Titanic – A Materials, Design, and Safety Failure

An Online Continuing Education Course for Engineers

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Credit: 4 Hours / 4 PDH / 4 CPD

Titanic – A Materials, Design, and Safety Failure

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In this course, you will learn:

a. History of the *Titanic's* design and construction
b. Hull plate and rivet composition and properties and their effect on the failure
c. The *Titanic's* design deficiencies relating to the disaster
d. Inadequate safety standards and operational errors that influenced the disaster and contributed to a large loss of life
e. Lesson learned from the disaster and impact on marine safety requirements and ship design

1. Background

The Royal Mail Steamer (RMS) *Titanic*, Figure 1, sank on April 14th, 1912, during her maiden voyage from Southampton, England to New York City, United States. The *Titanic* struck a large iceberg estimated to be many times the size of the ship at a location several hundred miles off the coast of southeast Newfoundland. The ship started taking on water, and in less than three hours, it sank. The *Titanic* disaster resulted in the deaths of approximately 1,514 passengers and crew out of 2,224 total people on the ship. The sinking of the *Titanic* was one of the worst and most famous maritime disasters in history. The large size of the ship combined with advances in shipbuilding led to the mistaken belief that the ship was "unsinkable." The magnitude of the *Titanic* disaster and the deaths of several prominent people captured the imagination of the world at the time.

Figure 1. Picture of the Royal Mail Steamer (RMS) *Titanic* leaving Southampton, England.

The Oceanic Steam Navigation Company, better known as the White Star line, owned the *Titanic*. When it was constructed, the ship was the largest luxury passenger liner ever built. Harland and Wolff, an Irish shipbuilding company in Belfast, Ireland, built the passenger steamship. The Titanic was one of three sister ships of the *Olympi*c-class ocean liners, including the RMS *Olympic* and the RMS *Britannic* that were planned by White Star line and Harland and Wolff. They were being built as competition to the Cunard Steamship Company's largest and fastest passenger liner ships, the *Lusitania* and *Mauritania,* for the transatlantic passenger and mail service. The two Cunard ships were capable of averaging approximately 25 knots and were the fastest transatlantic passenger liners until 1929. Instead of speed, the White Star line planned to compete with Cunard's ships on size and luxury. Furthermore, at the time, British shipyards were the world leaders in shipbuilding, and the new passenger liners were to incorporate the latest techniques in ship design and construction, technology, and safety features to reduce the chance of flooding and sinking. This led to the belief that the ship was "unsinkable" by her designer and the public. The *Titanic's* Captain, Edward John Smith, was quoted as saying, "I cannot conceive of any condition which would cause a ship to founder" and that "modern shipbuilding has gone beyond that." According to the *Titanic's* builders, even in the worst possible case of two ships colliding, the vessel should stay afloat for at least two to three days, providing adequate time for passengers to be ferried to safety. Unfortunately for the *Titanic* and its passengers, this was not the case.

2. Introduction

The wreckage of the *Titanic* was discovered at a depth of over 3,700 m (12,000 ft.) on September 1, 1985, by an expedition led by Dr. Robert Ballard of the Woods Hole Oceanographic Institute in collaboration with Jean-Louis Michel of the Institut Français de Recherches pour l'Exposition des Mers (IFREMER), a French oceanographic institute. Using the unmanned submersible *Argo* and remotely operated vehicle (ROV) *Jason*, the expedition located the bow but did not locate the stern of the ship. The stern, which was completely crushed, was located in a 1986 expedition led by Dr. Ballard using the manned submersible *Alvin* and the ROV *Jason Jr*. Instead of sinking as one structure, the bow and stern had split in half and were found lying about 600 m (1969 ft.) apart facing in opposite directions surrounded by a large debris field. Both the bow and stern experienced additional damage due to impacting the seafloor, and furthermore, they are deteriorating. Between the bow and stern and in the debris field were pieces of hull steel, bulkhead plates, and rivets in addition to many other items from the ship. The discovery of the *Titanic* wreckage confirmed the testimony provided by some passengers that the ship split in two at the surface, but was contrary to accounts of the disaster given by the ship's surviving officers. This new information and contradicting accounts of the sinking led to questions on how and why the *Titanic* sank.

Since the *Titanic's* discovery, many commercial and research expeditions have been conducted at the site of the wreck to answer these questions. The expeditions uncovered scientific evidence related to the failure by sonar imaging, photography, and video. In addition, the first small piece of steel hull plate recovered from the wreck site of the *Titanic* was brought back in 1991 by a Canadian-American-Russian expedition during the filming of *Titanica*, an IMAX documentary about the sinking. A later expedition by RMS Titanic, Inc. (RMSTI) and IFREMER in 1996 located and attempted to raise a loose but large piece of the steel hull from the starboard side referred to as "The Big Piece," Figure 2. However, this attempt was unsuccessful. This section was successfully raised and recovered in a 1998 expedition by RMSTI and IFREMER. When originally recovered, the section weighed approximately 20-tons and measured roughly 4.6 m × 7.6 m (15 ft. × 25 ft.) and had four portholes and numerous rivets. This expedition also recovered over 40 loose rivets of four different types from the debris field. The aforementioned scientific evidence combined with metallurgical analysis of the recovered hull plates and rivets and modern computational modeling has formed the basis of theories related to how and why the *Titanic* sank.

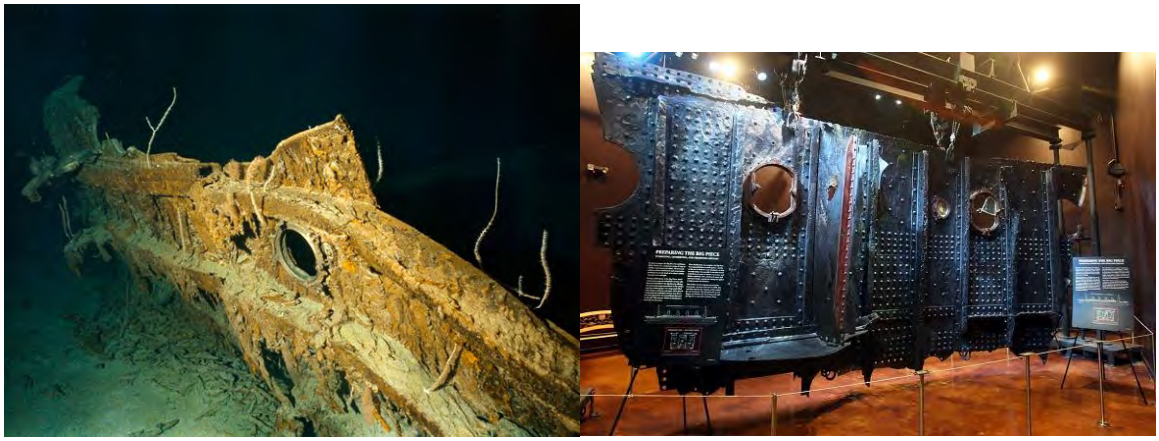

Figure 2. (Left) An approximately 20-ton section known as "The Big Piece" sits on the ocean floor before it was recovered. (Right) A 17-ton segment of the same section that is on display at the Luxor Las Vegas hotel and casino.

This course first presents background information about the *Titanic*. We will examine details about its design and construction, emphasizing the structure, materials, and power plant (boilers), engine, and propellers. We will also review facts about the ship's electrical system, bilge pumps, and wireless radiotelegraph equipment that are relevant to the disaster.

The course briefly covers events of the initial stages of the *Titanic's* maiden voyage and then focuses on events on the day of the collision and the immediate aftermath. The course examines the causes contributing to the collision, subsequent rapid sinking, and the large loss of life. We examine operational errors by the ship's captain and crew on the day of the collision and sinking; the effect of the hull steel's composition, microstructure, and properties; the effect of the wrought iron and steel rivet composition, microstructure, and properties; deficiencies in ship design for bulkheads and double hulls; and inadequate safety requirements for lifeboats.

We'll examine the reason the large ship essentially split in half near the rear expansion joint. We discuss modern steel used in shipbuilding compared to the steel used in the construction of the *Titanic*. Lastly, we discuss lessons learned from the disaster and changes made to ship design, the first International Convention for Safety of Life at Sea (SOLAS) in 1913, implementation of the first International Treaty in 1915, new requirements for lifeboats and training, changes to ship operations, and the formation of the International Ice Patrol (IIP).

As we discuss the Titanic disaster, one should bear in mind the six fundamental canons of engineers in fulfillment of their professional duties, as stated in the National Society of Professional Engineers (NSPE) Code of Ethics for Engineers.

- Hold paramount the safety, health, and welfare of the public.
- Perform services only in areas of their competence.
- Issue public statements only in an objective and truthful manner.
- Act for each employer or client as faithful agents or trustees.
- Avoid deceptive acts.
- Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

3. Design and Construction of the Titanic

3.1. Overview

The *Titanic* was essentially built side-by-side with her sister ship the *Olympic*, Figure 3. The keel of the *Olympic* was laid down first on December 16, 1908, while the *Titanic's* keel followed on March 31, 1909. The *Olympic* was launched on October 20, 1910, and the *Titanic* was launched on May 31, 1911. The *Olympic* was completed on May 31, 1911, and the *Titanic* was completed on April 2, 1912. The keel of the *Britannic* was laid down on November 30, 1911. It was launched on February 26, 1914, and completed on December 12, 1915. Following the sinking of the *Titanic*, the *Olympic* was refitted, whereas the *Britannic's* design and construction were modified to improve both ships' design and safety features. It is interesting to note that of the three ships, only the *Olympic* had a long service life. The *Olympic* made

hundreds of round trips between Southampton and New York on the transatlantic route before it was retired in 1935 and was finally broken up for scrap in 1937. It also has the distinction that in 1919, it became the first large ship to be converted from coal to oil. On the other hand, the *Britannic* was converted to a hospital ship before it was completed due to the start of World War I. But the ship served less than a year in that capacity since it struck a mine on November 21, 1916, in the Aegean Sea off the coast of Greece and sank in 50 minutes.

Figure 3. The Titanic (left) and the Olympic (right) were built in parallel by Harland and Wolff in their dry docks in Belfast, Ireland. A part of the large gantry system is also visible. Large steel plates used in the hull are visible in the foreground.

Because of the size of these ships, much of Harland and Wolff's shipyard in Belfast, Ireland, had to be rebuilt before construction could begin. The existing three dry docks were converted to two larger dry docks that were the largest in the world at the time. A new gantry or crane system with a larger load-carrying capacity was designed and installed to facilitate the construction of the larger ships. The gantry system was also the largest in the world when it was built. In general, construction of the *Titanic* and her sister ships followed standard industry practices at the time

3.2. Dimensions and Structure

3.2.1. Overview

At the time of her construction, the *Titanic* was the largest moving object ever built. She measured 46,328 gross registered tonnages (GRT) and had a displacement of 52,310 long tons. Her dimensions were approximately 269.1 m (882.9 ft.) in length, 28.2 m (92.5 ft.) at her maximum width, and 53.3 m (174.9 ft.) total height measuring from the base of her keel to the top of her funnels. She had an approximate draft of 10.5 m (34.45 ft.) and a depth of 19.7 m (64.63 ft.). Three of the four funnels in the *Titanic* were functional while one was for aesthetic purposes. The ship had ten decks, eight of which were used for passengers and crew and two used for cargo and ship functions. At full capacity, the ship could carry 2,453 passengers and 1,094 crew members for a total of 3,547 people. It could accommodate 833 first-class passengers, 614 second-class passengers, and 1,006 third-class passengers. The *Titanic* was designed for luxury, particularly for those traveling in first class. It had many unique features for the time, including the first heated swimming pool in a ship, a fully equipped gym, a squash court, spa, Turkish bath, barbershops, reading and writing rooms, libraries, darkroom, smoking rooms, fine dining restaurants, an infirmary, and operating room, state-of-the-art Marconi wireless radiotelegraph equipment, electric elevators, electric light, and heat. The second-lowest level of the ship was known as the "Orlop Deck" and contained cargo and storage rooms. The lowest level of the ship was known as the "Tank Top" and contained the boiler rooms, reciprocating engines, steam turbine, propeller shafts, coal bunkers, electrical generators, and other equipment for ship functions.

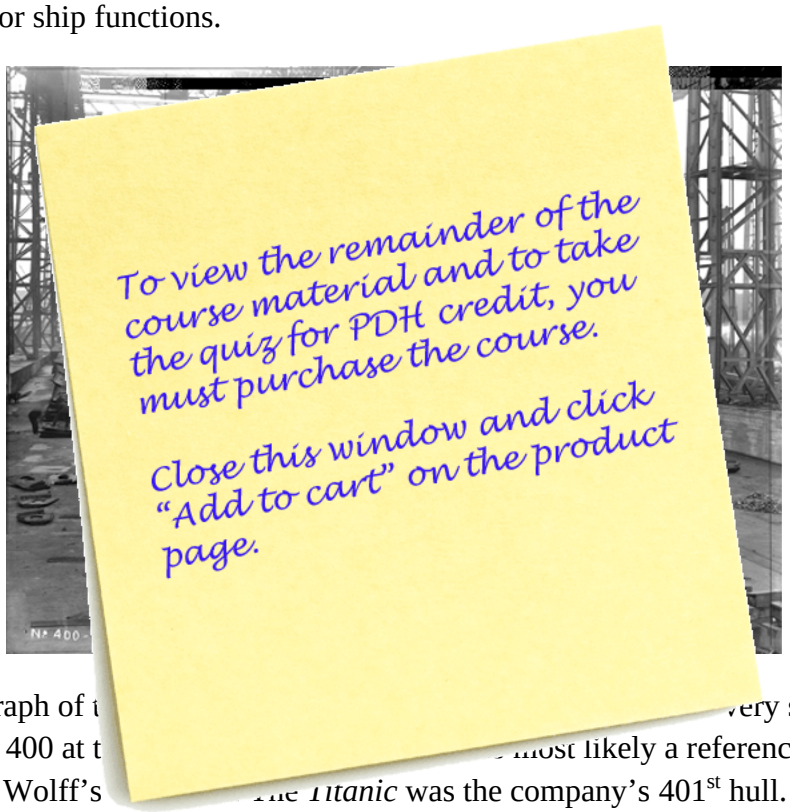

Figure 4. Photograph of t…very similar keel to the *Titanic*. The No. 400 at t… most likely a reference to Harland and Wolff's …*Titanic* was the company's 401st hull.