Renewing *Endeavour*'s standing rigging

In preparation for a 15-month circumnavigation of Australia, the *Endeavour* replica's standing rigging is being completely renewed for the first time since the ship was launched in 1993. **Anthony Longhurst**, ANMM leading hand shipwright and rigger, reveals the intricacies of traditional rigging techniques – beginning with his visit to the 17th-century ropewalk at England's Chatham Dockyard, to watch the ship's new ropes being manufactured.

The replica of James Cook's HMB *Endeavour* has sailed twice around the world since her commissioning in 1994. She has logged many additional sea miles under the Australian National Maritime Museum's management since 2005. Her rigging has been exposed to dust from a Sahara sandstorm blown out to sea, snow in Europe, hot and humid conditions in the tropics, storm-force winds and the strains of breasting huge seas. From the beginning the rig has undergone methodical maintenance, and judicious replacement of parts of it, but now the time has come to replace *Endeavour*'s entire standing rigging. For definitions see the glossary on page 11.

The original *Endeavour* carried standing rigging constructed of hemp. Hemp was widely used throughout England and Europe in the 18th century; the best came from the southern steppes of Russia. For the *Endeavour* replica's standing rigging, built and installed in the early 1990s, manila was chosen instead of hemp. Manila fibre was more readily available than hemp and was cheaper. It also has a higher natural resistance to mildew: unlike hemp, the fibres do not easily absorb and hold moisture. A synthetic rig had initially been considered, but the tendency for synthetic rope to continue stretching and thus to give inadequate support to the masts ruled it out.

Our replica's standing rigging comprises a variety of rope sizes ranging from three millimetres in diameter for small seizings, up to 104 mm diameter for the anchor cable. *Endeavour* uses ropes of three different constructions. First there is hawser-laid rope, the basic three-strand rope that is twisted right-handed, and is generally found in your hardware store or chandlery. Second there is cable-laid rope, in which three hawser-laid ropes are twisted together in a left-handed direction. Lastly, we have shroud-laid rope, a right-hand laid rope built up of four strands around a central, hawser-laid core.

A rope holds its form and gains its strength by applying opposing twists during the different stages of construction. First, the rope's constituent fibre is spun clockwise or right-handed into a yarn. The yarns are then spun in the opposite direction – anticlockwise or left-handed – to form a strand. In hawser-laid rope, the diameter of the strand is half of the finished rope's diameter, and so the quantity of yarns used in a strand varies accordingly. Three strands are then twisted together clockwise or right-handed to close the hawser-laid rope. If you then take three hawser-laid ropes and twist them together anticlockwise or left-handed, you will have a cable-laid rope.

above right: Hawser-laid rope of coir (coconut-husk fibre) at left, with a cable-laid rope of manila (right). All photographs of ropemaking and rig construction by Anthony Longhurst/ANMM unless otherwise specified.

opposite: The main items of standing rigging visible in this view of the ship's fore and main masts are the shrouds (with their ratlines or rope ladders) giving the masts lateral support, and various stays running diagonally downwards from the masts.

clockwise from above:

The rope works at Chatham Dockyard, home of the ropewalk where the *Endeavour* replica's new manila rigging was manufactured.

Manila yarn is led from spools to forming dies where it is spun into the strands that will be twisted up into finished rope.

Manila fibres enter the Number 2 spreader in the ropewalk at Chatham Dockyard before being spun into yarn.

The historic Chatham Dockyard to the east of London is the only such facility to have survived since the age of sail. Its ropewalk, quarter of a mile long, dates back to 1618

Ropes of natural fibres used to be laid up in establishments called ropewalks. In James Cook's time there were numerous Royal Navy ropewalks. The Portsmouth ropewalk was blitzed during World War II and others have closed down due to the diminishing need for large supplies of traditional rope, as synthetics and different types of manufacture, such as braid, took over. There are now few ropewalks left in the world that produce natural-fibre rope spun using the traditional methods. In February 2010 I was given the opportunity to work with the rope makers in the historic dockyard at Chatham, to the east of London – the only dockyard to have survived since the age of sail. Located within Chatham Dockyard is the ropewalk, quarter of a mile long. Rope making on the site dates back to 1618. The ropewalk is now operated by Master Rope Makers Limited, who have constructed some of the rope that is being used to build *Endeavour*'s new standing rigging.

Making our manila rope

Manila fibre is obtained from the leaves of a species of banana native to the Philippines locally known as abacá. Once the plant reaches maturity (18 months to two years), it is cut down and the long fibres are taken from the overlapping sections of the leaves where they form a false trunk. The fibres are exceptionally strong and durable and are generally 1.5–3.5 metres long. Once the fibre has been extracted from the sheaths of the leaves, it is left to dry and then packaged into 125-kg compressed bales before being shipped.

At the ropewalk, the fibre is separated and cut to lengths of no more than 1.5 metres. Any longer and the fibres would tangle and be torn during the initial combing process, while if the fibres are too short they weaken the finished rope. After being sorted, the fibre is sent though the first of six combing (hatchelling) machines. Here, the fibre is progressively combed and knit together as it is passed through progressively smaller combs. An emulsion of mineral oil, natural waxes, fatty acids and water – called batching oil – is added to help the fibre comb out easier, and as a waterproofing agent. Originally, whale oil was used. Before the introduction of hatchelling and spinning machines, the fibre was hatchelled by hand. It was drawn though steel spikes that were set into boards known as hatchelling boards. These came in a series of grades, the pins of which became progressively finer and set closer together. This ensured the fibre was straight and evenly fine before being sent to the spinner.

The spinners were regarded as the most skilled tradesmen employed in the ropewalk. The quality of their work governed the strength of the finished rope. The spinner would gather a 'streak' (a 60-pound [27.25 kg] bundle) of fibre around his waist with the ends at his back. A small loop was drawn out and attached to a hook on a spinning wheel that was operated by a young boy. The spinner walked backwards down the length of the walk uniformly feeding in the combed fibre as the yarn was spun by the revolving hook. To keep the yarn off the floor, it was placed onto stakes every 10 metres or so. An experienced spinner was capable of spinning 1,000 feet (305 metres) in 12 minutes.

Today the spinning is performed by a machine. The spinning machine used for *Endeavour*'s yarn is able to spin the yarn onto 24 spools, each containing a little over 900 metres of yarn. Each cycle takes approximately 20 minutes to produce over 20 kilometres of spun yarn.

At the ropewalk the spools of spun yarn are arranged onto a frame (bank) that enables the yarn to feed freely when being drawn out to form the strands. The required number of yarns are led from the banks, through a register plate that keeps the yarns separated and directs them into the die (a tight tube). The die controls the forming of the strands as the yarns are drawn through it and twisted by the strand-forming machine as it travels down the length of the walk. Up to three strands can be spun at once and they are drawn to a length of approximately 250 metres. The forming machine that was used for *Endeavour*'s rope is known as Maud, and dates from 1811. It is the oldest machine employed in the ropewalk.

Once the strands have been formed, they are cut and secured under tension to posts at either end of the ropewalk and left to rest for 24 hours. This allows the tension in the fibres to release and relax before the strands are twisted again and closed into rope.

For this final process, the strands are transferred to rotating hooks on machines called the 'jack' and the 'sledge'. The jack is stationary, while the sledge moves along rails. This is because the length of the strands shortens while they are being twisted for closing, thus requiring the sledge to move. The sledge has weights attached, to act as a drag and keep tension on the length of rope to prevent it from kinking.

The strands are attached to a single rotating hook on the sledge and to separate rotating hooks on the jack. A top (a conical-shaped piece of timber with grooves) is placed between the strands near the sledge. As the strands are twisted together the top moves along allowing the strands to close into rope behind it. The completed rope is coiled and weighed. A short length is cut from every batch and sent to be break-tested, to ensure that it meets the required standards.

Making *Endeavour*'s standing rigging

Of the 17 kilometres of rope ordered for the replacement of the *Endeavour* replica's standing rigging, only four and a half kilometres are made of manila. The rest is polyester. The manila makes up the main components of the standing rigging: shrouds, stays and backstays. These are the components that transfer all of the stresses and forces imposed by the sails and movement of the ship down to the hull. We use the polyester only for the seizings, servings and worming. These are components that require strength and are applied very tight, so there is very little concern about them stretching.

Endeavour's standing rigging comprises all the types of rope mentioned earlier – hawser-laid, cable-laid and shroud-laid – although not necessarily in the way you might expect from the terminology! *Endeavour*'s fore and main lower shrouds are cable-laid. All lower and topmast stays are shroud-laid. All other standing rigging is hawser-laid.

left top: As the strands are twisted together a piece of timber called a top is drawn along, allowing the strands to close into rope behind it.

left bottom: Cable-laid shroud, wormed and parcelled.

above: Cable-laid shroud, wormed and tarred.

right top: Author of this article, Anthony Longhurst, putting an eye splice into a main shroud at Sydney's Garden Island dockyard where the museum stretched, tarred and constructed *Endeavour*'s new rigging. Photographer Amy Spets/ANMM

right: Ross Pearce (left) and Ben Willoughby (right) demonstrate the use of a serving mallet.

Once our new manila rope was delivered from England, the coils of rope were opened, the required lengths were cut and the rope ends were whipped. Before construction of the rigging could commence, however, there were a number of preliminary steps of utmost importance. These steps are the foundation of the rigging's stability and survival in the years to come.

The lengths of rope were pre-stretched for a minimum of 24 hours by attaching a weight equivalent to their working-load limit, to let the fibre reach its maximum stretch and then relax and settle. Once manila has been pre-stretched, it has similar stretch characteristics to wire. Depending upon the rope's construction and how hard it has originally been laid, you can expect the stretch to be anything from 8% with hawser-laid rope to almost 15% for shroud-laid rope.

Shroud-laid ropes need a different treatment during stretching. As noted above, they are built up of four strands twisted around a core of hawser-laid rope. The core adds no strength, acting only as packing to keep the strands from falling into the void that would otherwise occur at the centre. The core stretches less than the strands around it. For shroud-laid rope to be properly stretched, the inner core needs to be broken in several places. This removes any loading from the core and lets the strands take it instead. If the core were unbroken, the strands would become loose and not sit properly after stretching, thus weakening the rope.

If the standing rigging is not sufficiently pre-stretched, it will continue stretching in operation and provide insufficient support for the masts. The stays and shrouds will need regular re-seizing around the deadeyes at their lower ends. As the rope stretches there is also a reduction in its diameter. If the rope continues to stretch on the ship, servings and seizings (integral to the strength of the rigging) will loosen. Proper pre-stretching before construction makes it easier to set up the finished rigging and ensures that all of the rigging shares the stresses equally.

The next step in the preparation is to preserve the manila rope. This is done by soaking it in raw and natural Stockholm tar, a residue left after distilling a gum that is extracted from pine and fir trees. It has been used for many centuries to preserve rigging and timber on sailing vessels. Soaking in Stockholm tar takes a minimum of 24 hours depending upon the size of the rope and the viscosity of the tar. If the weather is cold, the tar may require thinning to penetrate into the middle of the ropes. While the tar is not absorbed by the manila fibres, it coats the fibres and fills any voids between them, sealing out any moisture.

Once these preparatory measures have been completed, we can start turning the ropes into ship's rigging.

All the ropes that are to become standing rigging are stretched out firmly, but not tight, between strong posts. The centres of the eyes that sit over the mastheads are marked along with the areas that are to be served; these areas are then wormed. The lower shrouds are wormed over their full length, including portions that will not be served. This adds extra strength, but is a technique that has been subject to debate in square-rig circles due to the possibility of the worming trapping water. The *Endeavour* replica's first set of standing rigging survived with no problems in this respect; the concern probably originates from the problems encountered when using the more rot-prone hemp rigging.

After worming the rope is stretched out tight again, under loads similar to those that the rigging will encounter upon the ship. This allows us to accurately place all the required seizings at the lower ends. We have load-measuring equipment so we can apply uniform weight to the ropes throughout the construction.

The worming, already installed, pulls uniformly tight with the rope. The rope then acquires another coat of tar before a layer of parcelling is wound spirally with the lay of the rope, from the lower end up toward the eye that will fit over the masthead. The overlapping of the parcelling acts like shingles on a roof. If water were to penetrate through the serving it would run down and be shed away from the underlying rope. If the parcelling were applied the opposite way, the water would be directed into the rope and become trapped, leading to permanent dampness that will ultimately rot the rope. The parcelling then receives another coat of tar prior to the serving being applied.

The serving is then applied against the lay of the rope and in the opposite direction to the parcelling. Hence the age-old sailor's expression, 'Worm and parcel with the lay, turn and serve the other way'. Serving is applied using a serving mallet, and is wound on as tight as possible.

Once the ropes are served, the eyes are either seized or spliced into the ropes where they sit over the mastheads. *Endeavour*'s lower masts have seven shrouds on each side. Six of them are made as pairs, that is, one length of rope making two shrouds, with an eye seized in the middle to go over the masthead. The odd shroud needs to have an eye spliced in its upper end to sit over the masthead. The spliced eye is made oversize, well tarred, parcelled and served, and is then also seized to close the top of the splice. Seized eyes are preferable to splices due to the difficulties of sealing water out of the splices.

The rigging has been exposed to dust from Sahara sandstorms, snow in Europe, hot and humid conditions in the tropics, storm-force winds and the strains of breasting huge seas

clockwise from above: Main lower shroud with a fitting called a cable stocking that allows a weight to be attached for pre-stretching.

Rigger Amy Spets seizing the turn for a deadeye in the end of a stay.

The spindle eye at the upper end of a stay, parcelled ready for serving.

Lower ends of shrouds turned and seized ready for the placement of the deadeyes.

One of the reasons for building a replica is to learn about the problems that the original ship faced. Another is to keep skills from being lost to history.

Next, the lower ends of stays and shrouds are marked and are turned and seized ready for the placement of the deadeyes. In the standing rigging alone, there are almost 500 seizings and approximately 400 metres of serving. If we then add the seizings of ratlines and all the other components such as futtock staves, futtock shrouds and catharpins, the number of seizings comes closer to 1,000. If all of the blocks and components employed in the running rigging are included, this figure can easily be doubled again.

The eyes for the larger stays are constructed a little differently, so they can be replaced without housing or removing the topmasts and topgallant masts as is necessary for the replacement of the shrouds. The stays have a small eye, called a spindle eye, in the upper end. Once the eye is passed around the mast, the bitter end (tail) of the stay is passed through it and the loop is pulled up tight until the eye comes to rest on a rope bulge that is made on the stay, called a mouse.

The eye is too small to accommodate a secure splice. It is made by firstly unlaying several feet of the rope right back to its individual yarns. A round piece of timber referred to as the spindle has two bulges raised upon it with spun yarn, to act as a cradle for the yarns when they are individually taken over it and half-knotted to one another. The yarns are then tapered down and laid back along the stay. The entire spindle eye, taper and a percentage of the stay is then well tarred, parcelled and served over. The mouse is then raised upon the stay with serving and shaped roughly like a pear. This is then pointed over (a form of weaving) with smaller rope.

The lower ends of standing rigging are always seized around a deadeye or block rather than spliced. This allows adjustments to be made to the length of the rigging, if required over time, as well as maintaining the strength of the rope. A splice weakens the rope, whereas seizings do not. Where blocks or deadeyes are turned in, there is always a minimum of three seizings. They are the throat seizing (closest to the block or deadeye), middle seizing and end seizing. The end of the rope is whipped and cut off close to the end seizing, and then has a tarred canvas cap placed over it to prevent it from absorbing water.

Once the rigging is completed and placed into service upon the ship, the focus changes to full-time preservation. The number-one enemy is chafe, held at bay by the addition of leather, rope mats and additional lengths of serving. The rig requires regular retensioning until it settles in, and tarring is constant. Add to this the oiling and upkeep of nearly 700 blocks, eight kilometres of running rigging, 30 spars (masts, yards and booms) and 10,000 square feet (930 m²) of canvas that make up *Endeavour*'s sails. It is little wonder that the original *Endeavour* carried a sailing crew of 60 seamen.

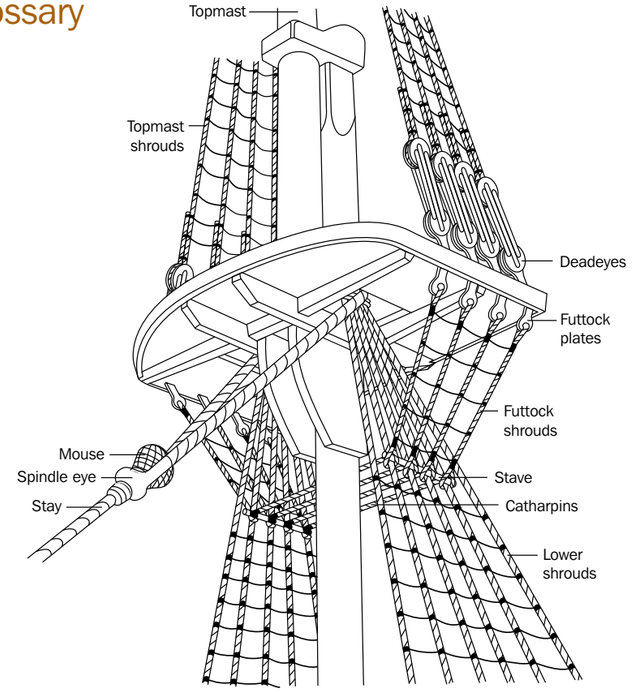
You may wonder why we bother with all this detailed work that most people will never notice, when there are stronger, longer-lasting synthetic products that could be used instead. One of the reasons for building a replica vessel is to learn about the problems that the original ship faced in its construction and components. Another is to keep skills that modern technology has superseded from being lost to history. We gain insights into the evolution of the sailing vessel, and build an appreciation for the men who built and sailed these impressive ships. ■

Author Anthony Longhurst is a leading hand, shipwright and rigger with the museum's Fleet team. His involvement with tall ships began in 1986 at age 13 and from 1995 until 2000 he sailed the world on the HM Bark *Endeavour* replica as a watch leader, shipwright, sailmaker and boatswain. Anthony's involvement with *Endeavour* continued in 2005 when she came under ANMM management.

left: The mouse, located on the upper part of a stay to position the spindle-eye, has been pointed over with small rope.

above: Futtock shrouds, staves and catharpins. Drawing after the illustration on page 230 of *The Oxford Companion to Ships and the Sea*.

Glossary



Standing rigging: Ropes that remain fixed, used to support the masts – shrouds, stays, backstays etc.

Running rigging: The ropes leading through various blocks, and to different places of the masts, yards, sails, and shrouds, which are moved according to the various operations of navigation. Running rigging includes lifts, braces, sheets, tacks, halyards, clewlines, buntlines, leechlines, bowlines, spilling lines, brails, downhauls etc.

Shrouds: A range of large ropes, extended from the mastheads to the port and starboard sides of the vessel, to support the masts laterally.

Stays: Strong ropes to support the masts forward, extending from the masthead towards the fore part of the ship. The stays are named according to their respective masts: lower stays, topmast stays, topgallant stays.

Backstays: These support the topmasts and topgallant masts from aft. They reach from the heads of the topmast and topgallant mast to the channel on each side of the ship, and assist the shrouds when strained by a press of sail.

Deadeyes: Round blocks with three holes, fitted at the ends of standing rigging. Lanyards threaded through the holes of a pair of deadeyes allow for adjusting and tensioning the rigging once it is on the ship.

Splicing: Joining one rope to another, by interweaving their ends, or uniting the end of a rope into another part of it. The eye splice forms an eye or circle at the end of a rope on itself, or round a block. The cunt splice or cut splice forms an eye in the middle of a rope. The long splice rejoins a rope or ropes intended to reeve through a block, without increasing the rope's diameter. The short splice is made by untwisting the ends of a rope, or of two ropes, and placing the strands of one between those of the other. Other specialised splices exist.

Seizing: The joining together of two ropes, or the two ends of one rope, by taking several close turns of small rope, line, or spun yarn round them.

Serving: Encircling a rope with small rope, line or spun yarn, for all or part of its length, to preserve it from being chafed.

Worming: Winding a rope close along the cuntings or contlines (the groove between the strands), to strengthen it, and make a fair surface for *parcelling* and *serving* (qv).

Parcelling: Wrapping worn canvas around ropes, to prepare them for serving.

Whipping: To encircle the end of a rope with multiple turns of thread, to prevent its unravelling.

Adapted from Steel's *Elements and Practice of Rigging and Seamanship*, 1794