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Extreme Loads in Navy Ship Design

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As we all know, The Ship Structure Committee had its origin in the days shortly after World War II. The impetus for its creation was the high incidence of catastrophic failures in the hulls of many welded ships built during the war years. Few of these losses were due to extreme loads, but rather were due to material and design deficiencies which were not fully understood at that time. Due largely in part to The Ship Structure Committee and its 250-odd structural research projects most of these deficiencies can now be designed out of our ships. We now understand the failure mechanisms of the World War II losses and can routinely design ships with adequate structural integrity.

But as far as "Extreme Loads" and the ship's response to them, the answers to the designer's problems are not as clear. We are, perhaps, as knowledgeable now about extreme loads as the World War II naval architect was about welded ship design. We know many of the answers, but there is still a great uncertainty. I ask each of you to seek out and study this least understood area of structural ship design so that we are prepared for any challenge we must face at sea in future years. We must be sure that our ships can traverse, or loiter, in all seas and oceans, good weather or bad. We should know the steps to take immediately if our ships run aground. We must fully understand the seakeeping characteristics of our ships so that our operational restrictions may be geared accordingly. We shall strive for collision avoidance, but baring that, at least make our ships more collision - forgiving by designing them so that the most common types of collision damage are minimized. And lastly, of greatest importance to the Navy, making sure that our ships can survive the extreme loadings mother nature does not inflict upon us: fire, battle damage, and nuclear blast.

The configurations of Navy ships are quite different from the ship types each of you represent, but our problems are very similar. Your structural designs are as conservative as is economically feasible, whereas ours must have a bare minimum of conservatism. Consequently, it is very important to know all probable loadings so that the critical ones can be designed for. Our ships must be able to maintain their highest speeds, no matter the weather, to satisfy their mission. They must be capable of staying on station once they get there regardless of the weather, or damage sustained en route. And while on station, all battle stations and weapons must be fully capable of inflicting the maximum possible damage to the enemy. Thus, we cannot run from bad weather nor limp into any port to repair minor damage. We must be fully capable of defining our problems in advance, and solving them before we launch our ships.

Extreme loads can best be defined as those loads which have the greatest probability of being the governing critical loading. It may turn out that, in fact, an economically practical ship structure will be overstressed by those loads. Due to the infrequency of these loadings this may not be of great concern. Most Naval ships are stressed beyond this design limit occassionally, with little or only minor structural repairs required. Assuming proper hull maintenance and inspection, these are acceptable risks, since failure would not result in the loss of a ship. We can tolerate an occassional fatigue crack which the ship's force, or a tender can repair, but nothing more catastrophic. We have to walk that thin line between minimizing the factors of safety (or "factors of ignorance") without noticably increasing the risk of terminating the ship's mission, or loosing the ship. Therein, lies the value of this symposium. A better knowledge of these extreme loads may allow us to design more economical and safer ships.

In addition to the extreme seaway loadings previously discussed, Navy ships must be designed for an unusual gamut of extreme loads. Some of these will be shown in the film clips I'll be showing in a moment. Extreme loads which some of our Navy ships must be designed for include:

aircraft launch and recovery loads

- helicopter operations
- weapons launch effects
- incoming weapons effects
- underwater shock
- continuous highest speed operation
- capability of being dry docked while fully loaded
- nuclear blast
- close proximity replenishment-at-sea

In addition to these are the more traditional extreme loads common to most ships:

- heavy seas - slamming, whipping, etc.
- launching and dry docking loads
- grounding loads
- ice loads
- collisions
- built-in residual stresses

The film clips which I have brought today are from incidents in which the Navy was involved directly or indirectly. Unfortunately, some of the more spectacular loadings due to weapons effects were classified, and I was unable to bring those.

1. The opening modern sequence, though not particularly rough seas show dramatically the unusual bow of one of our LST's due to its "unusual mission". The Navy has many unique ship-types which have their own individualized loadings and problems.

2. Another ship with no commercial equivalent is our aircraft carriers. Our newer aircraft carriers are over a 1000 feet long, displacing 90,000 tons, and carry over 90 aircraft, at speeds in excess of 30 knots. The flight deck you are seeing is about 65 feet above the waterline, and these pictures are being taken from the pilot house 110 feet above the waterline. It is hard to believe that waves can be hitting that high on our biggest ships. Can you imagine how this aircraft carrier's smaller support ships are responding to this same strom? Some storms come up very quickly and it's not always possible to recall all of our aircraft or clear our flight decks before the storm worsens. Consequently, aircraft must still be recovered in bad weather, night or day. Obviously, the wheel loadings on the flight deck for both landing and parking have large G-factors applied to them.

3. The inside of an aircraft carrier is not necessarily a safe haven from the weather either. These shots inside the hangar, 30 feet above the water level, show what can be expected in rough seas due to the number of large openings in the shell for aircraft elevators, fueling-at-sea stations, etc.

4. A unique requirement of Naval ships is the capability of replenishment-at-sea. Rough weather or good, night or day, our ships must constantly be replenished while underway. This requires the ships to be quite close together for extended periods of time. Its a wonder that we do not have more collisions during replenishment.

Destroyers, for instance, are required to maintain their fuel level at 70% of capacity or greater so that in an emergency they can respond quickly to a maximum range. Aircraft carriers must be refueled about every three days. Even the nuclear carriers require smaller quantities of aircraft and auxillary engine fuel. Consequently, our fleet oilers are almost continuously transferring fuel, often from both the port and starboard side simultaneously, thirty percent of these transfers are done at night, out of necessity and for wartime preparedness.

5. Here we see amphibious ABT's being launched from an LPD. Many of our ship-types have the capability of launching and recovering large landing craft and amphibious vehicles. These ships are capable of ballasting down and submerging their launching deck for operations. While these shots are not dramatic, visualize if you will what it is like inside the well with ship generated waves tossing small amphibians about.

6. Most of our ships have underwater shock requirements for both the hull, and equipment. Shock tests are often performed on new, manned ships with lower level explosives to verify the shock design.

To ascertain the full effect of underwater shock levels, tests were conducted on old unmanned ships using explosive charges much closer then shown previously.

7. Our ships must not only be designed for both the blast and shock of missile launch and gunfire, but also primarily to minimize the effect to the ship from incoming weapons. We see here first a test of a hit in the superstructure, then a hit in the side shell.

8. Many of our larger ships have nuclear blast over-pressure design requirements for critical spaces. The Bikini tests and the current Soviet threat determine our design criteria.

9. Our ships cannot always run from storms. It is sometimes necessary to remain on station with aircraft ready to go, as we see this LPH. The wind loading on these helos, which is transferred to the deck through the wheels and tiedowns, is sizeable. Our topside structure is designed for a 90 knot wind.

10. Another type of replenishment-at-sea is through VERTREP, vertical replenishment-

at-sea. Extensive use of VERTREP allows smaller quantities of supplies to be delivered to distant ships. Consequently, this large ship, through the smallest of our ships must have decks capable of supporting cargo transferred in this manner.

11. Here we see a destroyer having a rough time of it, trying to make headway in heavy seas.

12. This next sequence shows a low-energy collision between one of our destroyer's and a merchant ship in the channel in front of Morro Castle, San Juan, Puerto Rico. Fortunately there was little damage, but this is probably the most common type of accident.

13. Here we have a Korean ship (JIN YANZ) which has run aground. The CVS-33, USS KEAREARGE has sent helos to rescue the crew members.

14. A more spectacular collision in San Juan harbor resulted in the Liberian tanker OCEAN EAGLE breaking in two and blocking the channel. It was necessary for Navy tugs to tow the forward section out to sea.

15. A smaller but more spectacular grounding occured when our experimental hydrofoil TUCUMCARI ran aground on a shoal at full speed, on foils. We see first the ship at high tide; with air bags under her for added floatation, and again at low tide. It was necessary to use both a tug and a helicopter to both pull and lift the ship off the shoal.

16. Our most spectacular recent shipboard fire occured when the cruiser USS BELKNAP collided with an aircraft carrier, dumping tons of fuel into the USS BELKNAP's superstructure. The resulting fire gutted the aluminum superstructure. The ship was towed back from the Mediterranean and was refit at the Philadelphia Naval Shipyard.

And in conclusion, I wish that our ships could only experience a tranquil scenario, but we all know that is not possible. Therefore, let us try to have anticipated all possible scenarios so that our ships have the best possible chance of survival.