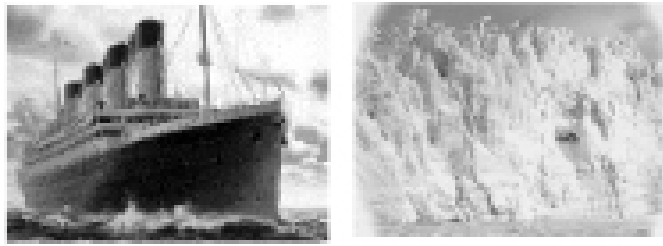


The Materials and the Design of the Titanic



<http://www.marinephotos.com/html/titanic.htm>

1

Specifications

- Length overall: 900 feet
- Width: 92 feet
- Depth: 60.5 feet (from water line to deck)
- Gross tonnage: 46,000 tons

<http://www.gpscities.com/TelevisionCity/Stage/1988/titanic.html>

2

First voyage

On 10 April 1912, the *Titanic* commenced her maiden voyage.

At 11:40 p.m., *Titanic* struck an iceberg on her right hand side of the front section facing forward while traveling at a speed of 20.5 knots.

At 2:20 a.m. *Titanic* sank (within 2 h 40 min).

What caused the Titanic to sink?

3

Reasons for sinking

I. Materials issues

- Type of steel (composition, microstructure and mechanical properties)

II. Design issues

- Design of watertight compartments

4

Composition

	Titanic hull plate	A36 modern structural steel
C	0.21	0.20
Mn	0.47	0.55
P	0.045	0.012
S	0.060	0.01 to 0.04
Si	0.017	0.007
Cu	0.024	0.01
O	0.013	-
N	0.0035	0.0032
Mn:S Ratio	7:1	15:1 (typical)

K. Felkins, H. P. Leighty, and A. Jankovic. JOM, 50(1), 1998, 12-18

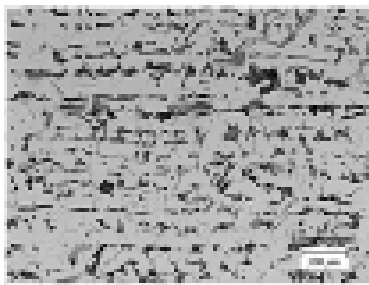
Composition of hull steels

- The presence of relatively high amounts of P and S embrittles the steel at low temperatures.
- The lower Mn:S ratio increases the ductile-brittle transition temperature.

6

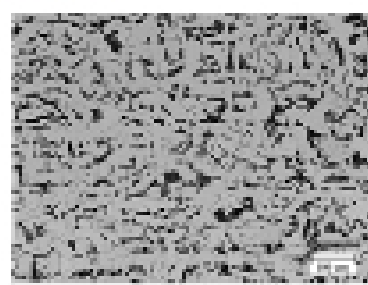
Microstructure of hull steel

Ferrite and pearlite



Longitudinal direction

Average grain diameter: 60.4 μm

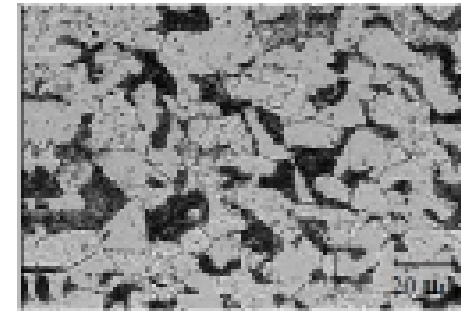


Transverse direction

Average grain diameter: 41.9 μm

7

Microstructure of modern structural steel



A36 steel

Average grain diameter: 26.2 μm

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Effect of grain size

How does the grain size affect strength?

Hall Petch equation: $YS = a + b d^{-1/2}$

Yield strength of a steel with 26 micrometer grain size is about 27% higher than that of a steel with 42 micrometer grain size, if the value of a is small.

Because structures are designed with adequate factor of safety, the grain size difference did not significantly contribute to the failure

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Material failures

When the Titanic collided with the iceberg, the hull steel and the wrought iron rivets failed.

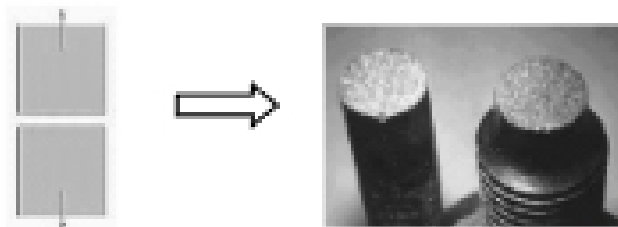
The steel and the wrought iron rivets failed by brittle fracture.

Brittle fracture is a failure of a metal by rapid crack propagation and without any significant deformation.

10

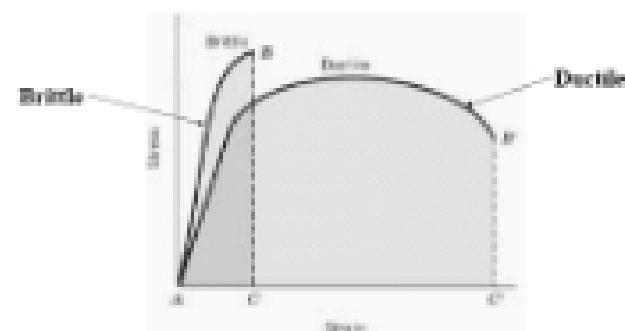
Brittle fracture

The direction of crack motion is very nearly perpendicular to the direction of the applied tensile stress and yields a relatively flat fracture surface.



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Brittle and ductile materials



Schematic representations of tensile stress-strain behavior for brittle and ductile materials loaded to fracture.

12

What caused the brittle fracture?

What was the effect of the impact with the iceberg?

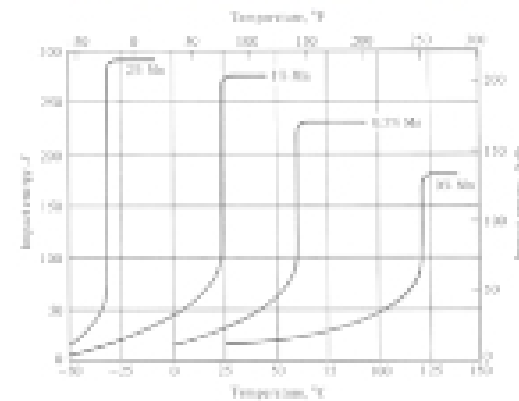
Did the sulphur content play a role in the failure?

What was the ductile to brittle transition temperature for the steel used to construct the hull of Titanic?

Did the sea water temperature experienced by the Titanic (-2°C) play a role?

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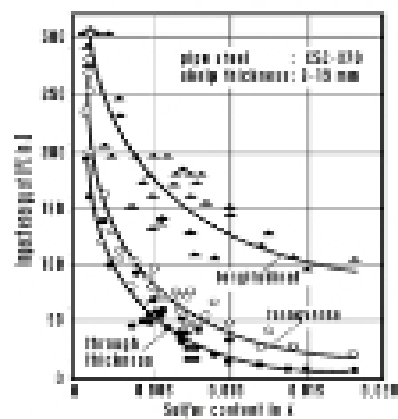
Effect of composition on ductile to brittle transition temperature



Higher %Mn is beneficial to prevent ductile to brittle transition because Mn prevents formation of brittle iron sulfides

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Effect of sulfur



<http://dl1.wde-jp.com/isij/pdf/199107/is310712.pdf>

15

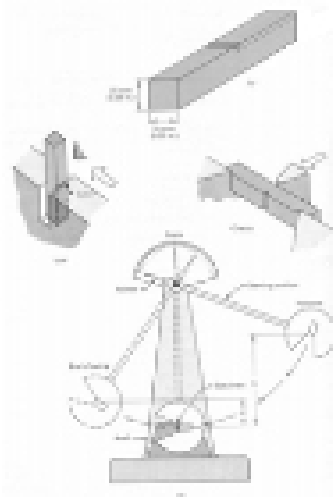
Tensile properties

	Titanic Steel	Modern Steel
Yield Strength (MPa)	193	338
Tensile Strength (MPa)	417	441
Total Elongation (%)	29.0	27.0
Reduction in area (%)	57.1	66.0

H. P. Leighty, B. L. Brasfit, and S. J. Lawrence. Practical Failure Analysis, 1(2), 2001

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Charpy impact test



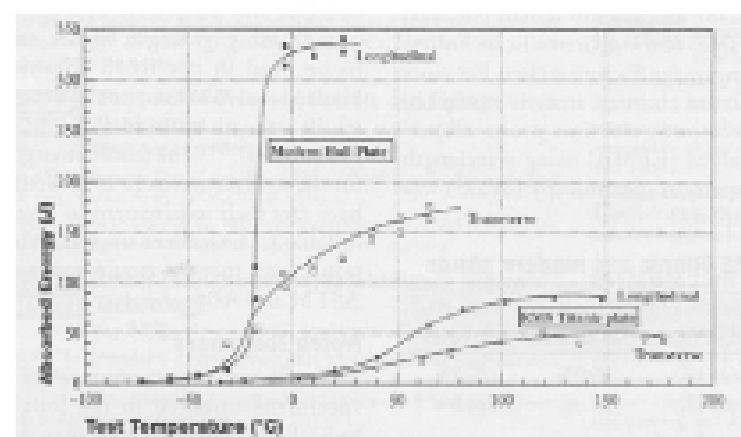
The energy absorption is a measure of the impact energy

The results are qualitative in nature and are useful in making comparisons

Determine whether or not a material experiences a ductile-brittle transition with decreasing temperature and, if so, the range of temperatures over which it occurs.

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Effect of temperature on toughness



H. P. Leighty, B. L. Brasfit, and S. J. Lawrence. Practical Failure Analysis, 1(2), 2001

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