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Maltese Falcon

Perini Navi's DynaRig brings square riggers to new age

The Maltese Falcon is undoubtedly one of the most significant sail yacht builds since the millennium and certainly one of the most talked about. The project ranks as amongst the largest privately funded development projects ever - the rig package alone, including masts, sails, yards and control systems, accounts for around 200,000 man hours. With a displacement of 1,368 tons, *Maltese Falcon* is the largest private sailing vessel afloat and with three free standing DynaRig masts driving her 88m of hull through the water; it is definitely one of the most spectacular.

By Guy Waddilove
Photography Perini Navi

Tom Perkins, Maltese Falcon's owner, is no stranger to superyachts having previously owned two Perini Navi sailing yachts both named Andromeda la Dea; the 1915 Herreschoff built classic Marriette; and the restored Edwardian motor launch Atlantide. Perkins says that he had always wanted a modern automated square rigger and, knowing that Perini Navi had an unfinished 88m hull and superstructure at their Yildiz, Turkey build facility, he started discussing his ideas and the suitability of the hull with the Perini management.

Tom Perkins also contacted naval architect Jerry Dijkstra about proposed rig plans as he knew of Djikstra's involvement with other significant large sailing vessel projects including the 62m fully rigged clipper *Stadt Amsterdam*, the J class yachts *Shamrock*, *Endeavour*, *Velsheda* and *Ranger*, the three masted schooner *Adix* and the 90m schooner *Athena* to mention but a few. Discussions with Dijkstra led the owner to choose the revolutionary DynaRig clipper rig concept for his automated square rigger project because of the potential outstanding ocean performance it offered within a compact package.

The DynaRig concept was originally developed at Hamburg University by Wilhelm Prolls in the 1960's to offset fuel costs for commercial shipping in the face of a predicted fuel crisis. The DynaRig design comprises a free standing mast with horizontal booms or yards rigidly attached to it from which rectangular sails are flown. Adjusting sail angles is done by rotating the mast. The concept did not leave the drawing board first time around because of both lack of funding and the problem that the appropriate materials strong enough to withhold the huge loads involved did not exist.

Jerry Dijkstra revisited and updated Prolls's DynaRig, and by using carbon fibre as the main fabrication material, he was able to overcome the frustrations that limited the application of Prolls's research.

The proposal of a three masted DynaRig configuration was attractive to the owner as with six horizontal booms on each mast an area of sail far in excess of the area that could be carried by a traditional 'fore and aft' rigged sailing yacht could be efficiently carried with lower mast heights. At 58m the designed masts would carry a total sail area of 2,396 square metres between fifteen sails, and thus be low enough to pass under the Bridge of the Americas in the Panama Canal, which many consider to be a very important feature for a world cruising yacht.

The DynaRig concept draws inspiration from the sail plans of square rig sailing vessels with the sails named in the same manner - from top to bottom on each mast- royals, topgallants, upper tops, lower tops and courses. Horizontal yards mounted across the beam of the vessel support rectangular sails as opposed to the triangular sails seen on more contemporary Bermudan rig plans. While a square rig sail plan allows greater sail area for mast height than a sail plan with bermudan sails, the drawback with traditional square rig vessels is that they do not perform well upwind as the aerodynamics of the sail do not allow the sail to draw and produce power at small wind angles. The DynaRig overcomes this problem by creating an aerodynamic sail shape that provides sufficient lift without the associated excessive drag. This shape is achieved by rigidly fixing the yards to the mast in one position and rotating the mast to adjust the sails to the optimum angle for the wind. The yards are curved so that the sails present an aerodynamic wing shape rather than a flat panel, allowing the yacht to sail upwind. For further sailing efficiency the rigs are set up so that there are no gaps between each of the five sail panels thus each mast's sail plan acts as a single sail. Because the masts rotate with the booms, it is not possible to support the mast with conventional standing rigging. Each carbon fibre mast is therefore unstayed, and supported only by two massive bearings, one at deck level and one at the mast's heel. The yards are cross braced with diagonal rigging to keep them in parallel.

During the development and build of *Maltese Falcon's* DynaRig, a continuous programme of testing was pursued on various models. Initially a 1/6th scale single sail model was built to check the sail handling system. Next a 1/30th scale model of *Maltese Falcon* was tested at Delft University of Technology and then wind tunnel tested at Southampton University. After this a full scale test rig was built at the Yildiz yard where further refinements to the sail handling systems could be developed and tested under a variety of weather conditions.

The yacht's sails are furled with five vertically mounted carbon mandrels housed within each mast. Each sail is attached to its mandrel by a tongue extension of the bolt ropes in the middle of the sail top and bottom. When the mandrel turns, the tongues are drawn into the slot in the mast and wrapped around the mandrel and the sail is effectively folded in half as it is furled onto the mandrel.

To set the sails four outhaul winches are used to unwind each sail from its mandrel. The bolt ropes at the top and bottom of each sail run along tracks in the yards and the sheets run around mechanical tensioning arms before being led back to the captive reel winches built into the rig. Doyle Sails produced the Dacron sails for the rig. Dacron cloth is more elastic than exotic, high performance materials and this elasticity was a property that was necessary for the rig design. The yards are tapered and designed to flex at their tips so sails with some element of elasticity were required to allow this flexing. Had the yards and sails not flexed, computer analysis showed that point loadings where the yards attach to the masts would have been too great for the mast's structure to bear. The

Above and below: The DynaRig and sails are fully computer controlled from an *out-of-this world* high technology helm display. Stresses in the rig sensed by fibre optic monitors are constantly displayed and all sail handling is fully automated.

Left: The DynaRig engineering and testing was one of the most extensive and expensive private yacht design projects ever undertaken.

long lasting service that has been proven with Dacron sails was also a deciding factor with sail cloth choice.

High clew loads, and indeed high stress loading in any area of the sail is avoided as the sail is supported along the entire length of its top and bottom edges. The sails are cross cut with a very small amount of shape built into them as increasing the draft of the sails would have led to potential problems when furling onto the mandrels.

The sails are not designed to be reefed individually as they would be with a conventional roller reefing system; they can only be flown in the fully out position. Deciding how much canvas to fly for the wind conditions is a matter of choosing how many sails you want up; generally the royals (the top most of the sails on each mast) will be furled away first as the wind increases followed by the top gallants and so on. The upper sails are made of a lighter Dacron than the lower sails reflecting the conditions that the different sails will be used under. The royals are designed to be light enough to blow out well before the rig's maximum design loads are reached, much as they would have done in a traditional square rigger.

When it came to rig construction, the Perini engineers' limited experience with carbon spar manufacture meant that they were reluctant to take on a project of this magnitude; not only were the masts to be very long carbon fibre tubes, they would also need to be self supporting as conventional standing rigging could not be used because of the nature of the design. Tom Perkins enlisted Damon Robert's company Insensys to build the rig. Insensys specialises in 'smart composite design' - embedding fibre optic strain sensors in highly loaded structures. Typical applications are in the oil and gas industry and in the blades of wind generator turbines. Although the technology is not normally aimed at the yacht market, Robert's prior experience running carbon mast maker Carbospars made his company the ideal candidate for the mast construction job. The masts and yards were fabricated in a shed that was leased at the Yildiz shipyard where the rest of the yacht was being built.

Each 58m tapered carbon fibre mast passes through a deck bearing and sits in a massive heel bearing which weighs approximately 9 tonnes. The masts can each rotate through 180 degrees by means of a toothed gear wheel driven by four hydraulic motors. Perini normal specify electric motors rather than hydraulic for load handling applications, but the limited space available at the mast base meant that hydraulic motors were necessary in this instance. The motors are attached to a housing in the mast base rather than the inside of the hull so that they stay in alignment with the mast when it flexes, as the mast tip is expected to bend up to four metres off centre in heavy conditions.

For a rig of this magnitude precise control and monitoring is vital. Rig control and monitoring functions are integrated on the bridge where panels displaying different views of the rig are accompanied by the relevant mast, sail and winch controls. One screen shows a bird's-eye view of the rig and the angle of the apparent wind; underneath this screen are three rotary dials to change the angles of the masts. Another screen shows the tension on the winches that control each sail. A screen showing a side view of the vessel has controls for setting and furling the sails, and the fourth screen, again with a side view of the vessel, shows the bend and torque figures received from the fibre optic strain gauges embedded in the mast. The information on this last screen is represented in the manner of a mercury thermometer for each mast, with the mercury rising inside a column as loads increase.

Maltese Falcon – Highlight of the 2006 Monaco Yacht Show

EACH 58M TAPERED CARBON FIBRE MAST PASSES THROUGH A DECK BEARING AND SITS IN A MASSIVE HEEL BEARING WHICH WEIGHS APPROXIMATELY 9 TONNES. THE MASTS CAN EACH ROTATE THROUGH 180 DEGREES BY MEANS OF A TOOTHED GEAR WHEEL DRIVEN BY FOUR HYDRAULIC MOTORS.

Maltese Falcon's suit of fifteen sails gives multiple options and many permutations for different conditions. Square rig vessels traditionally, in the absence of engines, relied on their sails in varying combinations for close quarters manoeuvring. *Maltese Falcon's* sail plan, being based on that of a cutter square rig, enables her to do similarly, although it is unlikely that the yacht will be sailing on to many marina berths!

Gybing is as simple as steering the yacht so that her stern passes through the wind whilst rotating the masts accordingly. Gybing can be safely carried out in heavy wind conditions as there is no fore aft boom to swing through the wind; the leech of each square sail simply becomes the luff on the opposite gybe. Tacking is more complex and relies on boat speed to carry way through the manoeuvre. From close hauled the yacht is steered through the wind; as soon as the sails start to back the three masts are rotated simultaneously to the same angle on the opposite tack. In heavy seas it may be necessary to back the foremast sails in order to make the yacht pay off on to the opposite tack, but in reality it may be safer and less wear on the rig if the yacht is gybed in these conditions.

Sailing performance figures to date have exceeded expectations; on initial sea trials, with royals and top gallants furled, speeds of 14 knots were recorded in 16 knots of wind at 60 degrees apparent wind angle. Mast loadings reached only 50% of maximum limits; the limits were initially pitched very conservatively and will be increased with experience.

Tom Perkins sums up the project: 'The *Maltese Falcon* has written a new page in the history of yachting, the DynaRig is no longer an experimental concept.'

The huge amount of research and development that went into the *Maltese Falcon* project will benefit the whole of the large sailing yacht industry. Not only have large technological steps been made in rig design, construction, control and monitoring, but Tom Perkins has demonstrated that a well funded private project with the right team behind it can float an extraordinarily ambitious ground breaking project. O