has been the development of electronic data interchange (EDI). EDI allows the shipping companies to exchange information

electronically, which reduces paperwork and speeds up the cargo handling process.

Another important technological advance is the use of satellite navigation systems. These systems allow the ships to be tracked in real time, which improves safety and efficiency.

Container ships are also increasingly using energy-efficient technologies. These technologies help to reduce fuel consumption and emissions, which is important for environmental sustainability.

Engineers are leveraging data analytics and machine learning algorithms to optimise various aspects of container ship operation, such as fuel consumption, route planning, and predictive maintenance. Internet of Things (IoT) and remote monitoring enable real-time monitoring of the ship's systems and components, allowing for early detection of potential issues and facilitating remote troubleshooting and decision-making.

The integration of advanced control systems in container ships enhances the operation and efficiency of the propulsion system, cargo handling, and other critical functions. Ships now rely on digital systems for route optimisation, cargo handling, and monitoring of various systems. These technologies have improved the overall operational efficiency and safety of container ships.

The use of digital twins allows designers to simulate, optimise, and validate designs before actual construction, reducing the risk of costly errors and enabling more rapid design iterations.

Research and development in autonomous shipping are paving the way for more efficient and safer operations. While fully autonomous container ships are not yet a reality, advancements in automation and remote control are already influencing the operation of modern vessels.

Efficiency

Silverstream's air lubrication system is an innovative technology designed to improve the energy efficiency of container ships. The system works by creating a thin layer of air bubbles along the ship's hull, which reduces friction between the hull and the water. This is achieved by using compressors to supply pressurised air to release units installed on the ship's hull. The system manages the air supply and monitors the performance of the air lubrication system in real-time. It has the ability to adjust the air flow to maintain optimal efficiency.

The reduction in friction enables the ship to move through the water more easily, leading to fuel savings and reduced carbon emissions.

Silverstream's layer of air bubbles on the ship's hull

The system can reduce fuel consumption by 5% to 10%, depending on factors such as ship design, operating conditions, and the air release unit configuration. The system can be installed on both existing ships (retrofit) and new-build vessels, providing flexibility for ship owners and operators looking to improve efficiency and reduce emissions.

Conclusion

In conclusion, container ships are critical components of the global economy, transporting goods across the world's oceans. The design, operation, and technology of these ships have undergone significant advancements to improve efficiency, safety, and sustainability. The world's largest

container ships, such as the *Ever Ace* are impressive feats of engineering. Operating these mega-ships comes with challenges and limitations. Environmental concerns, operational efficiency, safety, and regulatory requirements heavily influence container ship design. Continued advancements in engineering techniques, including computational fluid dynamics (CFD), advanced materials, data analytics, are crucial for enhancing container ship technology and meeting the demands of global trade. Container ships are designed to withstand the demands of long-distance ocean voyages and are operated by professional crews who ensure the safe and timely delivery of goods to their intended destinations. Container ships will undoubtedly remain indispensable for years to come, serving as vital conduits for global trade.

Hopefully this document has provided you with a comprehensive overview of container ships. For more information on the topic and additional learning resources visit our website at reedi.ie

RETHINKING ENGINEERING EDUCATION IN IRELAND
REEdI

Interested in Mechanical and Manufacturing Engineering?

The REEdI (Rethinking Engineering Education in Ireland) BEng (Honours) in Mechanical and Manufacturing Engineering is a blended degree that brings in the best of manufacturing and mechanical engineering, culminating in flexible and adaptable engineers to meet industry needs. The REEdI student engineer will learn about the design and development of processes whilst also gaining an equally strong knowledge of the design, development and operation of products and equipment.

The course is delivered using cutting edge technologies such as augmented and virtual reality. In addition, students get to learn from top lecturers in the field, study and work with emerging technologies, work with world-class companies, learning using a blended approach, through classroom-based, as well as hands-on experience. The goal of the REEdI programme is to turn curious, creative, innovative and adaptable people into the engineers of the future.

Two years of paid work placement is an integral element of the course. MTU will secure work placement for students.

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