Technical Meeting — 5 April 2023

Sean Langman, Managing Director, Noakes Group, gave a presentation on *Finite Element Analysis: Computed Prediction vs Reality*, to a joint meeting with the IMarEST in the Kirribilli Room, Royal Sydney Yacht Squadron, and streamed live on 5 April. The presentation was attended by 15 with an additional 7 online.

Introduction

Sean began his presentation by saying that he is a firm believer in the value of finite-element analysis (FEA), as it can give him the answers that he wants. One of his main interests in life is making boats safer and yachts go faster, and one element of the go-fast equation is a compromise between lightness and strength. FEA can ensure that you have the strength in the right area to take the envisioned loads.

And therein lie two of the problems: you have to know (or be able to estimate with some degree of assurance) what the loads will be, and you have to analyse a sufficient part of the structure to ensure that the loads are being transferred from the point of application to the overall surrounding structure. The first law of computing also applies to FEA: if you put garbage in, you will get garbage out!

Sean then went onto illustrate with several examples.

oneAustralia

Most people remember the dramatic photos of John Bertrand's o*neAustrala* breaking in halves and sinking within three minutes during round four of the round-robin stage of the America's Cup challenger series in a match race between *One Australia* and *Team New Zealand* on 5 March 1995.

oneAustralia sinking on 5 March 1995
(Photo from SMH website)

By way of background, it was a rainy, blustery day in San Diego, with winds gusting to 22 kn. The seas off Point Loma were confused, if not especially high, topping out at about 1.5 m. Several of the racing syndicates, wary of risking their multimillion-dollar International America's Cup-class yachts, radioed the race committee to recommend postponement, including *Team New Zealand*, *France3*, *Nippon Challenge* and o*neAustralia*. Race Director, Pat Healy, noting that the winds were forecast to gust no higher than 18 kn and were then blowing at only 12 to 14 kn, rejected all appeals.

In the race, *Team New Zealand* started well and led by 15 seconds at the first mark and was 21 seconds ahead when the boats made the second mark and turned back upwind. The breeze had picked up and was blowing some 20 kn. Halfway up that third leg, 45 mins into the race Bertrand, steering his boat through the heavy swells, heard a sound "almost like a cannon going off" and the honeycombed carbon-fibre hull of *oneAustralia* had hit a wave and cracked dead in the middle, a few metres behind the mast.

Unfortunately, the *cause* of the failure was not shared or made public at the time, although now summarised on https://www.sailingscuttlebutt.com/2019/03/05/americas-cup-sinking-one-australia/, for example.

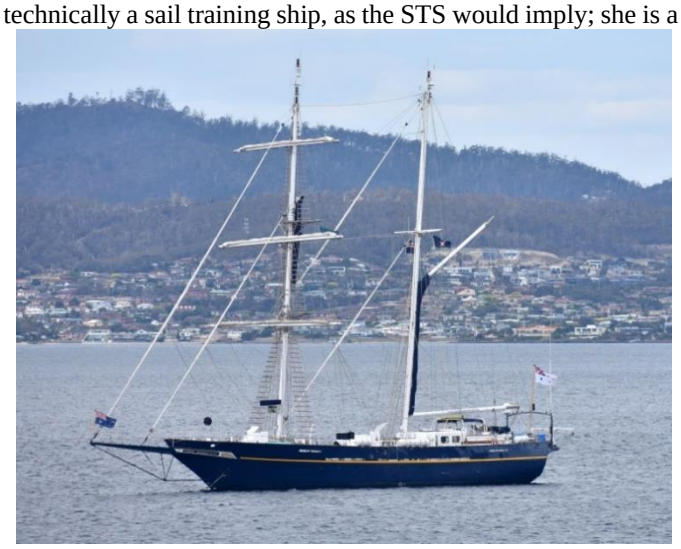
What had happened was that the primary genoa winch had failed and, in order to keep sailing, the crew had transferred the sheet to the running-backstay winch. The boat had not been designed to take the genoa load applied at twice the distance from the forestay, and the hull simply broke under the doubled bending load.

All of this shows up clearly with finite-element analysis — the hull can take the usual genoa load, even under wave impacts, but cannot take it when applied so far aft at the running-backstay winch.

Fortunately, no lives were lost!

STS *Young Endeavour*

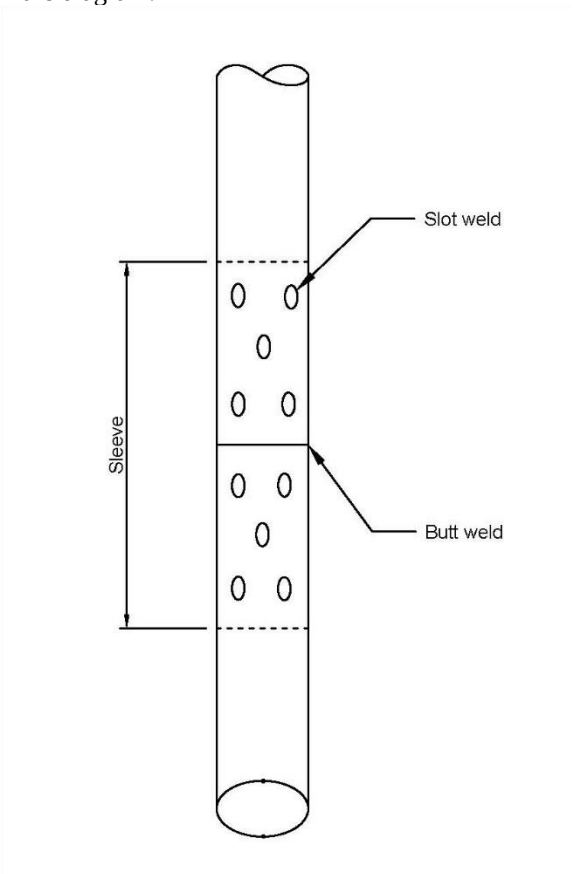
Young Endeavour is not technically a sail training ship, as the STS would imply; she is a youth development ship.



Young Endeavour
(Photo from Shipspotting website)

There have been two areas of concern.

The first is that, ten years ago they replaced the masts, prior to her world voyage, sailing past the two great capes, Cape Horn and the Cape of Good Hope. The masts are in 6061 T6 aluminium, and could not be extruded in one length, and so had to be joined — the largest mill in the world at that time was in South Africa, but has now been superseded by one in Melbourne. The FEA concentrated on the strength of the butt joint. On this vessel, the yards have to turn, and so there are gaps in the rigging, and the load paths are complex. The solution they came up with was to sleeve the joint for 1 m either side of the butt in the extrusions, and to stagger the slot welds through the mast to the sleeve, as shown in the diagram.



Schematic of *Young Endeavour*'s mast join
(Drawing Phil Helmore)

Analysing this in FEA gave insight into how close the slot welds had to be to keep within the allowable stresses for the 6061 T6 aluminium.
The second area of concern, more recently, was the bowsprit where the young crew often sit. The bowsprit was in need of repairs, and it was considered advisable to upgrade the whole unit in several ways. The first problem was that all the shell plating was severely corroded and required replacement; i.e. a new bowsprit. Also, the new sprit provided a better platform for sitting, and the guardrail system was upgraded, with rod rigging for the higher top rail. When the ship had arrived from the UK in 1988, the ship's rigging had not been set up as tautly as usual for this type of vessel, and so Sean had tightened everything up.
Here Sean passed around the original bobstay pin which was worn, and showing signs of fatigue.
Analysing the bowsprit and rigging with FEA showed where the maximum stresses occurred, and where they needed material to keep those within limits, bearing in mind that Lloyd's Register was looking over their shoulder.
One interesting aspect for this vessel is that the rig is usually tightened by tensioning the backstay; here they maximised the angle of the bobstay to minimise the tension in the forestay, and then tensioned the forestay itself.

Moneypenny
Moneypenny is a Reichel Pugh 69 built by McConaghy Boats and was languishing out of the water in a boatyard in Rhode Island, USA. She was designed as a centreboarder and had already been lengthened by 1.2 m, but without any FEA being done to check for extra loading. While laid up on the hard, a big storm came through and there was damage to the cabin top and to the hull on lines port and starboard of the centreboard opening.
Noakes Group purchased *Moneypenny* to fulfill a contract won with Naval Group as a team-building project and brought back to Australia. The damage was repaired and, with the help of FEA they located a problem in the slamming area. With hindsight, they should have included more of the structure aft of the forward bulkhead in order to ensure the transmission of loads into the surrounding structure. Additional frames were added in the bow and unidirectionals used for reinforcing in way of the centreboard opening damage. The boat was renamed *Naval Group*, and competed in the 2018 Sydney–Hobart Yacht Race, finishing 11th over the line and 39th overall on IRC.

Moneypenny as *Naval Group*
(Photo from Rolex Sydney–Hobart Yacht Race website)

In order to make the boat go faster, a VPP was used to help determine loadings and, of course, the FEA had to be completely remodelled. They then added further frames in the midship area. She competed in the 2019 SHYR as *Naval Group* again, finishing 8th over the line and 10th overall on IRC.
After Noakes' association with Naval Group ended, Sean changed the name back to *Moneypenny*. Further FEA analysis of the X-frame showed that the keel bulb could be moved further aft, giving less surface area (and, hence, less frictional resistance), improving steering and allowing the fin to twist and develop more lift. *Moneypenny* competed in the 2022 SHYR, finishing 10th over the line and 8th overall on IRC.

Conclusion
Sean has taken to finite-element analysis, as it gives him the answers he wants, which are all directed at making boats safer and to go faster. You have to be careful with what you analyse, and the loads which you impose, but the tools are there to be used!

Questions
Question time was lengthy and elicited some further interesting points.
The presentation was recorded and is expected to be available soon on the RINA YouTube channel.

The vote of thanks was proposed, and the certificate and “thank you” bottle of wine presented, by John Jeremy. The vote was carried with acclamation.

Sean Langman (L) with John Jeremy
(Photo Phil Helmore)