Technical Meeting — 1 February 2017

Valerio Corniani, Marine Manager, Diab Group, gave a presentation on *Designing for Slamming Loads on Composite Vessels* to a joint meeting with the IMarEST attended by 29 on 1 February in the Harricks Auditorium at Engineers Australia, Chatswood.

Introduction

Valerio began his presentation by saying that we need to distinguish carefully between static and dynamic loads. Static loads are of a steady, fixed (and usually known) value, applied for a significant time. Dynamic loads, on the other hand, are often of short duration, the maximum values may vary significantly, are not easy to define, and may not be well known at all! They depend on the speed of the vessel, the wave height, the shape of the vessel, etc.

As examples of static loads, he quoted a crew member standing on the end of a foil at the side of a yacht, or the whole crew seated on the windward rail. As examples of dynamic loads, he quoted the loads on the bottoms of high-performance yachts and motor-driven planing craft.

Static load on the end of a foil
(Photo courtesy Wild Oats Team)

Static load on the windward rail
(Photo courtesy Wil Oats Team)

Dynamic load on yacht bottom
(Photo courtesy Rolex/Carlo Borlenghi)

Dynamic load on planing boat
(Photo from Noal Boats website)

Slamming is a dynamic load on a vessel, and energy is absorbed both by the water and by the hull structure, both depending on hull size and shape, the speed of the vessel and, of course, the sea state. Slamming loads are becoming more and more important because vessels are going faster now than ever before, and vessel bottoms are becoming flatter.

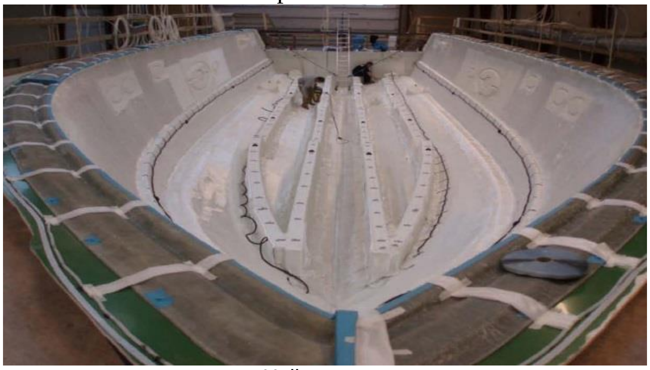
A flat-bottomed tinny, for example is fine in flat water (for which it is designed), but would behave poorly and suffer high loads in any sort of sea state. Vessels which have been designed for seagoing, often with V-shaped sections for high speed and seakeeping, behave well at sea and the loads are catered for.

Hull shape — a tinny on flat water
(Photo frm Sea Jay Aluminium Boats website)

Hull shape — very different for a seagoing vessel
Wally Power 118 Yacht
(Photo from Superyachts.com website)

Hull Structure

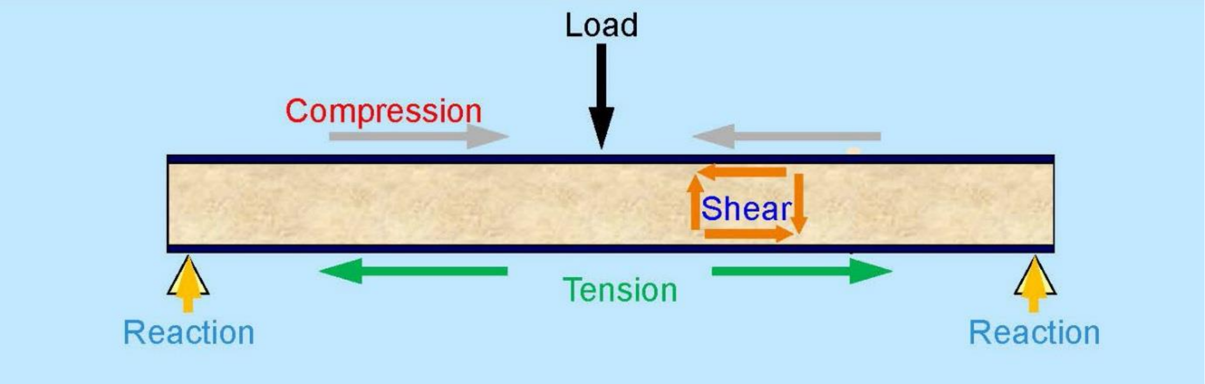
As a composite engineer, Valerio cannot tell a naval architect to design a hull with a V shape to reduce the loads. The lines of the hull are designed to suit a particular purpose and he, the composite engineer, has to design the structure to suit the loads on that hull shape.



Hull structure
(Photo courtesy Diab Group)

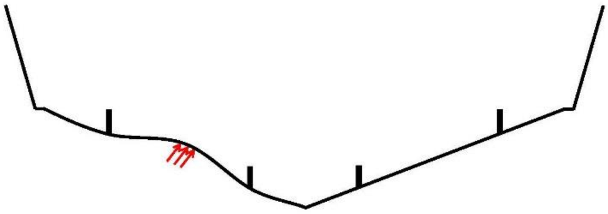
The focus tonight is on sandwich construction, and on the different materials we can use. Here Valerio passed around several example layups, including a sandwich panel, a sandwich I-beam, and a sandwich-to-single-laminate junction. These illustrated the extreme lightness and stiffness of the items.

Sandwich panels owe their strength to the separation of the skins (which take the bending loads) by the core (which takes the shear loads).

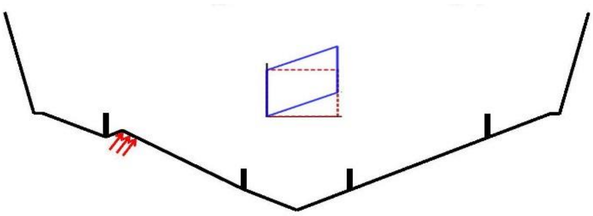


Loads in a sandwich panel
(Image courtesy Diab Group)

A slamming load in the middle of a panel causes bending of the whole panel, and the energy is mainly absorbed by the bending deformation. A slamming load close to a support, on the other hand, causes only shear and the energy is absorbed through core shear deformation.



Slamming in the middle of a panel
(Image courtesy Diab Group)

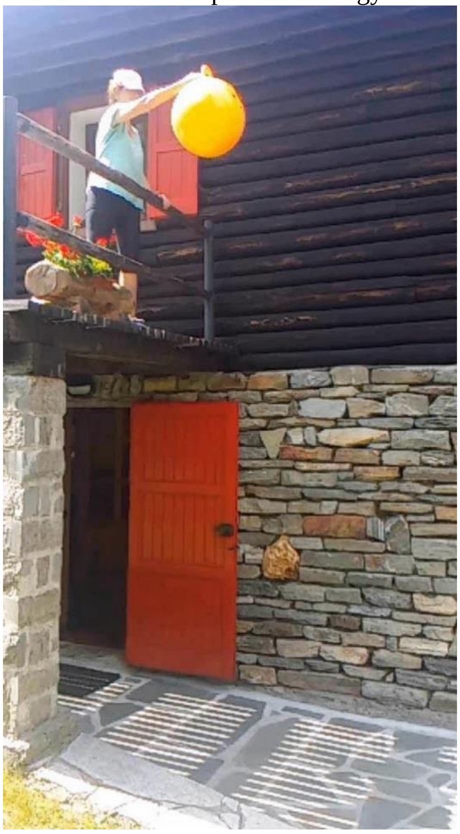


Slamming close to a support
(Image courtesy Diab Group)

Conservation of Energy

The law of conservation of energy states that “Energy can neither be created nor destroyed; rather, it transforms from one form to another.” There are many forms of energy, including elastic, gravitational potential, kinetic, thermal, chemical, electromagnetic and nuclear energy. For hydrodynamic loads on vessels, we are chiefly concerned with elastic, gravitational potential and kinetic energy.

Here Valerio used the example of dropping a ball from a balcony onto a concrete driveway. The potential energy at the balcony is first converted into kinetic energy as the ball drops. When it hits the driveway, the kinetic energy at impact is converted into elastic energy. When the ball rebounds, the elastic energy is converted back into kinetic energy which is, in turn converted to potential energy as the ball rises, and so on.



Dropping a ball onto a driveway
(Photo courtesy Valerio Corniani)

Elastic energy is governed by Hooke's Law

$$F = kx$$

The elastic potential energy is given by

$$E_{Kmax} = \frac{1}{2}F_{max}x_{max} = \frac{1}{2}F_{max}.F_{max}/k = \frac{1}{2}F^2_{max}/k$$

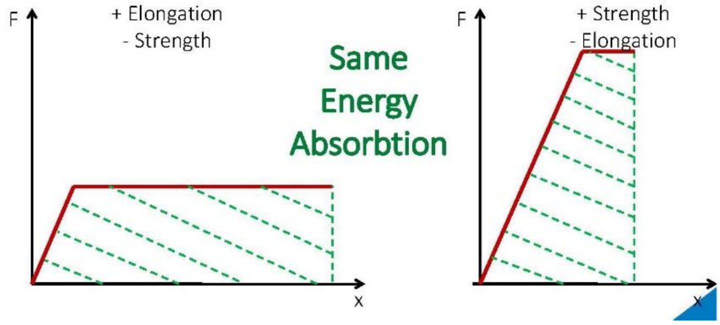
The gravitational potential energy is given by

$$E_{Pmax} = mgh$$

Equating, in the conversion from one to the other

$$mgh = \frac{1}{2}F^2_{max}/k$$

However, energy absorption should not be confused with elongation. One material may have low strength but high elongation, while another may have high strength but low elongation, and they could both absorb the same amount of energy.



Energy absorption
(Image courtesy Diab Group)

Design Rules

There is a number of design rules relevant for the design of composite structures for vessels. These include

- ISO 12215 Has lower safety factor for cores of elongation >35% everywhere
- GL Has lower safety factor for cores of elongation >35% for hull and watertight bulkheads
- ABS Has lower safety factor for cores of elongation >40% everywhere (40% is a lot!)
- DNV GL Includes approval for slamming (and is a more scientific approach)

DNV GL uses a high-speed Instron machine to determine whether a material is suitable for slamming areas. Valerio showed graphs of shear stress vs deflection for sets of three samples tested under static and slamming loads by DNV GL, and the resulting Type Approval certificate.

Practical Tests

Here Valerio showed a testing rig constructed by Diab in Sweden for testing sandwich samples under high-speed shear loads. The rig included a slug mass of 100 mm diameter about 200 mm long which could be dropped from different heights onto the samples to simulate the slamming loads. This was followed by a video of the test rig in use.

Diab test rig
(Photo courtesy Diab Group)

There was a new trend in the Open 60 class a few years ago, when it was proposed that a single laminate skin with many closely-spaced frames would be lighter than sandwich construction, and some vessels were built this way. When they were designing the structure for the new bow for *Wild Oats XI* a while ago, they investigated this option, but decided on staying with sandwich construction, with about 40 mm core and 2 mm laminate skins in the slamming zone.

The TP52s (Trans-Pacific 52s) are very light with all Nomex hull bottoms. However, when people bought second-hand vessels to sail them in open waters, they found that they were getting failures of the sandwich construction. Nomex is very strong but stiff, and failed under the slamming loads close to the panel supports

Conclusion

Designing for slamming loads is very different to designing for static loads. We have looked at the differences between the types of loads, and investigated the law of conservation of energy. The structure of a vessel has to be designed to take the loads imposed by slamming, and this means absorbing the energy imparted to the structure. In addition, we need to take account of the design rules relevant to the design of composite structures for vessels.

Questions

Question time was lengthy and elicited some further interesting points.

The core shear failures of the TP52s were not catastrophic. The failures were usually close to a support and so, while the laminate cracked and led to water ingress into the hull, it was usually spotted quickly and, while it slowed the boat, the crew were able to make port for repairs, even if temporary. However, in the long run, the whole bottom would have to be re-laminated.

How many cycles to failure in composite structures? A good question! There is still not much mention of fatigue behaviour of composite materials. The tendency is to say that composites behave like steel, in that if you design below the fatigue limit, then the structure will be safe. Epoxy resins are usually OK for extended life, but polyester resins are more likely to degrade in strength over time. There is, as yet, no definition of the number of cycles to failure of composite structures in the marine field.

The video of the test rig in use showed the slug mass appearing to have sharp edges, and this would have affected the results. In fact, the mass had 5 mm radii on the edges, as they did not want failure by denting and this was expected to have no effect on the results. The mass was held up electromagnetically, so that it could be dropped from different heights. in their initial trials, a rubber mat under the test rig did affect the results until they realised what was happening, and removed the rubber mat! The test rig was designed so that they could take it to trade shows and demonstrate the properties of various layups.

The main focus this evening has been on composite yachts. However, in the application to commercial vessels, lightweight construction is going to reduce energy consumption and, hence, engine emissions. In his role with Diab, Valerio is focussing quite a bit on that. Yachts and pleasure vessels in composites comprise something like 60–80% of the market. However, the SOLAS regulations are not good for composites, as composites bur rather well. Regulation 17 says effectively that, if a structure performs as well as steel in fire conditions, then it may be used. So there is a lot of work going on now developing resins and cores which can make sandwich composites pass Regulation 17.

SP in Sweden are focussing on a risk analysis as for steel. However, the shipping industry tends to be conservative, and it is hard to change minds. It does happen, albeit slowly!

The vote of thanks was proposed, and the certificate and “thank you” bottle of wine presented, by Phil Helmore.