Battleships & Broadsides

William Clayton :: Thomas Cecil :: Sean Munson

For Centuries the Fates of Empires were Decided on the High Seas

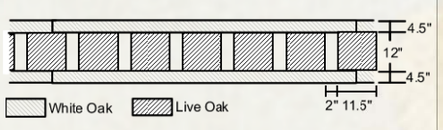
Throughout time, a nation's ability to project its power across the world has been intimately tied to that nation's naval prowess. From the late 1600s onward, before the aircraft carrier and bomber recast the field of battle, the ships of the line that determined the rise and fall of nations.

This project investigated the progressive improvements in the materials used in warship construction over the past 300 years. How did the toughness of warships advance with the shift from wooden hulled "tall ships" to ironclad ships and ultimately to the modern steel navies of the 20th century?

The Ships

USS *Constitution*
Launched 1797

Average Hull Cross Section:



Samples Tested: White Oak, 6 x 9.7 x 60 mm

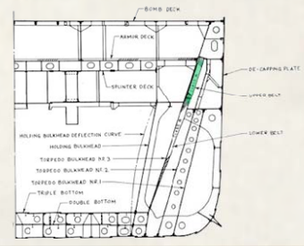
CSS *Virginia*
Launched 1861

Armor: 1-2" iron plate, 2" red oak

Samples Tested:
Layer 1: Red Oak, 3 x 11 x 51 mm
Layer 2: Steel, 1 x 11 x 51 mm
Adhered with epoxy.

USS *New Jersey*
Launched 1942

Hull Cross Section:
main armor belt shaded green



Samples Tested:
4140 steel,
9.7 x 9.7 x 54.4 mm

Tests & Results

Impact Test

Average Energy Absorbed to Fracture: 2.64 J

Optical Microscopy

Fracture surface for USS *Constitution*. Observe that pores remain intact.

Hardness: *ASTM Type D Durometer*

	Average Hardness	StdDev
Before Impact	68.85	±6.43
After Impact	61.90	±6.02

Impact Test

Average Energy Absorbed to Fracture: 3.07 J

Optical Microscopy

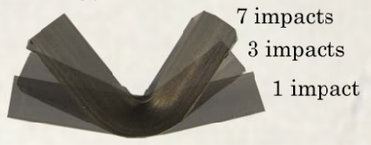
Fracture surface for CSS *Virginia* (left) vs. cut sample (right); pores remain intact

Hardness: *ASTM Type D Durometer*

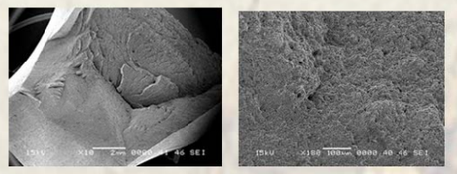
	Average Hardness	StdDev
Before Impact	92.75	±3.86
After Impact	90.43	±7.14

Impact Test

Average Energy Absorbed to Fracture: 602.22 J



Scanning Electron Microscopy

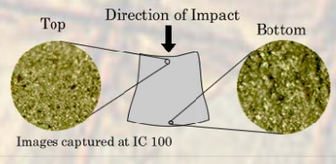


Fracture surface for USS *New Jersey*, Consistent with ductile fracture. Upper right surface (left image) created by breaking sample for study after impact.

Hardness: *Rockwell HRB*

# Impacts	Average Hardness	StdDev
0	97.3	±2.58
1	96.7	±4.84
3	95.4	±7.03
6	92.7	±7.96
7	93.5	±7.63

Etching & Optical Microscopy



Polished samples etched with Nital.

In about half of the samples, the grains appeared larger on the bottom of the cross section than the top.

Percent Strain Hardened

# Impacts	Area (mm^3)	% Cold Work
0	94.1	0.0
1	92.2	2.1
3	90.2	4.1
7	83.7	11.0
9	79.8	15.2

Conclusions

USS *Constitution*
- Hardness decreased due to damage to fiber structure.

CSS *Virginia*
- Hardness data inconclusive
- Deformation of armor layer likely a greater threat to ship than fracture

USS *New Jersey*
- Fracture, when it occured, was ductile
- Hardness data inconsistent with observed changes in microscopic and macroscopic geometry

General Conclusions

Warship armor strength increased significantly:
- *Virginia* absorbed 1.16x the energy as *Constitution*
- *New Jersey* absorbed 228x the energy as *Constitution*

Results do not indicate that *Constitution* or *Virginia* could have withstood the impacts we know they did. This indicates that the full ship hull (armor + frame) is more than the sum of its parts.