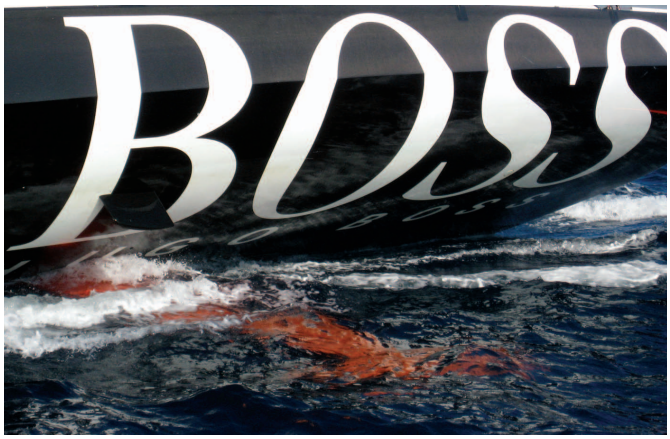
CANTING KEELS

Since they were introduced in the early 1990's, canting keel boats have proved themselves to be consistent race-winners, whether single-handed raceboats or fully-crewed maxiyachts. With the power and performance of race yachts continuing to improve, there was only one way Gurit's engineering team could check that their vital keel load calculations were still relevant...

Canting keels have changed modern racing yachts. By offering a significant increase in the performance of monohull yachts, they significantly increase boat righting moment with only a small increase in weight of the keel system, achieved by moving the keel bulb laterally by swinging the keel to windward.

Gurit first became involved with engineering canting keel boats with Juno Plano, an Open 60 yacht designed by Fabio Buzzi in 1992. Since then it has contributed to the structural engineering of more than 20 canting keel yachts, from a 30 foot inshore racer to the 140-foot Mari Cha IV, which has a single keel ram claimed to be capable of lifting a jumbo jet.

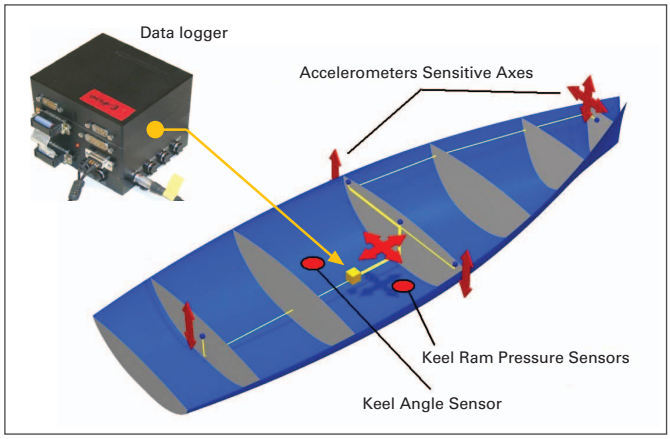
During this time Gurit has developed and constantly refined load cases and analysis techniques used to design the composite structures supporting the keel systems. This typically uses quasi-static analysis techniques under a range of load cases, derived by grouping the loads into a number of worst case scenarios. However, derivation of the worst case loads for canting keel boats is complicated by the fact that the bending moment in the keel fin can be influenced by the yacht heel and keel cant angle, as well as the assumed acceleration envelope of the yacht. Both fixed and swing keel yachts experience higher accelerations in the vertical direction of the boat's frame of reference and this can be more marked for canting keel boats, which tend to sail more upright and faster than conventional keel yachts.



HUGO BOSS' canting keel clearly visible

As the performance and power of canting keel boats has continually increased, the engineering team felt it was increasingly important to establish that the load cases used in the analysis remain appropriate. The remit of these assumptions is further complicated by design criteria which change according to rules and guides of different yacht classes, including different requirements for the ABS guide for classing offshore racing yachts, Volvo 70 class rules and International Monohull Open Class Association (IMOCA) Open 60 class rules.

Gathering the data



Sensors layout on the Open 60' HUGO BOSS

There was only one feasible way the Gurit team could obtain reliable first-hand data – by gathering it under full race conditions in some of the harshest conditions where boat structures would be put to the test. With this in mind the Gurit team enlisted the help of the Marc Lombard-designed HUGO BOSS Open 60 and Wild Oats XI, the Reichel Pugh-designed 100 foot canting keel maxi, both of which were monitored and measured during the 2006 Velux 5 Oceans Race and 2006 Sydney-Hobart race respectively.

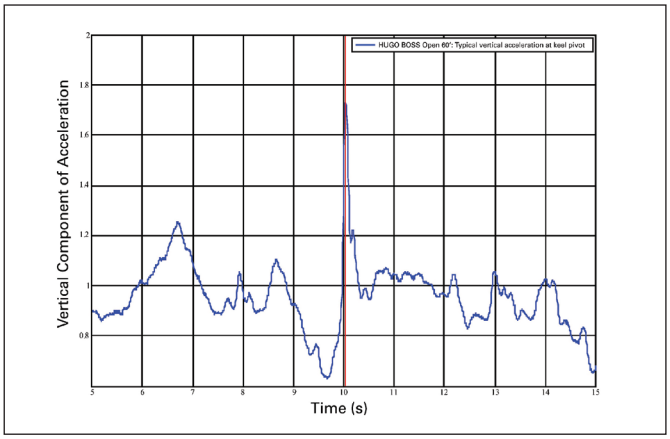
Data systems fitted to the boats consisted of an autonomous data logger, connected to a number of accelerometers and pressure sensors located around the boat that enabled the motions of the boat to be derived and the loads on the ram bearings to be calculated. Data was also logged from the yacht instruments to provide position and environmental information.

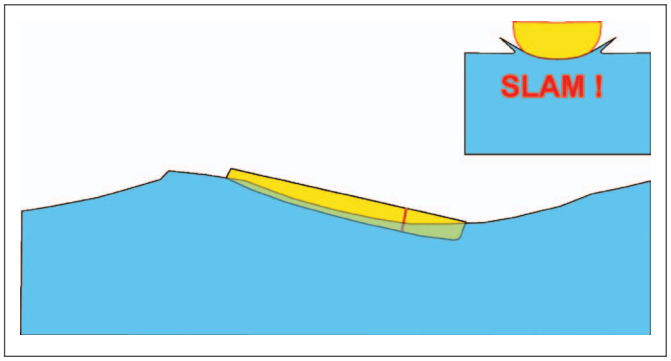
Results & Conclusions

The data gathered from both boats was analysed by Gurit to investigate the rigid body accelerations experienced by each boat and the loads generated in the keel structure. The data recorded the frequency of various magnitudes of accelerations transverse to the keel fin encountered at the keel centre of gravity. These accelerations were rigid body motions that the boats wanted to apply to the keel bulb and were used to calculate the inertial loads on the keel structure.

The measurements showed both boats experienced significant rigid body motion accelerations, which in the case of the Open 60 approached the ultimate accelerations used in the analysis of the keel structure. These rigid body motions were significantly lower on the maxi yacht, due in part to the differing hull shapes of the boats but also to the significant difference in displacements, with Wild Oats offering 2.5 times the displacement of HUGO BOSS.

The loads from the rams were significantly lower than would be calculated using a quasi-static analysis of the keel structure under the derived rigid body accelerations. This was due to the dynamic response of the keel structure to the impulse loading, which resulted in the bulb seeing a lower acceleration due to keel structure flexibility.





Recorded vertical acceleration and typical attitude of the boat relative to the wave profile during a slamming event

The dynamic response of the keel structure to impulse loading was also investigated, with the load cases and assumptions currently used shown to be appropriate for the keel supporting structures designed so far. Whilst this gives full confidence that the design load cases and analysis methods are giving suitable safety margins for the current keel structures, the team concluded that the design of novel keel structures - especially those with keel fins which are significantly stiffer in transverse bending – should always require analysis of the dynamic response of the keel structure at the design phase.

A full report detailing measurements and analysis of the project was authored and presented by Gurit engineers Mark Hobbs and Paolo Manganelli in October 2007. For more information and a copy of the report please e-mail: gurit@gurit.com