RMS TITANIC CASE STUDY

On April 14, 1912, the R.M.S. Titanic collided with a massive iceberg and sank in less than three hours. At the time, more than 2,200 passengers and crew were aboard the Titanic for her maiden voyage to the United States. Only 705 survived. According to the builders of the Titanic, even in the worst possible accident at sea, the ship should have stayed afloat for two to three days. This article discusses the material failures and design flaws that contributed to the rapid sinking of the Titanic. In addition, the article addresses the changes that have been made in both the design of ships and the safety regulations governing ships at sea as a result of the Titanic disaster.

Introduction

At the time of her construction, the Titanic was the largest ship ever built. She was nearly 900 feet long, stood 25 stories high, and weighed an incredible 46,000 tons. With turn-of-the-century design and technology, including sixteen major watertight compartments in her lower section that could easily be sealed off in the event of a punctured hull, the Titanic was deemed an unsinkable ship. According to her builders, even in the worst possible accident at sea, two ships colliding, the Titanic would stay afloat for two to three days, which would provide enough time for nearby ships to help.

On April 14, 1912, however, the Titanic sideswiped a massive iceberg and sank in less than three hours. Damaging nearly 300 feet of the ship's hull, the collision allowed water to flood six of her sixteen major watertight compartments. She was on her maiden voyage to the United States, carrying more than 2,200 passengers and crew, when she foundered. Only 705 of those aboard the Titanic ever reached their destination. After what seemed like a minor collision with an iceberg, the largest ship ever built sank in a fraction of the time estimated for her worst possible accident at sea.

The purpose of this article is to explain the material failures and design flaws that contributed to the rapid sinking of the Titanic. Specifically, brittle fracture of the hull steel, failure of the rivets, and flaws in the watertight compartments will be analyzed. Human factors that contributed to the sinking will not be reviewed. In addition to the causes for the sinking, the effects of the disaster are reviewed. As a result of the Titanic disaster, changes were made in ship design, such as double hulls and taller bulkheads. Also, stricter standards for safety regulations governing ships at sea were implemented, including mandatory use of electronic communication, minimum lifeboat capacities, and the development of the ice patrol.

Causes of the Rapid Sinking

On an expedition in 1991 to the Titanic wreck, scientists discovered a chunk of metal lying on the ocean floor that once was a part of the Titanic's hull. The Frisbee sized piece of steel was an inch thick with three rivet holes, each 1,25 inches in diameter. Since the retrieval of this piece of steel, extensive research has been done to uncover additional clues to the cause of the rapid sinking of the Titanic. The following is a discussion of the material failures and design flaws that contributed to the disaster.

Material Failures

When the Titanic collided with the iceberg, the hull steel and the wrought iron rivets failed because of brittle fracture. A type of catastrophic failure in structural materials, brittle fracture occurs without prior plastic deformation and at extremely high speeds. The causes of brittle fracture include low temperature, high impact loading, and high sulphur content. On the night of the Titanic disaster, each of these three factors was present: The water temperature was below freezing, the Titanic was travelling at a high speed on impact with the iceberg, and the hull steel contained high levels of sulphur.

The Hull Steel

The first hint that brittle fracture of the hull steel contributed to the Titanic disaster came following the recovery of a piece of the hull steel from the Titanic wreck. After cleaning the piece of steel, the scientists noted the condition of the edges. Jagged and sharp, the edges of the piece of steel appeared almost shattered, like broken china. Also, the metal showed no evidence bending or deformation. Typical high-quality ship steel is more ductile and deforms rather than breaks.

Similar behavior was found in the damaged hull steel of the Titanic's sister ship, Olympic, after a collision while leaving harbor on September 20, 1911. A 36-foot high opening was torn into the starboard side of the Olympic's hull when a British cruiser broadsided her.

Failure of the riveted joints and ripping of the hull plates were apparent in the area of impact. However, the plate tears exhibited little plastic deformation and the edges were unusually sharp, having the appearance of brittle fractures. Further evidence of the brittle fracture of the hull steel was found when a cigarette-sized coupon of the steel taken from the Titanic wreck was subjected to a Charpy test. Used to measure the brittleness of a material, the Charpy test is run by holding the coupon against a steel backing and striking the coupon with a 67 pound pendulum on a 2,5-foot-long arm. The pendulum's point of contact is instrumented, with a readout of forces electronically recorded in millisecond detail.

A piece of modern high-quality steel was tested along with the coupon from the hull steel. Both coupons were placed in a bath of alcohol at -1° C to simulate the conditions on the night of the Titanic disaster. When the coupon of the modern steel was tested, the pendulum swung down and halted with a thud; the test piece had bent into a "V." However, when the coupon of the Titanic steel was tested, the pendulum struck the coupon with a sharp "ping," barely slowed, and continued up on its swing; the sample, broken into two pieces, sailed across the room.

Pictures of the two coupons following the Charpy test are shown in Figure 1. What the test showed, and the readout confirmed, is the brittleness of the Titanic's hull steel. When the Titanic struck the iceberg, the hull plates did not deform. They fractured.

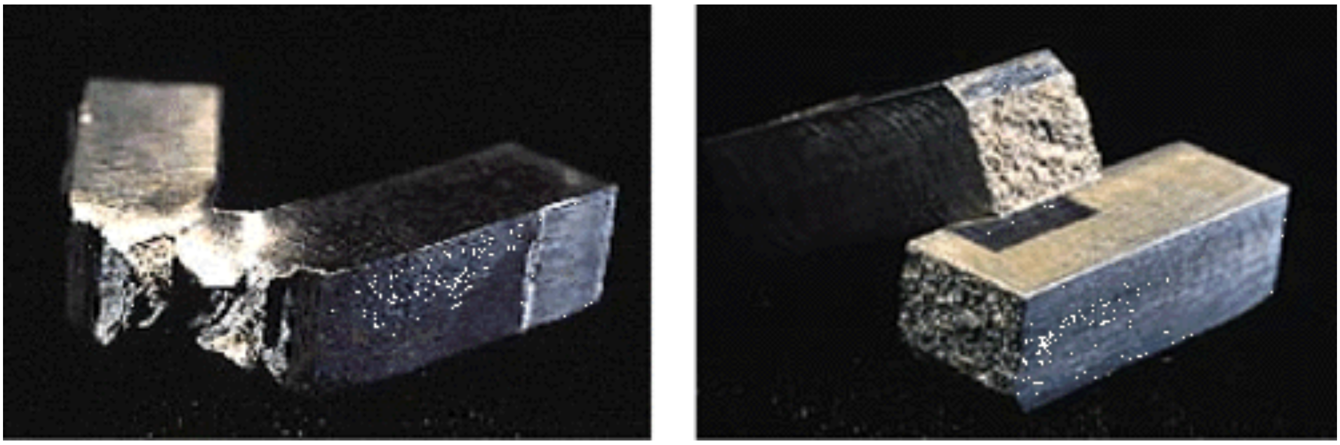

Figure 1. Results of the Charpy test for modern steel and Titanic steel. When a pendulum struck the modern steel, on the left, with a large force, the sample bent without breaking into pieces; it was ductile. Under the same impact loading, the Titanic steel, on the right, was extremely brittle; it broke in two pieces with little deformation.

A microstructural analysis of the Titanic steel also showed the plausibility of brittle fracture of the hull steel. The test showed high levels of both oxygen and sulphur, which implies that the steel was semi-kilned low carbon steel, made using the open-hearth process. High oxygen content leads to an increased ductile-to-brittle transition temperature, which was determined as 25 to 35° C for the Titanic steel. Most modern steels would need to be chilled below -60°C before they exhibited similar behavior.

High sulphur content increases the brittleness of steel by disrupting the grain structure. The sulphur combines with magnesium in the steel to form stringers of magnesium sulphide, which act as "highways" for crack propagation. Although most of the steel used for shipbuilding in the early 1900s had a relatively high sulphur content, the Titanic's steel was high even for the times.

<u>The Rivets</u>

The wrought iron rivets that fastened the hull plates to the Titanic's main structure also failed because of brittle fracture from the high impact loading of the collision with the iceberg and the low temperature water on the night of the disaster. With the ship travelling at nearly 25 mph, the contact with the iceberg was probably a series of impacts that caused the rivets to fail either in shear or by elongation. As the iceberg scraped along sections of the Titanic's hull, the rivets were sheared off, which opened up riveted seams. Also, because of the tremendous forces created on impact with the iceberg, the rivet heads in the areas of contact were simply popped off, which caused more seams to open up. Normally, the rivets would have deformed before failing because of their ductility, but with water temperatures below freezing, the rivets had become extremely brittle.

Conclusion

The sinking of the Titanic has become one of the most well known disasters in history. Because of the terrible loss of life and the demise of what everyone believed was an "unsinkable" ship, people are intrigued and curious about what caused the rapid sinking of the Titanic. Several theories have developed since the sinking to explain the events that occurred on that fateful night. This article has presented the most probable theory, which has become dominant as a result of evidence acquired during several expeditions to the Titanic site.

The failure of the hull steel resulted from brittle fractures caused by the high sulphur content of the steel, the low temperature water on the night of the disaster, and the high impact loading of the collision with the iceberg. When the Titanic hit the iceberg, the hull plates split open and continued cracking as the water flooded the ship. Low water temperatures and high impact loading also caused the brittle failure of the rivets used to fasten the hull plates to the ship's main structure. On impact, the rivets were either sheared off or the heads popped off because of excessive loading, which opened up riveted seams. Also, the rivets around the perimeter of the plates elongated due to the stresses applied by the water, which broke the caulking and provided another inlet for the water.

The rapid sinking of the Titanic was worsened by the poor design of the transverse bulkheads of the watertight compartments. As water flooded the damaged compartments of the hull, the ship began to pitch forward, and water in the damaged compartments was able to spill over into adjacent compartments. Not only did the compartments not control the flooding, but they also contained the water in the bow, which increased the rate of sinking.

Following the Titanic disaster, double-sided hulls were added to ships to prevent minor hull punctures from causing major damage. Also, the transverse bulkheads of the watertight compartments were raised so that water could not spill over the tops if the ship were pitched at a slight angle. Safety regulations established after the sinking include the mandatory use of the wireless for large ships, the minimum lifeboat capacity equal to the number of passengers and crew aboard, and the implementation of the ice patrol to warn ships of nearby ice fields.

Understanding the causes for the rapid sinking of the Titanic is necessary to prevent similar accidents in the future. The changes made in ship design and safety regulations following the disaster were effective in decreasing the casualties of accidents at sea. Examples include the successful rescues of 1,600 passengers and crew from the Andrea Doria in 1956, 700 passengers from the Prinsendam in 1980, and all the passengers and crew from Mikhail Lermentov in 1986 and the Oceanos in 1992.

Other lessons need to be learned, however. Just because shipbuilding companies have the technology to build something does not mean that they should. In the case of the Titanic disaster, the causes for the sinking indicate that shipbuilding technology was far more advanced than the understanding which engineers had of the materials they were using to build the ships.