How Carriers Fought - Carrier Operations in WWII

Best Carrier Design of WWII

by Lars Celander, updated June 13th 2022

About this text

This text is an extension and follow-up of my treatment of this topic in my book How Carriers Fought - Carrier Operations in WWII. Since the publication of that book, there have been further discussions and some new facts have emerged. No second edition of the book is planned so this text can be regarded as a bonus chapter.

Introduction

There are many aspects of the design of a fleet carrier but one stands out in particular: Whether or not to have an armoured flight deck. The pros and cons of this design choice has been hotly debated for years, seemingly never arriving at a conclusion. This text is brave enough to think that a definite conclusion can be arrived at, finally laying that discussion to rest.

The conventional wisdom appear to be that if you put the deck armour on the level of the flight deck, then that will necessarily lead to only operating a smaller air group. Firepower has been sacrificed for protection. The British went for an armoured flight deck while the Americans went for an open hangar design with the armour at the hangar deck. It is then often said that the British approach was better suited to the cramped waters for the European Theatre of Operations while the American approach was better suited to the Pacific Theatre of Operations, the 'horses for courses' rationale.

Much of this is quite wrong. What actually went on is more complex and nuanced. It is also in a sense simpler.

Why Have An Armoured Flight Deck?

Very obviously, it protects the hangar against bombs. The hangar of an aircraft carrier will typically have fuelled and armed aircraft in it. A bomb hit in that area could, and often did, cause major fires that threatened the survival of the ship.

Deck armour will always have a difficult time protecting against armour piercing bombs dropped from high altitude level bombers. Dropped from high altitude, these bombs will impact at high speed and will likely be able to penetrate any deck armour. Slower falling bombs, like those released by a dive bomber, are easier to keep out.

Before the war, level bombers were seen as the main threat. Later, as dive bombing developed, with its high precision and ability to be done by carrier-borne aircraft, this became the main threat. Against this type of bombs, deck armour was effective. Late in the war, kamikazes appeared and armoured flight decks proved effective against these as well.

The Problem With Armouring The Flight Deck

Raising the deck armour to the level of the flight deck raises the centre of gravity which reduces stability. With the deck armour above the hangar, the hangar sides will now also need to be armoured, creating an armoured box around the hangar. This further increases weight and reduces stability. Exactly how much the side belt should be extended upwards, and how thick it should be, depends on expected threats. The early war threat of gunfire, as a result of a chance encounter with enemy surface forces, was largely eliminated by radar. Other low-angle threats replaced it however, such as strafing, rockets, skip bombing, glide bombs and guided missiles (guided by humans or otherwise).

Reducing That Problem

First of all, please note that we are not taking about increasing or decreasing the total weight of the armour, we are mainly talking about where it should be placed.

The most obvious way of lowering the centre of gravity is to then lower the flight deck. Everything else held constant, this will lead to a lower hull volume. Keeping the size of the ship constant, the lower hull volume will likely result in a smaller hangar.

The entire hangar might not need to be protected, reducing the size of the armour slab required, keeping weight down. An example of this was the Midway, the armour only covered the area between the centerline elevators.

With the removal of the surface threat, the thickness of the side belt can be reduced and the AA battery no longer needs to be dual purpose. Indeed, the heavy AA battery can now be removed entirely as its role of area AA defence can be performed just as well by the escorts. Only light and medium AA should be retained. Removing all heavy AA saves considerable top weight while also increasing the area available on the flight deck.

It is always possible to simply increase the beam of the ship, increasing both stability and hull volume. The drawback here is that, everything else held constant, maximum speed will be reduced by something like a couple of knots. In terms of flight operations, the main effect is a reduced ability to generate wind over the deck and a corresponding reduced ability to launch aircraft in calm conditions. How important this is will depend on the characteristics of the aircraft types operated and on mission profiles. The USN had a special problem here as its carriers needed to be able to pass through the Panama Canal, giving the USN a very hard limit on the width of its carriers. As it was, the Essex class could only barely squeeze through. For the USN, increasing the beam was not an option.

Another solution is to have two hangars stacked on top of each other. A smaller sheet of armour can now cover two hangars. That same sheet then has approximately the right size to also cover the machinery and magazine spaces. The ends of the ship are left unprotected. This is similar to the all-or-nothing philosophy for battleships. The main problem here is to make room for two stacked hangars underneath the armoured flight deck. In particular, it can become difficult to arrange the boiler uptakes. There are several ways to work around this. The simplest is to have boilers that require less head room.

Another alternative is to allow the boiler uptakes to intrude on the lower hangar. A more subtle way is to have a deeper hull shape allowing the boilers to be placed lower in the hull.

The Taiho appears to use all three of these tweaks. Part of her lower hangar had a sloped floor in order to make room for the boiler uptakes. She also had an unusually deep hull with a rounded bottom. This obviously affects her stability curve, in a seaway she should have a more pronounced rolling motion. However, this should not impact air operations as they are done while heading into the wind and hence straight onto the waves. The Taiho did not use a beamier hull, had not sacrificed any speed and could pass through the Canal.

Other Arguments Against Having An Armoured Flight Deck

A lightly built hangar can have more headroom which can then be used to store spare aircraft. This is useful primarily when the hangar is packed with aircraft with tightly folding wings. In a less crowded hangar, there is normally enough room between aircraft to store bits and pieces of disassembled aircraft. For various reasons, overhead storage gradually became less popular. The Midway class stored spares in the hangar aft of the aft elevator (that was not covered by the armoured flight deck).

Building the hangar and the flight deck as a light structure is supposed to enable large side openings. These then provided the ventilation required to allow aircraft engines to be warmed up while in the hangar. In practice, this feature was not used much. If still required, oil heaters can be used to warm up engines without actually running. Finally, it should be noted that it is perfectly possible to have large side openings together with an armoured flight deck. Yes, in this case there will be large holes in the sides of the armoured box but 90% coverage is better than 0%.

Deck edge elevators are useful as it removes the elevator from the flight path. It is true that it is easier to fit a deck edge elevator if there is only one hangar. However, it is still possible to have a deck edge elevators reach the lower hangar in a stacked hangar configuration. In that case the elevator should be outside of the flight path at the level of the flight deck but inside the hull at the level of the lower hangar, which could be achieved by having the elevator slide inwards as it descends. If this is deemed impractical, then having the deck edge elevator only reach the upper hangar might well suffice.

With stacked hangars, the lower hangar will be close to the waterline. In particularly the elevator wells might present a vulnerability. Again, a solvable design problem, should it be seen as important and likely enough to warrant a solution.

Building the hangar and the flight deck as a light structure has been said to make it easier to repair. This is doubtful as, generally speaking, a more lightly built structure will likely suffer more damage when hit. More damage usually also means more casualties.

Armoured box hangars have been accused of leading to the hull becoming warped after a major fire. This assumes that the armoured flight is the strength deck. Again, if you have a major fire in the hangar then you have a much more immediate problem than any possible warping of the hull. It is assumed that extensive firefighting resources are in place, including fire doors. Should warping still be a problem, occurring often enough to warrant a solution, then there are various ways to engineer a mitigation of the problem.

Another argument sometimes used against an armoured flight deck is that it doesn't protect everything. This is of course true, there are areas of the flight deck that are left unprotected, where a bomb hit can still put the flight deck out of action. It should be

remembered that the main reason for armouring the flight deck is not to protect the flight deck itself, it is to protect what's beneath the flight deck. Armouring the entire flight deck would be incredibly wasteful use of available weight.

A similar point sometimes raised is that the flight deck armour can still be penetrated by using heavier bombs. Certainly true, but if so, it has still forced the enemy to use heavier and/or AP bombs. Necessarily, this will mean some combination of longer take-off run, shorter range, fewer bombs and the smaller bursting charge of an AP bomb.

Finally, an armoured flight deck doesn't protect against torpedoes and it takes torpedoes to sink a carrier. Again, this is largely true but in almost all cases the sequence of events that led to a carrier being sunk by torpedoes was started with a bomb hit on the flight deck.

An armoured flight deck will never protect against everything and at all times. That is a given. It is also besides the point. The point is to give the carrier better odds of survival. It is always a game of percentages, never of absolutes.

The 'Horses For Courses' Argument

How about the vast distances of the Pacific vs the more cramped waters around Europe? This is often said to drive the different design philosophies of the RN and USN carriers.

The longer distances of the Pacific certainly influences logistics but to what extent do they influence actual combat? Will battle distances be longer if the ocean is bigger? Are hit percentages and the effectiveness of deck armour affected by the distance to land?

Every carrier battle in the Pacific was fought within range of land-based air. Not much difference there. If the presence of land-based air is a factor, then there are several other differences that also should be taken into account. Examples include availability of these bases, relative strengths of carrier-borne air vs land-based air and the nature of the relationship to an air force that is either independent or run by the army. These discussions can go in many directions other than just protection vs firepower. For example, if the main task is to achieve air superiority over a fixed point target like a beach, shouldn't protection be more important than for example speed?

Of course, the entire reasoning hinges on there actually being much of a trade-off between armoured flight deck and size of air group.

Discussion

In terms of naval architecture, there is only a weak correlation between hangar size and having the deck armour at the level of the flight deck. It is quite possible to have both. These are only two parameters of many in the design of an aircraft carrier.

Given a certain size of the hangar, the number of aircraft operated varied greatly. Therefore, the conventional wisdom that having an armoured flight deck necessarily means having a smaller air group, is just wrong.

Why did conventional wisdom get it so wrong? Pretty simple. Looking at the carrier designs of WWII and the air groups they operated, there is indeed a strong correlation between having an armoured flight deck and operating a smaller air group. But as always, correlation is not causation. In fact, that correlation is largely accidental.

The USN operated in fairly benign climates so could indulge in parking aircraft up on the flight deck. This practice enabled them to operate larger air groups. Americans also

compensated for their limited hangar spaces by having aircraft with wings that folded compactly. With more of the wing folding, the mechanism had to be stronger which increased weight. Performance suffered, requiring engines that were more powerful and hence thirstier. Finally, towards the end of the war, the US carriers mainly did CAP and ground support. The carriers were effectively anchored off a beach somewhere, acting as floating gas stations. In this scenario, carriers could and should be stuffed with as many aircraft as at all possible. This is why we see very large air groups being employed despite the limited hangar space available in single hangar designs.

At the opposite end of the spectrum we have the night time surprise torpedo attack. Here there is less need for fighters and none at all for dive bombers. Laden with a heavy torpedo, a long take-off run is required and only a limited number of aircraft that can be spotted on the flight deck. The second wave is not going to enjoy surprise and might not be worthwhile. With this mission profile, a large air group is of limited use.

With the Illustrious class, the RN sacrificed the size of the air group in order to have an armoured flight deck. However, they really didn't have to make that sacrifice. In the following Indomitable and Implacable classes they didn't. These had a half-size lower hangar, as much as would fit above the engine spaces (but that wouldn't fit above the boiler spaces due to the trunking needed for the boiler uptakes, as discussed earlier).

The Taiho had an armoured flight deck and operated a modest air group. Managing to squeeze in two full hangars underneath an armoured flight deck, she had an enormous hangar space. She could easily have operated a much larger air group. She didn't because her air group didn't have wings that folded compactly (or at all). This was a deliberate choice in order to operate lighter and hence higher performance aircraft.

A major problem in this discussion is that a carriers capacity to operate a large air group is so often judged by the size of the air group actually operated. This is a mistake. The offensive capability of a carrier should be judged by the size of its hangar. How that hangar space is then employed is a separate issue.

Conclusion

The optimal design of a WWII fleet carrier was an armoured flight deck on top of two stacked hangars. The only WWII fleet carrier to get this right was the Taiho, and to a lesser extent, the Indomitable and Implacable designs.

That said, having two hangars stacked underneath an armoured flight deck implies a certain minimum depth of the hull and hence a certain minimum size off the ship. It might also involve sacrifices in other areas, such as endurance and crew habitability. The Taiho went for an extremely large hangar area and relative to that area, a small air group. Assuming an air group less averse to folding wings, then the one and a half hangar designs of Indomitable and Implacable might be more optimal.

Where does this leave us with the Yorktown and Essex classes? Certainly excellent ships in many ways but in terms of the core parameters of firepower and protection, the Taiho had both a much larger hangar *and* an armoured flight deck.

The optimal design for a carrier that is not necessarily a WWII fleet carrier is a separate question. It is certainly possible to envisage scenarios, for example for more supporting and less exposed roles, where an armoured flight deck might not be suitable.

The optimal design for the post-WWII jet era is also a different question. The Midway design made a lot of sense but was clearly a transitional carrier. WWII was in itself a period of huge transitions. The war started with biplanes and ended with jets.

Carriers began the war as largely complementary to the battleline, to be used for scouting and raiding. They ended the war dominating the battlespace, now being the backbone of a navy. Emphasis shifted from speed to staying power. Its role had fundamentally shifted in just a few years. In respect of the various design bureaus, it is not an easy task to design the optimal carrier with such rapidly changing requirements.