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# Ultimate Longitudinal Strength of Ship Hull Girder: Historical Review and State of the Art

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## ABSTRACT

**This paper introduces the historical matters and state of the art regarding the research works on the ultimate longitudinal strength of a ship's hull girder. At first, it describes how the longitudinal strength assessment started, and past experimental works on full-scale and small-scale hull girders applying longitudinal bending load are introduced. Then, the paper explains how the yielding and buckling affect the progressive collapse behaviour of a cross-section of a ship's hull under longitudinal bending, showing the results of example calculations. The methods of analysis as well as research works on ultimate longitudinal strength and progressive collapse behaviour of a ship's hull are reviewed, and some important results are introduced. At the end, benchmark calculation on progressive collapse behaviour under longitudinal bending is described.**

## INTRODUCTION

A ship's hull is a box girder structure composed of stiffened plating, and it is subjected to longitudinal bending load produced by distributed hull weight, cargo weight, buoyancy force and wave force. The hull strength against longitudinal bending/shearing loads is called *longitudinal strength*, which may be the most fundamental strength of a ship structure. This is because the buckling/plastic collapse of the deck and/or bottom structure takes place and a ship's hull may break if the working longitudinal bending moment exceeds the capacity of the cross-section.

It can be said that ship structures do not undergo buckling/plastic collapse if the working load is below the design load. However, a ship's hull may be exposed to an extreme load in some occasions when the ship fails to escape from a storm or when the cargo and/or ballast is unduly loaded. It should be noted that an ordinary load below the design load can also be an extreme load for a ship's hull suffering from corrosion damage or fatigue cracking.

On the other hand, the thickness of plating in ship structures is recently decreasing because of the introduction of rational design by analysis and the wide use of high tensile-strength steel. Hence, it has become more important to accurately assess the ultimate longitudinal strength of a hull girder from a safety viewpoint.

The present paper introduces how the research works on ultimate longitudinal strength started, and the collapse tests on full-scale ship hulls in the early days are reviewed. Later tests on small-scale models and girders are also introduced.

Then, the influences of yielding and buckling on the progressive collapse behaviour of a cross-section of a ship's hull under longitudinal bending are explained based on the results of example calculations. Recent research works on methods of analysis to evaluate ultimate longitudinal strength and to simulate progressive collapse behaviour are reviewed. In this connection, results of progressive collapse analysis on existing ship hull girders are introduced.

At the end, results of benchmark calculation on the progressive collapse behaviour of a 1/3-scale welded steel frigate model are introduced to examine the validity of the existing methods of analysis to simulate the progressive collapse behaviour of a ship-hull girder.

## START OF LONGITUDINAL STRENGTH ASSESSMENT

Thomas Young, who is well-known by Young's modulus, was the first person to calculate the longitudinal strength of a ship's hull (Timoshenko, 1953). He considered a ship's hull as a beam, and calculated shear force and bending moment diagrams assuming the distributions of weight and buoyancy forces along a ship's hull. The buoyancy force was calculated based on the assumed wave mode.

On the other hand, it was Sir Isambard K. Brunel who initially assessed the longitudinal strength of a ship's hull under extreme conditions (Rutherford and Caldwell, 1990). When Sir Isambard designed the *Great Eastern*, 18,915 GT in displacements, 207.13 m in length and completed in 1860, he performed some theoretical assessments. She was a huge iron ship whose length was double that of the standard ships of the time. Based on the calculated results on the longitudinal bending moment assuming a grounded condition, Sir Isambard determined the thicknesses of deck and bottom plating. The design criterion at that time was a beaking of the plating in the tension side of longitudinal bending. It should be noticed that the *Great Eastern* had a double-hull structure below the water line. It is reported that she had no problem even after she got a crack 30 m in length due to grounding on a rock (Ueno, 1980).

It was quite reasonable that Sir Isambard performed longitudinal strength assessment in the design of a huge ship, since the longitudinal bending moment increases approximately in proportion to the square of a ship's length.

John (1874) presented a fundamental idea to assess the longitudinal strength of a ship's hull at the 15th Session of the Institute of Naval Architects. He calculated the bending moment at the midship section of an ordinary merchant ship assuming a wave whose length is equal to the ship's length. Based on the results of

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