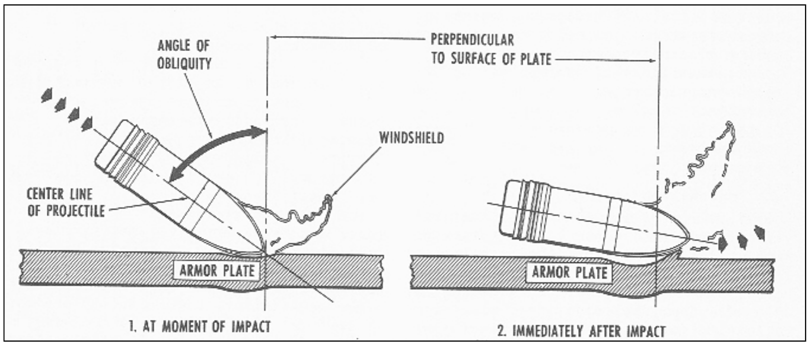
NAVAL GAZING

December 24, 2017

Armor Part 2

Armor penetration is a phenomenally complex issue, and one that isn't wholly understood even today. But a basic explanation is necessary to understand why warship armor was designed the way it was during the dreadnought era.[1] The basic factors that drive armor penetration can be roughly broken down into the armor, the shell, and how they meet. We'll start with the last of these.

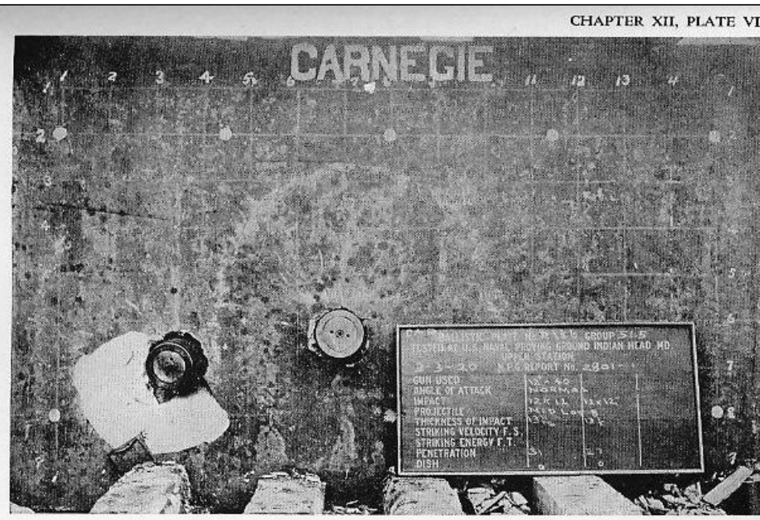
"How the armor and shell meet" boils down to impact velocity and obliquity, or angle of impact. A higher striking velocity is always going to result in higher penetration, all else equal. Obliquity is measured between the axis of the shell and the line normal (perpendicular) to the plate, so 0 obliquity is a direct hit and 80 degrees is a very glancing blow indeed. Oblique impacts have less penetration than direct ones, sometimes significantly so. This is not simply due to the geometry of the impact sending the shell through more metal, despite what most works that discuss armor penetration would have you believe. The front of the shell hits first, and the contact tends to make it rotate, either glancing off or hitting the armor side-first. This is obviously tremendously less efficient than a direct hit, and the usual counter was to design the projectile to dig in to the armor slightly, which would actually reverse this process. A shell hitting and piercing at high obliquity would come out with a lower obliquity than it went in at.[2]



The effectiveness of the armor is a matter of thickness and material properties. Obviously, thicker armor is more difficult to penetrate, but at the same time, it's heavier. The ideal material properties vary by application. For a battleship's belt, the plates are usually decrementally hardened to approximately 30% of depth, and sometimes cemented. This hardened layer is intended to damage the projectile, making it less effective at piercing the rest of the plate, which is left soft and tough (resistant to cracking under sudden loading). Hardening armor makes it brittle, which can cause it to crack under impact. A fully-hardened plate is likely to simply crack at the point of contact and send a plug of armor flying into the interior of the ship, usually followed by the shell itself.

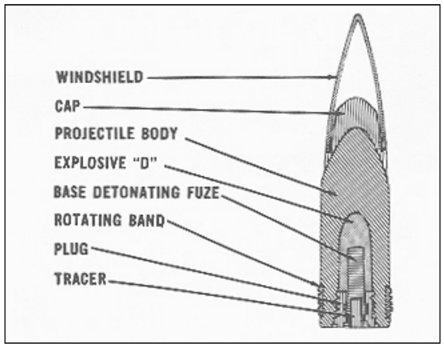
For thin armor plates, the most important factor is the thickness of the tough back, to the point where face-hardening armor under 3" or so actually makes it easier to penetrate. For deck armor, which is expected to be hit at very high obliquity, face-hardening is even worse. Besides the reduction in the tough back layer, the face-hardened layer significantly increases the chances of the shell breaking and digging in. The only use of horizontal face-hardened armor I'm aware of is on the tops of the turrets of the *Richelieu* class battleships, intended to counter bombing attack. Unfortunately, the only hit taken in this area was a battleship shell which penetrated, possibly due to the face-hardening.

CHAPTER XII, PLATE VI.



A Ballistic Test Plate.

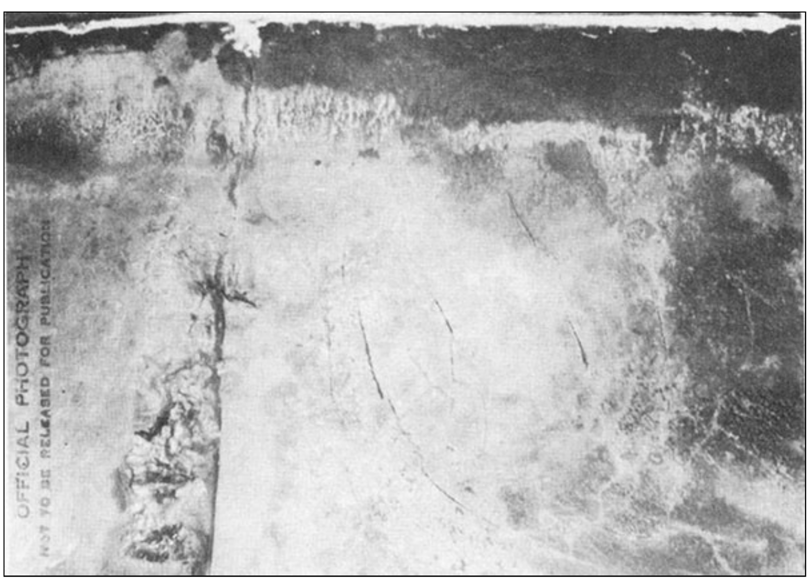
The size of the shell is obviously important. The key metric is called sectional density, essentially the mass of the shell divided by the area of the shell. A heavier shell is going to perform better at a given impact velocity, but a gun of a given size is, to a first approximation, limited by energy, so a heavier shell will be fired slower. Overall, though, heavier shells tended to perform better, particularly as they carry more of their velocity to long range. The most famous example is the American superheavy shell. Shortly before WW2, the USN introduced longer, heavier versions of most of its shells. The pre-war 16" shell was 2100 lbs, while the final version was 2700 lb, and was considered equivalent to a conventional 18″ shell at long range.



The design and construction of the shell is as important as weight. Armor works by breaking shells before they can penetrate, so a strong shell is obviously necessary. Face-hardening in particular was effective at shattering shells. Shell metallurgy evolved in parallel with armor metallurgy, with shells usually being forged and heat-treated. Face-hardening for a while shifted the balance in favor of armor, until the AP cap was invented.

The AP cap was more or less what it sounds like, a sacrificial cap on the AP shell designed to absorb the impact with the face-hardened layer and leave the shell intact to penetrate the armor. Initial caps were soft, but they were ineffective at high obliquity. Later hard caps were much less likely to be peeled off during impact, and remained effective at over 20° obliquity. They also acted as punch, creating a divot in the hardened face of the armor and helping the shell to dig in.

Another factor that could affect penetration was the shell's filling. A solid projectile, known as shot, is very good at penetrating armor, but it's also not particularly effective at doing damage behind it. An explosive filling is used to increase damage behind armor, but a poor choice of filling can render shells ineffective. The British used picric acid , which they called lyddite, throughout most of WWI. It was too sensitive, and had a bad tendency to detonate while penetrating the target's armor. Usually, a splinter layer behind the main armor would absorb the fragments produced. Many early fuses had the same problem, detonating on impact or during penetration.



A dent in *South Dakota*'s barbette from a 14″ shell

Penetration was not an all-or-nothing phenomenon. Even armor that successfully kept out a shell might be dented, and it was not uncommon for a shell that didn't penetrate to throw fragments off the back of a plate (known as spall) or for some pieces of a broken shell to penetrate, while others were kept out. Depending on how the shell broke, it may or may not still have been able to explode.

This is just a brief overview of how the armor of battleships worked. There are lots of phenomena that I haven't covered, and the best place to start is with the information Nathan Okun has posted at Navweps.[3]

Next time, we'll look at the evolution of armor during the dreadnought era, including the rise of schemes optimized for long-range combat.

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1. Before that era, armor schemes were relatively simple. ⇑
2. To put some numbers on this, I tried some experiments with Nathan Okun's FaceHard program. Pitting a plate at a 45 degree obliquity against a plate of 1.414 times the thickness at 0 degrees (so the plates themselves weigh the same for a given area protected), the sloped plate required the shell to be going 22% faster to penetrate. ⇑
3. Thanks to Nathan Okun for reviewing this post. ⇑

- by bean
-
- 3 comment(s)

Comments

1. December 25, 2017Eltargrim said...

   > Picric acid
   >
   > It was too sensitive

   You don't f***ing say.

   My department has a big display of chemicals that can be derived from coal. It's ancient, and has good-sized sample vials of all sorts of different derivatives. When an observant student noticed, and brought it to the attention of the department head, he did the rational thing and *immediately closed down the department and called the bomb squad*. Picric acid is firmly on my list of things I'll never work with.

2. December 27, 2017ADifferentAnonymous said...

   @Eltargrim

   I've heard several versions of that story before--not always picric acid, but the general idea of a chemistry department/lab having a 'collection' that, when noticed, requires a bomb squad.

   Normally I'd say that indicates an urban legend, but the accounts tend to be first- rather than secondhand, so I think this might just happen a lot.

3. June 18, 2018bean said...

   > I thought it explodes on the armor and the explosion itself breaks the armor!

   The problem is that the explosion would rather spend its energy pushing air than pushing steel. It follows the path of least resistance. There are ways to breach armor using explosives, but they weren't developed until WWII. Before that, you had to hit armor really hard to break it.

   (Another disappearing post. I've asked Said Achmiz to look into this.)

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- Filling out the list of gods we have:…
- Prince Eugene of Savoy was indeed the name I was looking for. Noticed it when I…
- I don't know how I feel about classing the martyrs as non-