National Safety Committee

Dynamic Testing of Yacht Stanchions

Conducted during August 2013

Executive summary

Yacht stanchions made from four different materials were subjected to **impact** tests in order to characterise their **dynamic behaviour** and determine whether the mode of failure of the stanchions containing carbon fibre would result in “**shattering**”[1] which could expose crew to additional hazards. The metallic stanchions failed by buckling while the stanchions made from carbon fibre/E-glass-epoxy and carbon fibre-epoxy absorbed energy through elastic deformation and permanent deformation. No “shattering” of stanchions containing carbon fibre was observed and no additional hazard to crew was observed. The special regulations describe the purpose of the guardrail/lifeline system to “minimise the risk of people falling overboard” (ISAF) and to “form a continuous barrier around a working deck” (YA). The carbon fibre and E-glass composite stanchions were found to do this best as the stainless steel and aluminium stanchions do not retain their height after impact.

Earlier static tests had determined that stanchions containing carbon fibre complied with ISO15085:2003. Stanchions containing carbon fibre can form a suitable part of a yacht’s guardrail system. The prohibition of carbon fibre in stanchions and pulpits that currently exists in ISAF OSR 3.14.7 should be removed while lifelines should be treated separately in Table 9 of that section. It is not suggested that carbon fibre is a suitable material for lifelines and no testing for that application has been undertaken. Stanchions should comply with ISO15085:2003.

Table 1 – Summary of results:

TEST	Stanchion type	Mass (g)	Mount	Impact energy (Joules)	Elastic tip deflection (mm)	Permanent tip deflection (mm)	Failure type	Shattering?	Dynamic behaviour	Sharp edges?
#1	Stainless steel	450	Alu. spigot/socket	790	0	—	Spigot sheared	No	—	No
#2	Stainless steel	450	Stainless spigot/socket	790	0	Collapsed	Spigot buckled to ~45°	No	Buckling	No
#3	Aluminium	350	Socket	790	0	Collapsed	Buckled/tore to ~90°	No	Buckling/tearing	Yes
#4	Carbon fibre/E-glass epoxy	250	Socket	790	700	100	Compression tear in tube	No	Elastic deflection	No
#5	Carbon fibre/epoxy test#1	240	Socket	790	300	50	Wrinkling in tube wall	No	Elastic deflection	No
#6	Carbon fibre/epoxy test#2	240	Socket	790	—	50	Wrinkling in tube wall	No	Elastic deflection	No

Report contents:

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[1] **Shatter** [http://www.thefreedictionary.com/shattered]

v. **shat·tered**, **shat·ter·ing**, **shat·ters**
1. To cause to break or burst suddenly into pieces, as with a violent blow.
2. To damage seriously; disable. To cause the destruction or ruin of; destroy:

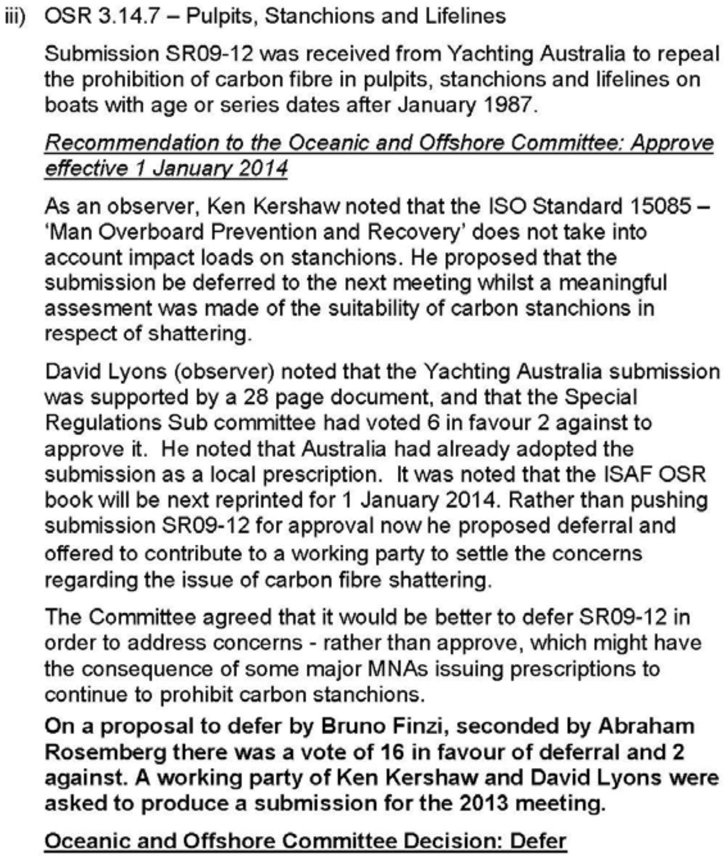
Objective

Yachting Australia took submission SR09-12 to ISAF in November 2012 to repeal the ISAF Offshore Special Regulations prohibition on carbon fibre in pulpits, stanchions and lifelines. After lengthy committee discussion, the submission was deferred pending the outcome of investigations by a working party.

The **objective** of the tests described in this report is:

To investigated the dynamic behaviour due to impact and hypothetical "shattering" of carbon stanchions

Minute 9. (c) (iii) of the ISAF Oceanic and Offshore Committee [November 2012] stated:



iii) OSR 3.14.7 – Pulpits, Stanchions and Lifelines

Submission SR09-12 was received from Yachting Australia to repeal the prohibition of carbon fibre in pulpits, stanchions and lifelines on boats with age or series dates after January 1987.

Recommendation to the Oceanic and Offshore Committee: Approve effective 1 January 2014

As an observer, Ken Kershaw noted that the ISO Standard 15085 – 'Man Overboard Prevention and Recovery' does not take into account impact loads on stanchions. He proposed that the submission be deferred to the next meeting whilst a meaningful assesment was made of the suitability of carbon stanchions in respect of shattering.

David Lyons (observer) noted that the Yachting Australia submission was supported by a 28 page document, and that the Special Regulations Sub committee had voted 6 in favour 2 against to approve it. He noted that Australia had already adopted the submission as a local prescription. It was noted that the ISAF OSR book will be next reprinted for 1 January 2014. Rather than pushing submission SR09-12 for approval now he proposed deferral and offered to contribute to a working party to settle the concerns regarding the issue of carbon fibre shattering.

The Committee agreed that it would be better to defer SR09-12 in order to address concerns - rather than approve, which might have the consequence of some major MNAs issuing prescriptions to continue to prohibit carbon stanchions.

On a proposal to defer by Bruno Finzi, seconded by Abraham Rosemberg there was a vote of 16 in favour of deferral and 2 against. A working party of Ken Kershaw and David Lyons were asked to produce a submission for the 2013 meeting.

Oceanic and Offshore Committee Decision: Defer

Background

The superseded Yachting Australia (YA) Special Regulations [2009-2012 edition] prohibited the use of carbon fibre in stanchions, pulpits and lifelines at Regulation 3.12.7, as do the current ISAF Special Regulations [2012-2013] at 3.14.7, for yachts with Age Date post-01/87.

The current edition of the YA Special Regulations [2013-2016] repeals the prohibition by removing Regulation 3.12.7. This change was not accompanied by a lack of concern from Australian state MYAs that raised various objections to the removal of the prohibition when CESR (Clarification of Existing Special Regulation) No.2 of 3 May 2012 was published and public comment was invited. CESR2/2012 held that carbon fibre could be used provided the stanchion, pulpit or lifeline complied with international standard ISO15085:2003 *Small craft – Man overboard prevention and recovery*. The CESR arose after YA Interpretation No. 6 of 9 March 2012 was published for a brief time, which held that the then prohibition did not apply to the "cosmetic" application of carbon fibre, which was not deemed to constitute substantial construction of carbon fibre. Interpretation 6 was withdrawn on 7 May 2012.

In removing the prohibition, Yachting Australia relied on the results of its own investigations into static testing of stanchions using a method based on ISO15085 at paragraph 12.2.2, which requires a maximum tip deflection of 50mm at a perpendicular load of 280N and a minimum tip breaking load perpendicular to the stanchion of 560N. Results indicated strengths for carbon fibre and carbon fibre/E-glass stanchions that exceeded the minimum ISO15085 requirements by a large margin.

Yachting Australia's continuing role

Following the earlier work done by YA which measured the static bending strength of stainless steel, carbon fibre/E-glass and carbon fibre stanchions, it was decided to undertake dynamic testing in order to better understand the failure modes during an impact event. The results of this work would feed in to the ISAF working party effort.

A test rig was designed that would repeatably deliver a dynamic load to a series of stanchions.

The test rig is shown at Figure 1, while carbon fibre/E-glass and carbon fibre stanchions were designed and made (see Figure 2.) so they could be compared with stainless steel and aluminium stanchions in an impact.

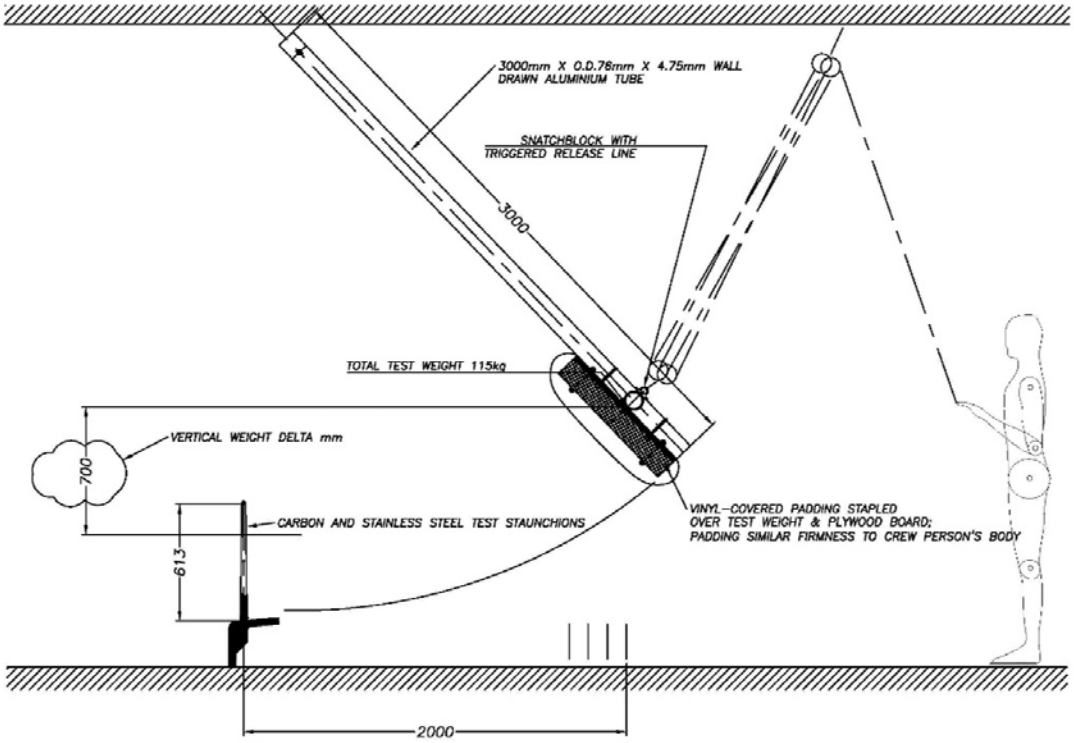


Figure 1. – Dynamic impact test rig

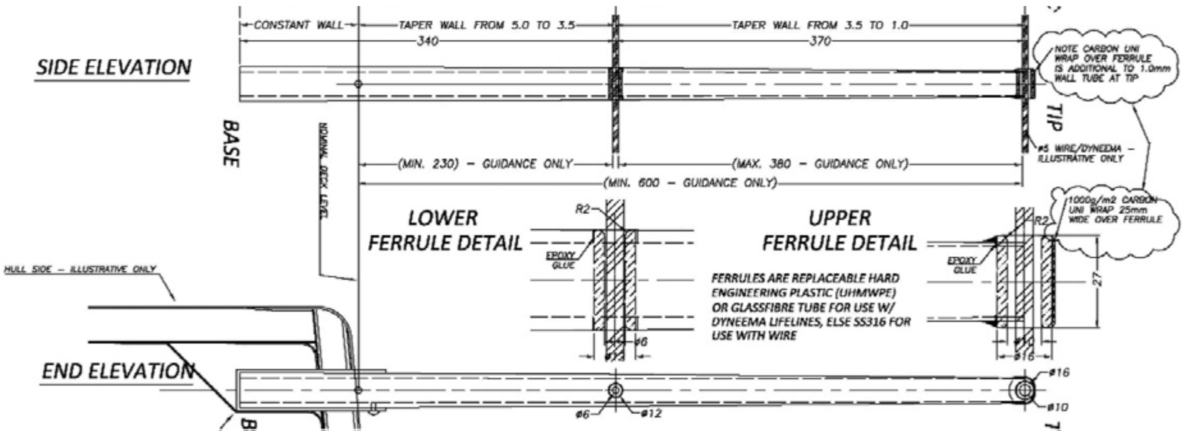


Figure 2. – Carbon fibre/E-glass and carbon fibre stanchion design

Test method

The dynamic test rig (Fig.1) can deliver a repeatable and measurable amount of kinetic energy to the stanchion. At a vertical height delta of 700mm as shown in Figure 1, this energy is 790 Joules. To put this into context, this is the same amount of energy as an 85kg crew person falling into a stanchion from the centre-line of a yacht with 4m beam while heeled at 30°.

The mass fitted to the test pendulum is padded and covered with vinyl in order to simulate the softness/firmness characteristics of the human body.

Sample description and mounting

Turning to the design and construction of carbon fibre and carbon fibre/E-glass stanchions (Fig.2), the following laminate compositions were chosen in collaboration with the manufacturer:

Carbon fibre/E-glass stanchion: 60% E-glass, 40% carbon fibre, 50% woven, 50% unidirectional – pre-preg/epoxy

Carbon fibre stanchion: 50% woven, 50% unidirectional – pre-preg/epoxy

The weights of all candidate stanchions were:

Carbon fibre: 240g

Carbon fibre/E-glass: 250g

Aluminium: 350g

Stainless steel: 450g

Most metal stanchions are inserted into metal brackets bolted through the deck and/or hull.

Most composite stanchions are directly inserted into sockets in the deck or use spigots that are inserted into the stanchion lower end and the deck sockets.

To simplify, the test rig simulated a deck edge with a socket as would be most commonly seen on a modern composite yacht with composite stanchions. Varying stanchion diameters meant that some stanchions had spigots or sleeves fitted while some were directly inserted, as follows:

Carbon fibre: Direct to sleeved socket

Carbon fibre/E-glass: Direct to sleeved socket

Aluminium: Direct to sleeved socket

Stainless steel: One with solid aluminium spigot, one with turned stainless steel tubular spigot.

Fig. 3: Carbon fibre stanchion

Fig 4.: carbon fibre/E-glass stanchion.

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Fig. 5: Aluminium tubular stanchion

Fig 6: Stainless steel stanchion (Ronstan RF1695-61)

Fig. 7: Left to right - Stainless steel ϕ25 x 1.6; carbon fibre ϕ29.6 x 5.0; carbon fibre/E-glass ϕ32 x 5; aluminium ϕ31.5 x 2.5

Fig. 8: Test rig set-up with stainless steel stanchion in place.

The composition of the test mass was 100kg of lead bolted to 40mm of plywood and secured to a ϕ76 x 4.75 x 3m aluminium swing-arm. The impact face was then padded with high-density foam rubber and covered with vinyl:

Fig. 9: 100kg lead weights on back face.

Fig. 10: Padded front face.

The testing

All stanchions were subjected to the same impact energy of 790 Joules. Tests were numbered TEST#1 to TEST#6. The following video files depict the test events:

1. TEST#1 - Stainless steel stanchion with aluminium spigot:

   http://tinyurl.com/pbk6xus

2. TEST#2 - Stainless steel stanchion with tubular stainless steel spigot:

   http://tinyurl.com/ojuvj2r

3. TEST#3 - Aluminium tubular stanchion inserted into deck socket:

   http://tinyurl.com/kmmjuhm

4. TEST#4 - Carbon/E-glass stanchion inserted into deck socket:

   http://tinyurl.com/pxfug2x

5. TEST#5 - Carbon stanchion inserted into deck socket:

   http://tinyurl.com/no6mat6

6. TEST#6 - Damaged carbon stanchion subjected to second test:

   http://tinyurl.com/olv99bf

Results

TEST#1 The aluminium spigot sheared, leaving the stainless steel stanchion intact:

Fig. 11: Fractured aluminium spigot taken from stainless steel stanchion (TEST#1).

TEST#2 The stainless steel tube spigot buckled, leaving the stainless stanchion intact. It is expected the same behaviour would have occurred even if the stainless steel stanchion was inserted directly into the deck socket or a conventional deck-mount bracket:

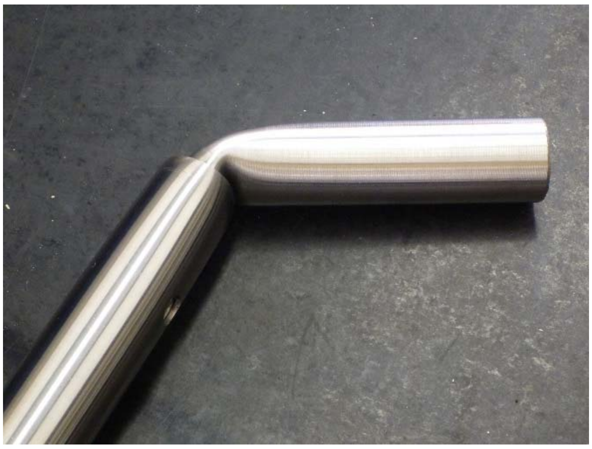
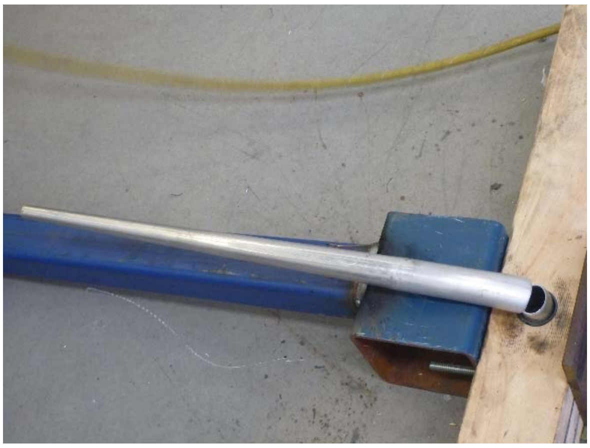


Fig. 12: Spigot in Test#2

TEST#3 The hollow tubular aluminium stanchion buckled and tore, exposing a sharp edge while just remaining in one piece – see Figs. 13 and 14 below:



TEST#4 The carbon/E-glass stanchion fractured but remained intact and showed a momentary elastic bend of 700mm and permanent yield of 100mm at the tip – see Figs. 15 and 16 below:

TEST#5 The carbon stanchion displayed little damage but elastically deflected up to 300mm during impact and retained a permanent yield of 50mm (see Figs. 17 and 18 below):

TEST#6 The same carbon stanchion was subjected to a second impact, which broke the test rig and caused some additional damage to the stanchion (see Figs. 19 and 20 below):

Discussion of results

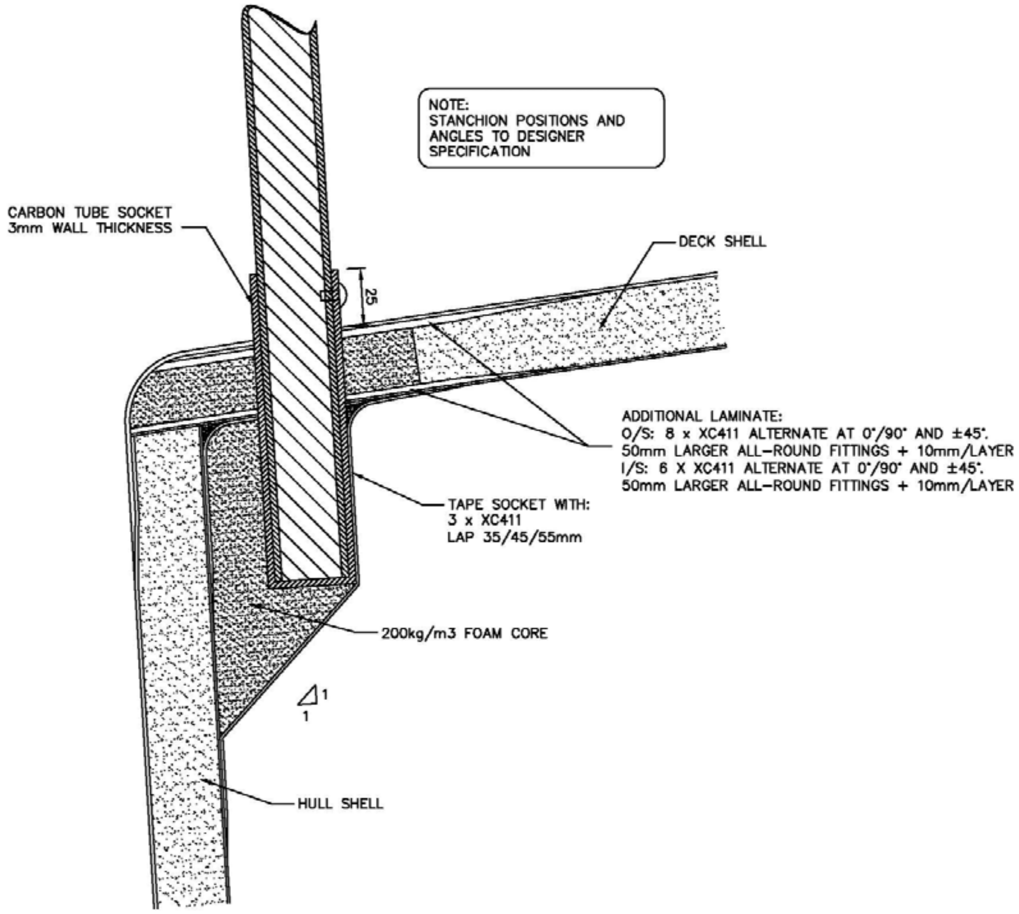
The stainless steel and aluminium stanchions fail in a predictable ductile manner. The stainless steel stanchion buckled and remained in one piece (Fig. 12), as did the aluminium stanchion although it exposed a sharp fractured edge (Figs. 13 and 14).

The carbon fibre/E-glass stanchion displayed elastic yield upon impact of 700mm while permanent tip yield was 100mm and remained intact (Fig.16). It exposed a fractured edge that was rough but not sharp or able to cause any injury (Fig. 15).

Upon first impact, the carbon fibre stanchion displayed 300mm of elastic impact yield and remained intact with no exposed fracture surface (Figs. 17 and 18). Upon second impact, it was sufficiently strong to break the test rig (Fig. 19). This was mostly due to the disposition and inertia of the lead weights about the centrally mounted vertical aluminium swing arm (Fig. 9). Although rather spectacular, the appearance of the failure belied a behaviour that may not be prevalent in the case of human contact with the stanchion.

The simulated deck edge socket, made from pine wood (Fig. 17), remained intact in all instances after suffering 6 successive impacts. It was constructed so as to simulate the design strength of a composite hull/deck join incorporating stanchion socket, commonly found today.

Such a design is shown below – Fig. 21:



It is important to note that the deck-edge and stanchion mounting design must have strength exceeding the bending strength of the stanchion. This is easily achieved but a heirarchy of failure should have the stanchion failing before the deck-edge and socket. An alternative way to achieve the same result is to incorporate a spigot that fails before the deck-edge and socket can be compromised.

Conclusions

From emprical evidence and supported by these tests, the behaviour of stainless steel and aluminium stanchions is well understood. These tests did not produce any surprises with these two stanchion materials.

The composite stanchion incorporating a blend of carbon fibre and E-glass displayed significant energy-absorbing elasticity (700mm impact deflection), remained intact and did not exhibit any fracture surface that may injure crew. A permanent yield of 100mm occurred. The epoxy resin used in the composite tube laminate plays an important part in toughness and elasticity while the 50% woven content binds the laminate together and prevents splintering.

The 100% carbon fibre stanchion did not exhibit any fracture surface that could injure crew either. Elastic impact deflection was 300mm with 50mm residual permanent yield. In the case of the carbon stanchion designed and built for this test program, the material quantity and diameter were somewhat excessive. A smaller diameter carbon fibre stanchion with less material content and additional taper would exhibit even more flex and energy absorption at lower strength.

A 100% carbon fibre stanchion is the strongest and lightest design. In order to avoid the potential for crew injury it should exhibit reasonable elasticity.

- The contention that crew could be injured by sharp carbon fibre edges was disproven.
- The contention that stanchions containing carbon fibre would “shatter” was disproven.
- The dynamic behaviour during an impact event of all stanchions has been characterised. Metal stanchions buckle and can tear while composite stanchions containing carbon fibre deform elastically and show some permanent yield.
- All stanchion types performed at or above the requirements for deflection and strength given in ISO15085:2003 as evidenced by previous YA testing in 2012.

ISAF Special Regulation 3.14.1 and YA Special Regulation 3.12 speak of the overall purpose of the guardrail/lifeline system to “minimise the risk of people falling overboard” (ISAF) and to “form a continuous barrier around a working deck” (YA). The carbon fibre and E-glass composite stanchions were found to do this best as the stainless steel and aluminium stanchions do not retain their height after impact, so it can be envisaged that a crew person would pass more easily beyond the guardrail system and into the water with metal stanchions.

Whilst complying with ISO15085, a stanchion should also prevent falling overboard while exhibiting qualities that best avoid injury to crew. A composite stanchion with approximately 50% E-glass/50% carbon fibre provides desirable energy-absorbing yield.

The focus of this test has been completely on stanchions and for practical reasons the stanchions were tested in isolation of the overall guardrail system including pulpits.

Design detailing of *any* stanchion regardless of material is required so that chafe of lifelines is avoided where they pass through. Lifeline holes need suitable ferrules with smooth edges whether the ferrules are housed in a metal or composite stanchion or pulpit/pushpit or whether the lifeline is steel wire or polyethylene (eg. Dyneema ®).

Recommendations

Stanchions and pulpits containing carbon fibre should be considered a suitable part of a yacht’s guardrail system.

The prohibition of carbon fibre in stanchions and pulpits that currently exists in ISAF OSR 3.14.7 should be removed while lifelines should be treated separately in Table 9 of this section. It is not suggested that carbon fibre is a suitable material for lifelines and no testing for that application has been undertaken.

Stanchions should comply with ISO15085:2003.