CASE 22

Keel Failure Leads to Loss of Life

Narrative

Following a very successful 2006 racing season, the owner of a 10 metre yacht put the boat into a boatyard for repairs and maintenance. The boat looked in great shape as the 5-man delivery crew arrived to take it back to its home port. The boat was checked over, the two new crew members were briefed on the safety gear, and the mainsail and genoa were rigged as the boat sailed at 2335. There was an 8 -10 knot north-easterly wind, and the boat was on a port tack and heeling about 15° to starboard when the first reef was put in the mainsail just before midnight.

Everything was normal, the boat felt businesslike – this promised to be an exhilarating trip and the chance for the new crew to gain experience. Unfortunately this expectation was soon to change.

By 0045 the owner, one of the watch leaders, and crew were in the cabin, having put the second reef in the mainsail. By 0245 the wind had increased to 25 knots, gusting 35 knots, and the boat was heeling 25° to starboard. At 0300 the relief crew arrived on deck, and at 0315 the heel increased to 30° and preparations were made to put the third reef in the mainsail, the genoa having already been ⅔ furled.

Before the mainsail could be reefed, the heel rapidly increased, and at about 0320 the boat very quickly inverted, trapping the skipper inside the cabin. Once in the water, three of the crew made their way to the transom and immediately noticed that the keel was missing.

One of the crew was not wearing a lifejacket and found it difficult to keep himself afloat; despite this he set about cutting the liferaft lashings at the transom. One of the others was wearing an auto-inflation lifejacket, which had operated, and the other crew member was wearing a manual inflation lifejacket, which he did not inflate. Despite this rapid change in circumstances, the skipper kept calm in the upturned yacht. He managed to locate and push the flare box and grab bag out of the cabin. These floated to the surface and the flares were set off. At the third attempt the skipper escaped from the cabin, but there was no sign of the fifth crew member.

The skipper, who was not wearing a lifejacket, was slipping in and out of consciousness, and was suffering the effects of hypothermia. Fortunately the crewman wearing the auto-inflated lifejacket was able to support him.

The crew managed to cut the liferaft free and set off the flares held in the liferaft. They were rescued at 0430 by a nearby ship. The body of the missing crew member was recovered by a lifeboat at 0655.

Investigations found that the fabricated steel keel had failed just below the fillet weld connecting the fin to the taper box (see Figure 1). Laboratory metallurgical analysis confirmed that the keel had suffered fatigue failure due to reverse bending stresses. Defects were also found in the keel taper box welds, and two of the three keel bolts had also failed.

It was further discovered that the boat builder had sub-contracted the hollow keel construction to a steel fabricator who had no marine experience. The fabricator changed the original design, and incorporated a fillet weld in a critical area. He did so to ease manufacture and reduce costs, but without the supporting calculations to assess the stresses to which the keel would be subjected. He did not consult with the designer on the changes. In 2005, 160kg of lead was added to the keel bulb for racing optimisation reasons. Once again there were no supporting calculations, nor were there detailed checks made against the "original" or "as built" designs to ensure that the modification was safe.

It was found that none of the designs achieved the required Safety Factor of 2. The addition of

Figure 1

Figure 2

the extra bulb weight exacerbated the problem and the keel was unable to withstand the "in service" bending stresses, and this led to the conditions of failure.

When the boat was taken out of the water at the end of the 2006 racing season, considerable detachment of the keel's epoxy filler and anti-fouling was found (see Figure 2). There was also evidence of the likelihood of fine cracking in the steel adjacent to the fillet weld, but this went undetected by the repairer, so the last chance to prevent the accident was missed.

The Lessons

1. **Yacht designers should ensure component designs satisfy the appropriate standard safety factor requirements. In this case, the keel steel's full ultimate tensile strength was used in the calculations instead of yield strength, and thus an artificially high safety factor was achieved.**

2. **Changes to critical parts such as hollow, highly stressed keels, should be properly worked through and supported with calculations to ensure their suitability. Owners should seek expert professional advice, and wherever possible, reference should be made to design drawings, and the designer/builder consulted to check construction details and suitability of the modification.**

3. **Do not dismiss the importance of keel coating detachment, or evidence of cracking of the coatings at the keel to hull interface; this may indicate more deep seated keel structural problems. Seek expert advice – you may need to use non-destructive procedures to check that the keel structure is sound. Also, regularly check the tightness of keel bolts and thoroughly investigate the cause of any failures. *Remember*, action at this stage could save your life.**

4. **The RNLI recommends that liferafts are secured on deck and that nothing is stowed on top of them. Hydrostatic Release Units (HRU) can be fitted to automatically release liferafts in a sinking or capsize situation. Where it is not practicable to fit an HRU, skippers and owners should consider securing liferafts with quick release knots to expedite release.**

5. **It is always good practice to wear your lifejacket while on deck. It significantly improves the chances of survival, and in cold waters, in the middle of the night, it will prove to be your very best friend. Look after it, know how to use it and maintain it correctly.**