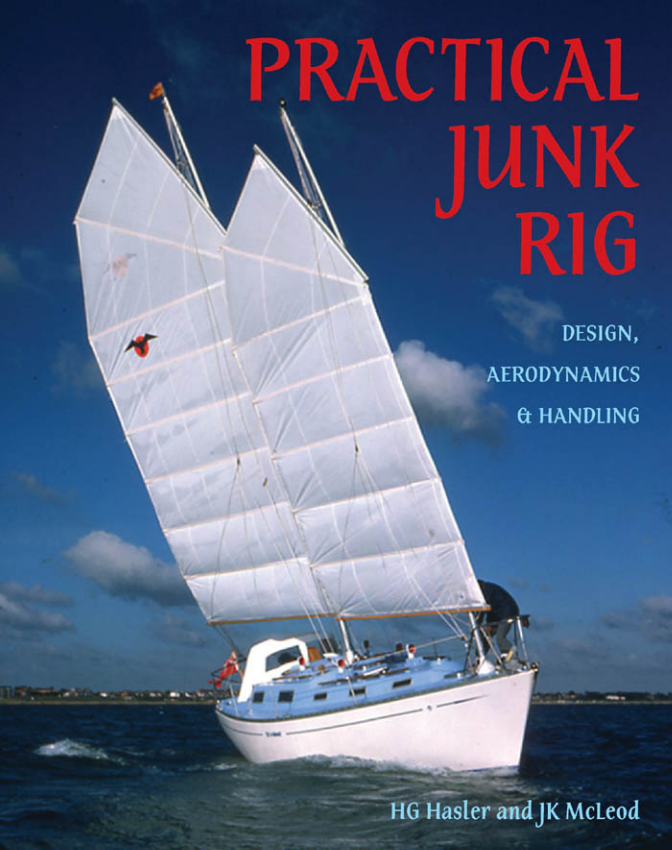
PRACTICAL JUNK RIG

DESIGN, AERODYNAMICS & HANDLING



HG Hasler and JK McLeod

HG Hasler
JK McLeod

PRACTICAL JUNK RIG

Design, Aerodynamics and Handling

ADLARD COLES
NAUTICAL

Content

APPENDICES

Foreword

Blondie Hasler died after completion of the present work but before its publication. The name Hasler is readily associated with a number of marine projects of which perhaps the most significant was the development of wind vane steering for yachts. However, it may be that his most enduring contribution will be seen to be the adaptation of the principles underlying the traditional Chinese rig to western sailing craft. He devoted his last twenty years to it.

Blondie was of course responsible for the first singlehanded transatlantic race in 1960, and shortly before it he altered the rig of his modified folkboat *Jester* from the experimental Lapwing to a single Chinese lugsail slung on an unstayed mast. The boat has used the same rig ever since on her many long voyages, which include thirteen transatlantic passages.

With his co-author Jock McLeod Blondie designed junk rigs for a number of vessels and, in addition to their own considerable experience, was able to profit by the seagoing experience of others such as Bill King whose junk-rigged *Galway Blazer II* completed a circumnavigation in 1973. This book is the result of all that work. But it is more.

There appears to be no comprehensive Chinese text on the rig and although a number of Western sources describe in detail the rigging of contemporary Chinese vessels, there is nothing that tells you how to design junk rigs or how to sail them. Neither is there any work on the geometry and aerodynamic theory that lie behind them. *Practical Junk Rig* admirably fills that need. It is both a handbook for the mariner and a work of reference for anyone who wants to study in detail this most appealing and seamanlike of rigs.

Michael Richey
Yacht Jester
Plymouth

Preface to the Hardback Edition

Sail enthusiasts all over the world are showing an increasing interest in the Chinese, or 'junk', rig. This is because the rig is incomparably safe, seamanlike, and easy to handle. It is particularly suitable for small boats and for short-handed or family sailing, in open water and in unpredictable weather conditions.

This book is intended to provide a primer for those who want to study the rig in detail. It describes the process of designing a rig for any specific boat, rigging it, and sailing it. It is written equally for the amateur owner and for the professional designer who may be approaching the subject for the first time.

The authors' qualifications are simply that we have worked together on the development of the Chinese rig for 25 years, using it on our own boats and designing rigs for other yachtsmen in various parts of the world. Between us we have sailed at least 65,000 miles of open sea with it, including ten crossings of the North Atlantic. The more we sail with it the more we like it, and this is true both on ocean passages and when cruising in coastal waters.

Our most distinguished client is undoubtedly Bill King, whose 42 ft (12.8m) *Galway Blazer II* (pg 215 and Fig 16.3) carried him across 40,000 miles of ocean singlehanded before he sold her to Peter Crowther for further voyaging. We believe that she may have been the first junk-rigged vessel in history to have sailed round the world or round the Horn.

We are not experts on the vessels of the China coast, nor in the history of the rig, but hope that some of the references in the Bibliography will help readers whose interest lies in that direction. Inevitably this list is incomplete, as is our knowledge of the work done by other Western designers.

The adaptation of this ancient rig to modern needs is still in an early stage, but we have tried to provide a starting point from which other enthusiasts will make further headway. We hope they enjoy working with the rig as much as we do.

We would like to take this opportunity to express our thanks to those who have provided advice and information from their own experiences or specialist knowledge. The most important of these is Michael Richey, the present owner of *Jester* and the editor of a number of publications. His ability as an author and his experience and knowledge of publishing with his helpful criticism and advice have been invaluable to us. We would also like to include Peter Lucas of W G Lucas and Son, sailmakers; R Mason of R Mason and Son, the patentees of the 'Noble Mast' system; and David Hunt of Needlespar Ltd, Warsash; for their specialist advice and comments.

We also wish to thank Rear Admiral R L Fisher, the original owner of Yeong, Commander Bill King (*Galway Blazer II*), and Timothy Dunn of *Batwing*, for permission to use drawings and to mention their experiences. There are also other friends and acquaintances who have helped, encouraged or stimulated thought, and we extend our thanks to them too.

HGH, JKM 1987

Preface
to the Paperback Edition

In our original Preface we stated that the adaptation of this rig to modern needs was still in an early stage but that we hoped our book would provide a starting point from which other enthusiasts would make further headway. It is very pleasing to be able to say that this has certainly occurred, and that not only is the junk rig in use all over the world with designs produced from the advice in our book, but it is also used by enthusiasts who have developed their own ideas by experiment and trial.

It is probably true to say that most of these successful developments have produced slightly more complication into the rig to achieve the result that the experimenters required. Blondie Hasler and I were at pains to keep our design as simple as possible, and in some aspects this restricted us, but that was our choice.

One case in point was our decision to have all the battens in one sail the same length. This restricts the almost infinite choice of sail shape as used by the Chinese and some modern designers, but it enables users to carry a few spare battens that will fit in any panel of the sail without modification; a very important consideration when faced with replacing a batten in wild weather and seas. However with the progress of new materials and design it can be argued that much stronger battens can be devised than those suggested by us, but probably at greater expense. Further experiments have also been carried out with articulated battens that can produce a more aerodynamic shaped sail, closer to the curvature of a bermudian sail. This can entail some complication and expense in manufacture but has produced results that please the designers who claim that it improves the closewindedness of their rig.

There is no room in this reprint to cover all the new ideas that have developed since 1987 but there are some excellent sources of information for those who wish to consider alternative ideas to those in this book, which is really a primer on the subject to provide a sound starting point.

The best source of information is the Junk Rig Association (JRA), which has members around the world, many of whom are active in development of the rig, and I am most grateful to the current Chairman and Secretary for kindly producing an update for this new edition (Appendix C) giving a brief account of the progress that many members have made after trial and experiment, and giving other sources of information and advice.

JKM
2004

PART I

THE CHINESE RIG

*A large Chinese Junk running goosewinged. Note the huge mainsail and the different balance of the sails and their design. (*Photo: South China Morning Post Ltd*)*

Introduction

The first Chinese lugsails, made of matting woven from thin strips of bamboo and stiffened by bamboo or pine battens, are believed to have appeared in China before AD 300. By 1430 the seagoing junks of the Ming dynasty seem to have been substantially larger than any ships of the Western world and to have voyaged in huge fleets at least as far as the Red Sea and East Africa.

The great junks of this time may have reached 500 ft (152 m) in overall length, which is far larger than any seen since and nearly twice as long as the *Cutty Sark*, but by the 16th century the Ming navy had all but vanished, a victim of political change. This left only the smaller coasters and river traders that have continued to develop in design, but not in size, into the 20th century. These include junks of 180 ft (55 m) in length with anything up to five masts, some of them over 6 ft (1.8 m) in diameter at the deck and carrying sails of over 3,000 sq ft (279 m^2).

From Marco Polo onwards, Western observers on the China coast have become fascinated by junks in their endless variety of size and type, and have praised their efficiency as practical sailing craft while struggling to understand the thinking of Chinese shipwrights and sailors, which seemed so often to be the exact opposite of their own.

The junk rig is not a square rig but was one of the earliest of the true fore-and-aft rigs, that is to say rigs in which the wind blows against opposite sides of the sail on opposite tacks. For centuries it may have been the most efficient windward rig in the world, particularly in hard winds when the flat sail develops good drive while inducing minimum leeway.

The windward ability of Western rigs has been transformed in fairly recent times by the development of high-quality sailcloth and sophisticated sailmaking. Previously, all large Western sails tended to develop too much 'belly' for windward work, and seamen were continually trying to make them set flatter. The junk sail can be made to set very flat in all wind strengths regardless of whether it is made of good sailcloth, bamboo matting, or indeed old flour sacks.

Comparisons between rigs are difficult to make, particularly when mounted on different hulls, but nowadays the windward performance of a good junk rig seems to be comparable with that of a gaff rig – perhaps less good in light airs but better in a blow. Its worst point of sailing is ghosting to windward in a lop or swell. Off the wind, the sail is excellent for its area in all wind strengths. The

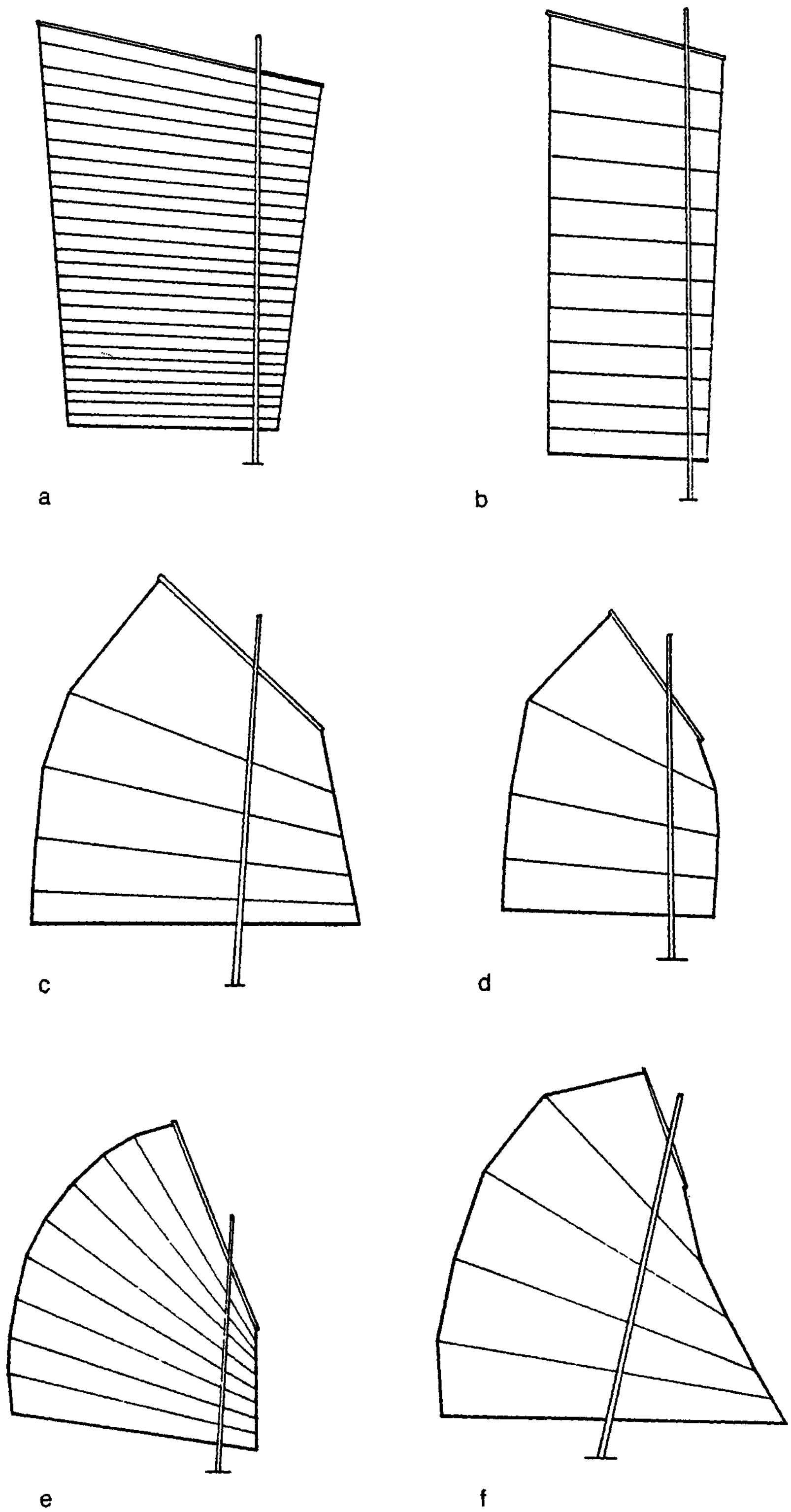


Fig. 1.1 Some sail shapes seen in China

ability to square the whole sail off at right angles to the boat is a considerable bonus. Conventional spinnakers are not efficient for their area; they are just an efficient way of setting a lot more area.

There is no standard type of sail in China, and every conceivable variation seems to exist. Fig. 1.1 shows some of the sail shapes recorded there in the past fifty years. The square-headed sail a seems to be the ancient shape and is still widely used, particularly on inland waters in the high-aspect-ratio form shown at b. The remaining sketches show forms in which the head is more steeply angled, that shown at f, which is the foresail of a three-master, having a head that is actually in line with the luff.

It will be seen that the number of battens, and hence the width of the sail panels, varies very considerably. It seems possible that the mat sails used in the past demanded narrow panels, a large number of battens, and square heads. The introduction of cotton sailcloth has probably contributed to the development of high-peaked sails with fewer battens and wider panels.

All native Chinese rigs share a number of features. They are constructed of cheap and readily available materials, with very few metal parts. The subdivision of the sail into a number of separate panels, each supported and controlled by its own system of sheets, battens, bolt ropes, and parrels, ensures that the stresses are shared between many load-carrying components and that no one part takes a heavy load except for the mast and halyard. Even on the mast, the lateral loads are distributed along it by the battens and parrels and not concentrated at the masthead as they are with the dipping lugsail favoured by British fishing boats in the last days of sail. The loads on sailcloth and sheets are vastly less than with the Western rig, and it is difficult to think of any other rig in which a huge seagoing sail could be made of bamboo matting and yet be able to sail through a gale without damage. In many ways it is valid to think of the junk sail as being a number of much smaller sails joined together.

The rig can be used on boats of widely different sizes and functions. A dinghy of 8 ft (2.4 m) overall length has given good service as a yacht's tender with a simplified and portable junk sail of 49 sq ft (4.6 m^2). At the other end of the scale it would clearly be possible to emulate the Chinese with junk-rigged cargo-carrying coasters. The upper limit of size is imposed by the fact that all halyard loads must be carried by the masthead and cannot be distributed lower down the mast. An area of about 3,000 sq ft (279 m^2) for a single sail would seem to be near the practical limit.

The 'twist' of a sail is defined as the variation in its incidence to the wind, taken at different heights above the deck. The junk sail commonly shows little or no twist whereas Western rigs, particularly the gaff rig, often develop far too much twist in a hard breeze, with the foot sheeted too flat and the head sagging too far off. Fig. 1.2 illustrates this difference as seen from the lee quarter.

The aerodynamicist may argue that a certain amount of twist is needed for efficiency when close-hauled with a tall sail, because the wind velocity increases with height. The Chinese sail and its sheeting system may be designed to give any such small amount of

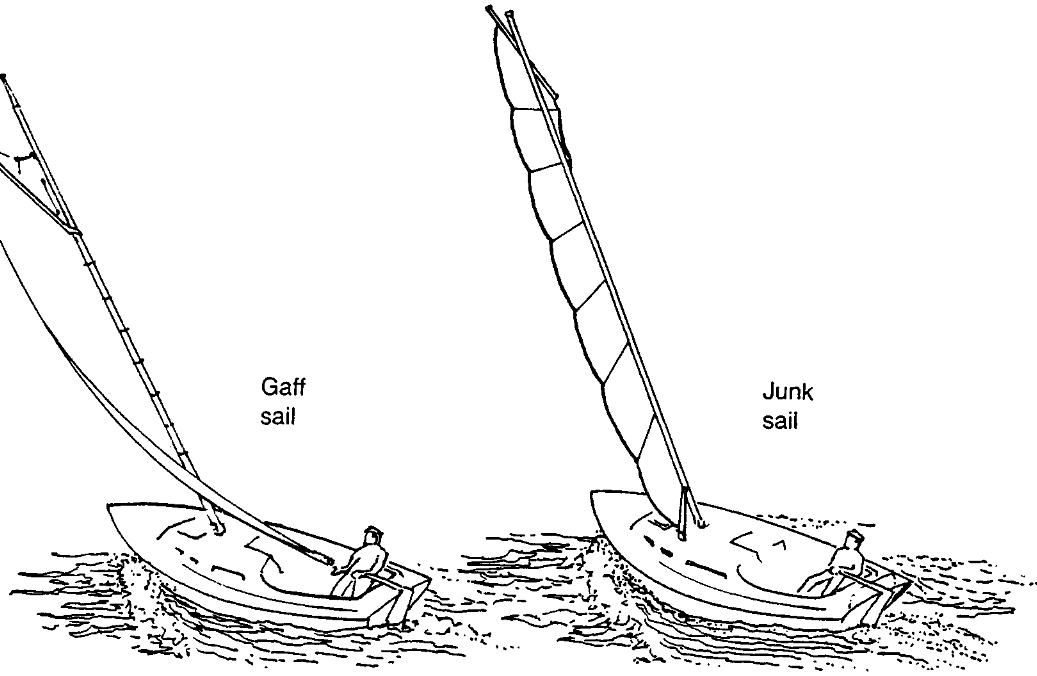


Fig. 1.2 Twist

twist as may be required.

The hulls of many Chinese workboats have very little lateral resistance, and there is evidence that such hulls can get to windward better with the Chinese than with a Western rig. Joshua Slocum chose a three-masted junk rig for the 35 ft (11 m) canoe *Liberdade* which he built for himself after the wreck of the barque *Aquidneck*, and in which he and his family sailed 5,500 miles from Brazil to South Carolina in 1888, averaging 105 miles a day. He wrote: 'Her rig was the Chinese *sampan* style, which is, I consider, the most convenient boat rig in the whole world.'

The mainsail of a large Chinese junk may weigh five tons, with a yard over 65 ft (20 m) long and two or more separate halyards. It can take the whole crew over an hour to hoist such a sail, but reefing and furling is a matter of seconds and the rig is almost squall-proof. Unlike other rigs, the junk sail *wants* to reef and furl itself, and will do so as soon as it is given the opportunity.

The battens hold the sail stretched from luff to leech at all times so that it cannot thrash or flog when head to wind with a slack sheet, but will 'weathercock' quietly, even in a gale, by just swinging gently from side to side. The flogging of a soft sail is unnerving, noisy, and a quick way of wearing out sailcloth and stitching. In a conventional rig with a fresh breeze it happens every time you hoist sail, every time you tack, and every time you luff up to a mooring or a man overboard. It altogether inhibits the useful and safe operation of hulling with slack sheets, something that is second nature to the docile junk rig.

Two lesser degrees of sail shaking may be defined: 'flapping', in which only a part of the sail oscillates rhythmically (for example, a flapping leech on a conventional sail), and 'fluttering', in which small oscillations are confined to a very small area of sail. Flapping is seldom experienced in the junk rig, and should be cured by a sailmaker. Fluttering may sometimes be found near the luff or leech, and also in the loose folds of cloth lying in the lifts when reefed or furled. Narrow sail panels are the best insurance against an untidy bundle that flutters.

When a Chinese sail becomes torn or lets go a seam, the damage remains localised and the repair may be postponed indefinitely. The Western observer, laughing at the sight of a junk with her sails full of holes, may overlook the fact that she is working briskly to windward through a crowded anchorage.

In the past, Western seamen have used the junk rig in three different ways:

(a) by using genuine Chinese rigs, designed and built in the East, on either Chinese or Western hulls;
(b) by devising hybrid rigs, which combine certain features of the junk rig with other major features not found in China;
(c) by using rigs that are Chinese in all major characteristics, but which have been designed and built in the West to suit Western requirements.

Of these, group (a) is beyond the scope of this book. In group (b) many experimenters are still at work, mainly in the development of battened fabric aerofoils embracing the mast. Here the main problems seem to be complexity of batten construction, lack of 'topsail' area for light going, and reluctance of the sail to furl itself neatly. None of these 'improvements' has yet proved superior to the standard junk sail for serious ocean cruising, whether up or down wind. In this book we concentrate on group (c), in which the recommended rigs have already proved themselves to be fully seaworthy and widely acceptable.

In general, we are dealing with fully-rigged sailing vessels, i.e. vessels in which sail provides the main means of propulsion or has at least an equal importance with the power unit, but the junk sail has also proved effective as an auxiliary sail for fully-powered vessels. In this role the apparent complexity of gear can be more than offset by its freedom from flogging, its self-stowing facility, and the possibility of handling all running ropes from inside the wheelhouse. One such user also found that the inertia effect of the cantilever mast slowed down the boat's period of roll, even with no sail set, to such an extent that he was able to remove his bilge keels and thereby get an extra half-knot under power.

The requirements of Western seamen are different from those of the Chinese in a number of ways. Commercial sail is almost extinct, or at least dormant, in the West, and the demand so far has been for yachts. Many Western yachtsmen now want to make long open-sea passages in very small boats, an ambition that has never been evident in China. Many also want to sail singlehanded, or with a weak crew of family or friends that may not include any other competent seamen. The advent of wind-vane steering gear has made it possible for these short-handed boats to make long passages efficiently, provided that the rig can be easily handled. The junk rig offers this ease of handling, together with safety and sailing efficiency, with the help of some fresh development work that started in Britain in 1960 and is still continuing.

In recent years there has been a movement, started in the United States, to develop other forms of easily-handled cruising rigs set on unstayed masts. Gary Hoyt's original Freedom rig uses wrap-around jib-headed sails spread by wishbone booms, and there have been many later variations on this idea. These rigs demonstrate that cruising yachtsmen are willing to turn away from the labour-intensive rig of conventional ocean-racers and to accept the idea of unstayed masts. The rigs themselves have not so far been able to compete with the main handling virtues of the junk rig, namely freedom from flogging, absence of concentrated stresses, and instantaneous reefing right down to bare poles. Similar objections apply to various modern developments of roller headsails and roller mainsails on stayed masts.

Chinese vessels commonly carry large crews and have ample decks protected by bulwarks. There is no requirement for short-handed sailing and the crew is prepared to do a lot of 'fiddling' with the rig. For example, many Chinese sheet systems must be flipped round the leech when tacking or gybing. The lower sheet block sometimes has a rope tail that is belayed to the weather rail and has to be changed over when tacking or gybing. Sheet hauling spans are often used, and have to be readjusted when reefing or furling. The first reef is often taken upwards, by heaving in on the topping-lifts. By accepting this kind of deck work the Chinese are able to use a wide variety of sail shapes and layouts.

As developed in Britain, the rig is fully automatic in that all sail handling is done simply by veering or hauling ropes from a single position, and without ever touching the sail itself. Tacking and gybing are performed simply by steering the boat round on to the new course, without touching the sheets. Gybing is noticeably gentler than with a gaff or Bermudian sail. Unlike a conventional spinnaker, the junk sail will never induce rhythmic rolling on a run. A junk-rigged yacht of 50 ft (15 m) in length never demands more than a single watchkeeper for any sailing operation, including tacking, gybing, reefing, furling, and making sail. When furled the sail remains ready for use, and never has to be unbent or stowed below. For fishing and workboats the rig is unrivalled, being docile and controllable when set but held well above the deck while reefing or when furled.

An aesthetic attraction of the rig for many sailors lies in its use of seamanlike cordage and traditional fittings. Whereas with a normal Western rig traditional gear is less efficient than modern gear, with the junk rig it is more efficient and the traditionalist need make no excuses for using it. All the hauling ropes may be led to the steering position and there will be no need for the watchkeeper to move around the deck – a valuable safety feature in a small boat at sea, especially when a gale blows up in the middle of the night.

A number of notable ocean passages with junk rig have been made singlehanded by severely disabled yachtsmen who could not possibly have coped with a conventional rig. Almost any squall can be ridden out in peace by letting go the sheet and lying a-hull. It is quite difficult for the sail to get itself into a real mess. The ends of all running ropes may be secured to the ship, and if you let go everything within sight the sail furls itself without smothering the deck in loose canvas. The smaller the boat the more demanding the deck work in bad weather at sea, and the greater the advantage of the junk rig.

In *Jester* (Fig. 16.1) the watchkeeper is protected from rain and spray. In *Ròn Glas* (Fig. 16.4) the system of protection goes further, in that all running ropes are led inside the doghouse so that the whole rig can be handled without wearing oilskins. Protection of this sort is seamanlike, since it eliminates the physical exposure that is one of the most potent sources of exhaustion.

The area of a junk sail may be kept constantly adjusted to changing conditions without imposing any real strain on the crew. It is not necessary to worry about what the weather is going to do, but only about what it is actually doing. It is often convenient to use reefing as a way of 'easing the throttle', slowing down temporarily for reasons of comfort or safety, or for better control in narrow channels.

By making the sail more controllable the junk rig is improving the capabilities of small cruising yachts and setting new standards for short-handed seamanship. In demanding a fully-automatic sail the Western designer accepts more restrictions on the shape of the sail than his Chinese counterpart, but his work remains wholly based on 1,700 years of continuous development in China.

1 The Rig

The word 'rig' is used for the whole assembly of sails, masts, spars, fittings and cordage as used on any one boat. Only one junk sail is carried on each mast, but the number of masts may be varied. In any one rig the sails may be of different sizes and shapes, but each sail will be rigged in substantially the same way, as described in the following pages. A few junk-rigged boats set lightweight unbattened ghosting sails in light airs, but these are not part of the working rig and will not be discussed until Chapter 5.

It is convenient to establish Western names for the various different arrangements of the rig, and Fig. 1.3 shows the names adopted for this book. This seems to cover all the variations likely to be used in the West, but anyone wishing to use four or more masts could extend the nomenclature for himself. So far the majority of Western rigs have been single-masted, and most of the rest have been two-masted schooners with the mainsail about twice the size of the foresail. The considerations that affect the choice of rig are discussed on p 94.

The junk sail may be described as a fully-battened balanced lugsail. Fig. 1.4 shows its essential features and the names of its parts.

The sail is spread between a yard and a boom and is stiffened by a number of full-length battens that divide the sail into panels. The battens are attached to the sail along most of their length as well as at either end, and are numbered upwards as shown. The yard is hoisted by a halyard leading from the masthead.

The sail remains always on the same side of the mast, and when sailing is therefore sometimes to windward and sometimes to leeward of it. A proportion of the sail, varying between 5 and 30 per cent of its area, lies forward of the mast, and this percentage is known as the 'balance'. Balance may also be measured in linear terms: e.g. a batten may have 10 per cent of its *length* forward of the mast.

The sail is sheeted by a system of ropes that pull on the after ends of all, or nearly all, the battens. Normal single sheets are shown, in which a single system is attached to the leech and controls the sail on either tack. The alternative, but rarely used, double sheets will be considered in Chapter 4. We use the word 'sheet' for the running part, and 'sheet spans' for the standing parts attached to the battens. Many Chinese and some Western variations interpose adjustable spans (not shown) between sheet and sheet spans, and we call these 'sheet hauling spans'.

When on a broad reach or run the sheets are paid out until the sail is square to the boat.

A system of topping-lifts, or lazy-jacks, leads from the masthead down one side of the sail and passes through eyes on the underside of the boom to a similar system on the other side of the sail. These lifts are slack when under full sail, but as soon as the sail is lowered for reefing or furling they automatically go taut and gather the furled panels into a bundle. The forward end of the bundle is supported by a 'mast lift' that leads from the masthead down the outside of the sail and finishes in a loose loop around the mast, holding the bundle in against the mast.

Each batten is held close to the mast by a batten parrel which permits it to slide freely up or down the mast.

Various secondary ropes, commonly used, are not shown here but will be described in Chapters 2 and 3.

In this simple form of the sail, reefing is achieved by paying out the halyard until one or more of the lowest panels of the sail have stowed themselves in the topping-lifts. As soon as the halyard is started the pressure on the sail is relieved because the sheet goes slack. After the halyard is belayed the slack sheet is taken in until the sail is correctly trimmed. Fig. 1.5 shows the same sail reefed down to two panels. It will be seen that the sheet spans hold the leech of the sail, including the furled part, down, and it is not normally necessary to pass any lashings, pendants, or reef points to hold it down.

If the remainder of the halyard is paid out the sail will furl itself into the lifts and the sheets may be set up to hold the furled bundle fore-and-aft.

Making sail, or shaking out reefs, is done by letting go the sheet, preferably until the sail is weathercocking, then hoisting on the halyard until the required amount of sail is spread. The slack of the sheet may then be taken in to trim the sail.

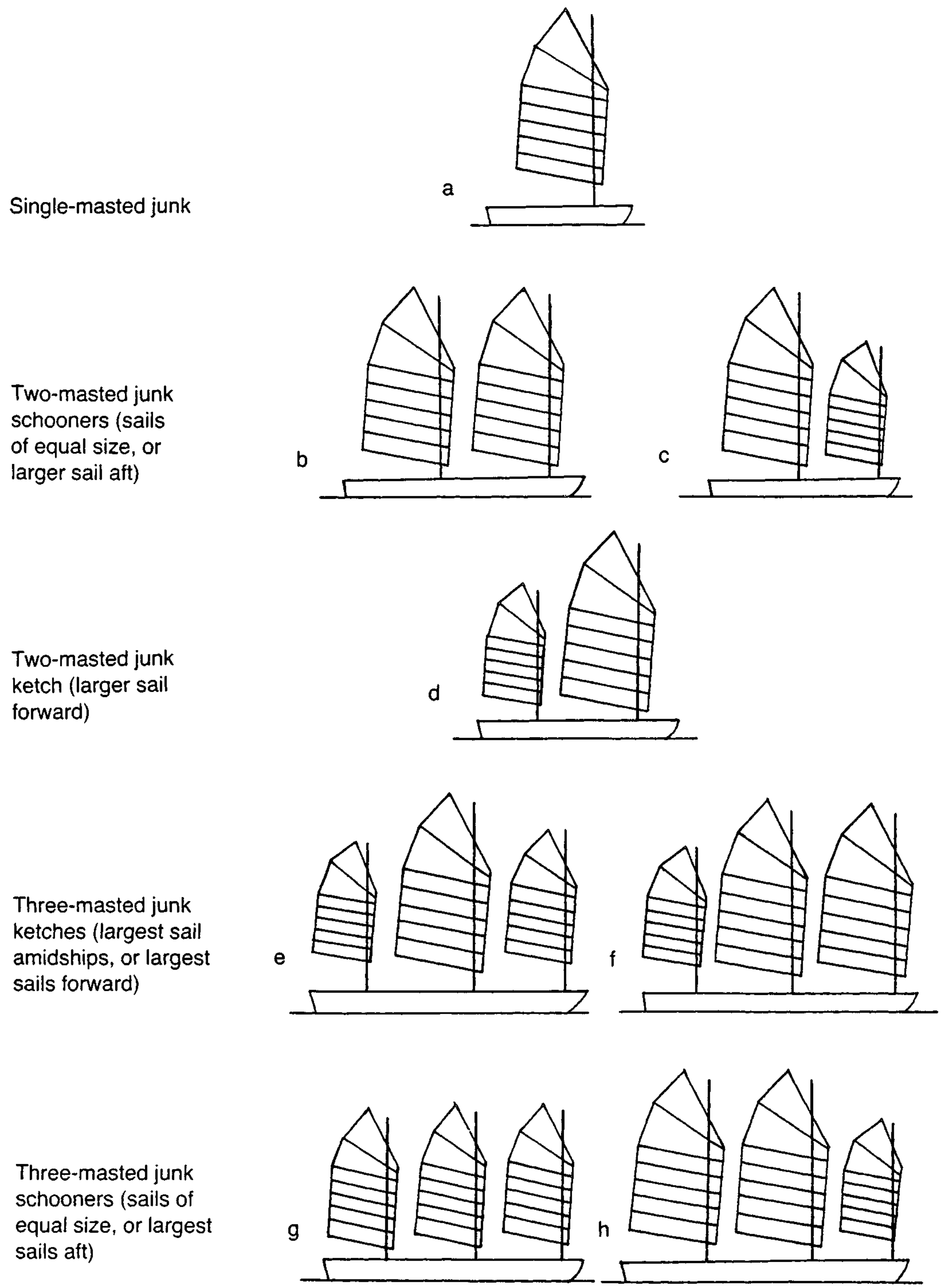


Fig. 1.3 Rig arrangements

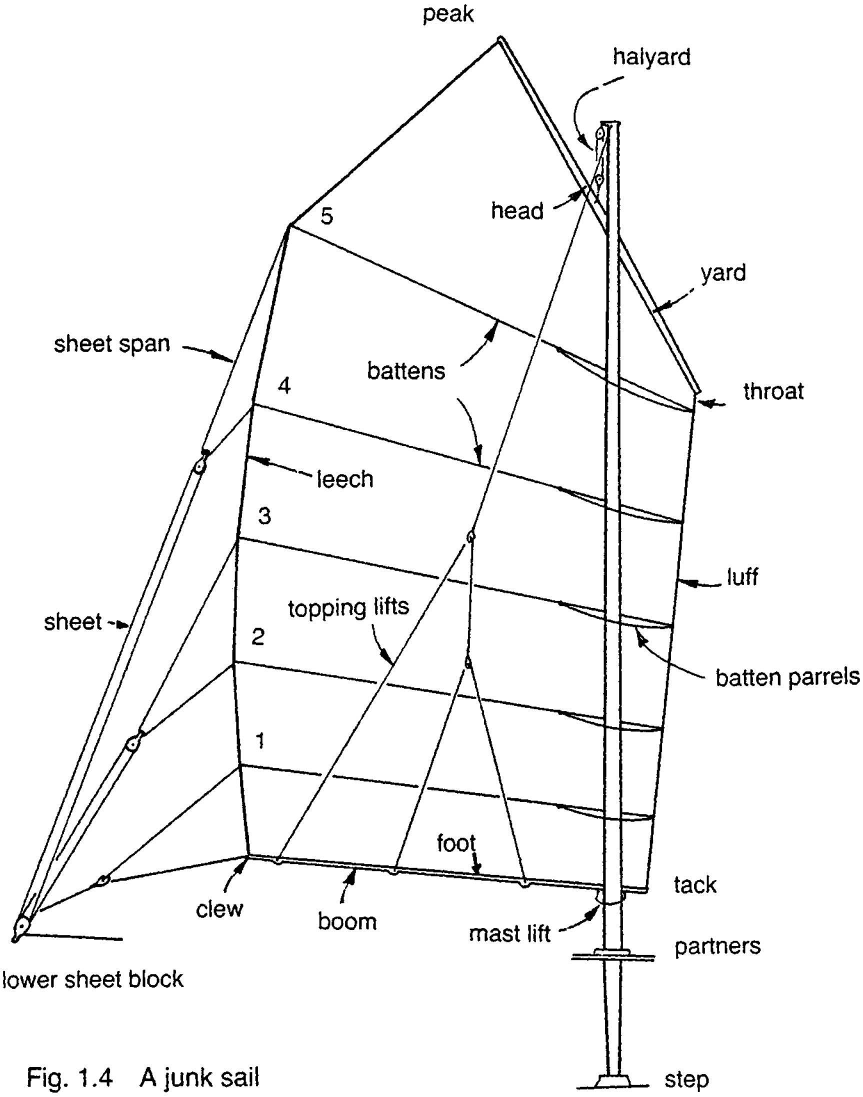


Fig. 1.4 A junk sail

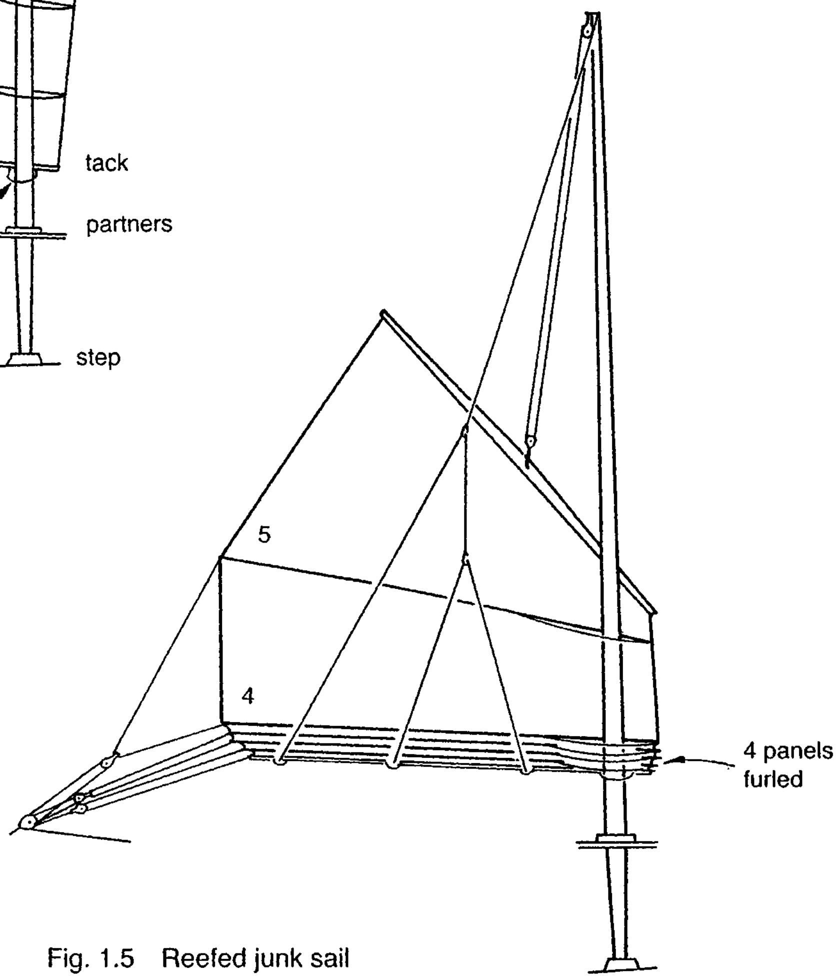


Fig. 1.5 Reefed junk sail

Although simple in concept, the geometry of the rig is fairly subtle, as discussed in Chapter 2, and imposes a number of limitations on the shape and battening of the sail if it is to reef and furl neatly.

The Mast

In China, this sail has usually in the past been carried on an unstayed (cantilever) mast, even in very large ocean-going junks. Such a mast stands up like a tree and bends like a tree under load, being stepped on the keelson and supported at the partners. There should be nothing in this to alarm the Western seaman, since many sizeable working vessels on both sides of the Atlantic were rigged with unstayed masts in the days of sail. For example, the Scottish Fifies and Zulus carried their huge dipping lugs, sometimes of 1,600 sq ft (149 m^2), on masts that were innocent of any standing rigging.

An unstayed mast naturally needs to be strongly connected to the hull at the partners and step, but the stresses transmitted to the hull are much lighter than those imposed by standing rigging, and much less likely to strain the hull.

In recent years some Chinese vessels have fitted shrouds to the masthead, perhaps in imitation of Western practice, and some Western users of the junk rig have done likewise. The disadvantages of using shrouds are:

1. On a run or broad reach the sail chafes against them.
2. The sail cannot be squared fully off at right angles to the hull. Weathercocking is restricted and running becomes less efficient and more prone to accidental gybes.
3. Since it is impossible to use lower shrouds, or to fit effective spreaders, the angle between shroud and mast is nearly always too small, giving poor lateral support, heavy shroud tensions, and severe compression loads that may actually break the mast instead of supporting it. It is considered that 15° is the minimum permissible angle between a masthead shroud and the mast, and this can seldom be achieved without spreaders on a mono-hulled boat, although possible with a multi-hull.

The authors have always used unstayed masts on all types of hull, and these have proved fully seaworthy if correctly designed and built. *Jester*'s original unstayed mast, of glued hollow spruce, survived 33 years of annual cruising and Atlantic crossings before it broke during a capsize in a storm at the end of her thirteenth crossing.

Unstayed masts cannot be used to carry conventional headsails or spinnakers except in the lightest of weather, as discussed in Chapter 5. Junk rigs carry one sail only on each mast. There is no sail changing, but only reefing and furling of this sail.

Junk sails may be designed to lie either on the port or starboard side of the mast, and both may be found in China, with some multi-masted junks setting some of their sails on one side and some on the other. There is no clear-cut difference in efficiency between sailing with the sail to windward or to leeward of the mast, and different users form different opinions. This is of course quite different from the soft Western lug, which performs much better when to leeward of the mast. The battens of a junk sail lie between the sail and the mast, and tend to hold the sail off the mast when on the windward side.

All the sails in this book are designed to lie on the port side of the mast for a practical reason: if anything should go wrong aloft it is then convenient to heave-to on the starboard tack, with right of way over other sailing vessels and with all the parrels and most of the other ropes on the windward side. This makes it easier to see what is wrong, and if necessary to get aloft and attend to the trouble. In this book it will be assumed, for convenience in description, that all Chinese sails are set on the port side of the mast.

Battens

The bending (arching) of the battens plays a vital part in the boat's performance and also affects her steering. From an aerodynamic point of view, with the wind on or forward of the beam the battens should be well arched in ghosting weather and should get progressively flatter as the wind speed increases. This is the exact opposite of the natural behaviour of battens, and we have as yet no way of achieving it. It is possible to make ingenious suggestions for compound or fabricated battens which incorporate some positive means of controlling the arching to suit the aerodynamic requirements, but none of these has yet looked like meeting the practical need for a batten that is very strong, light, unbreakable, and cheap. We are therefore stuck with battens that do the opposite of what we want, giving a flat sail in ghosting weather and a well-arched sail in a hard breeze. It is important that battens should not bend too much, particularly when close-hauled or reaching, since this gives less drive, more lateral force inducing heeling and leeway, and more weather helm. It has been found that fitting stiffer battens will reduce weather helm.

Luckily, as soon as the sail is reefed the topping lifts go taut and the sail leans against the leeward lifts, which then help to prevent the battens from bending too far. Battens are therefore designed to reach their maximum bend when running before the wind in a hard puff under full sail.

A batten acts partly as a beam and partly as a strut, having to deal with bending loads and longitudinal compression. The bending loads are caused by the wind

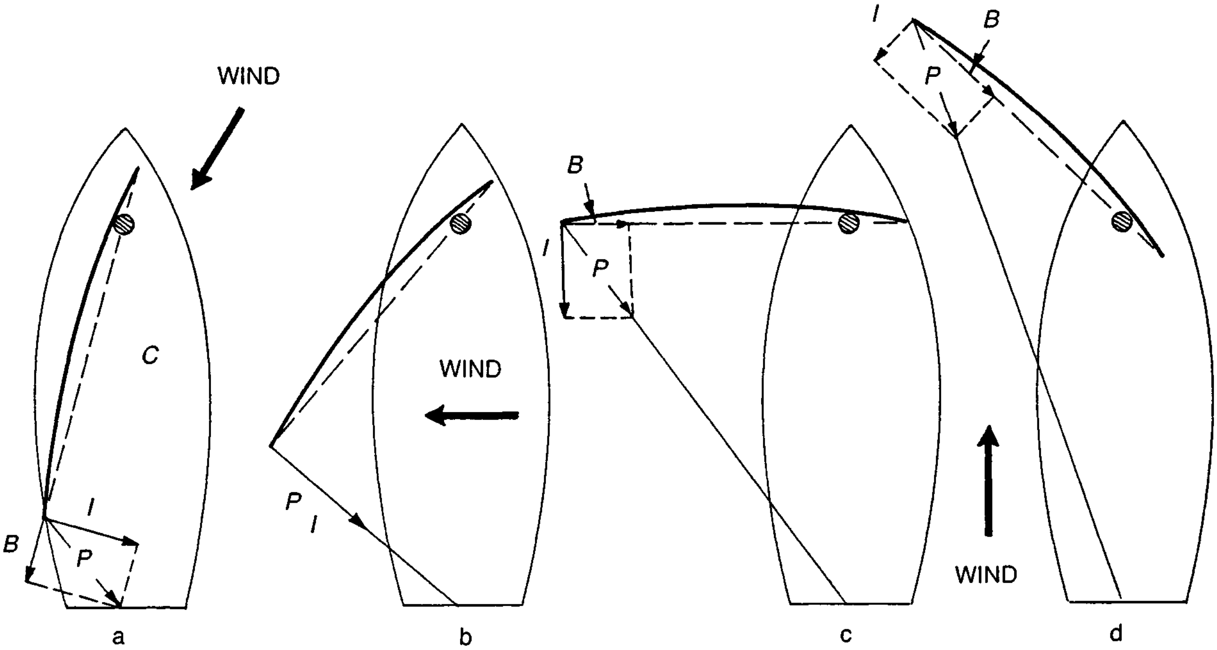


Fig. 1.6 Compression of battens

pressing the batten to leeward. The compression loads are more complex, and arise from a number of sources.

Viewed from above (Fig. 1.6), the sheet parts exert a pull *P* which may be resolved into a force *I* controlling the incidence of the sail by acting at 90° to its chord *C*, and a force *B* in line with the chord of the sail. Force *B* is trying to stretch and straighten the battens if it points away from the mast, or to compress and bend the battens if it points towards the mast. With the sheet anchorage well abaft the leech of the sail, situation a shows that the sheets are trying to straighten the battens when close-hauled. On a reach b, *P* and *I* may coincide so that there is no force *B*. In c the sail is squared off for a run and the pull of the sheets is increasing the compression of the battens. The final attitude d shows a situation that should never be allowed to develop; with the wind astern the sheets have been paid out until the leech of the sail is well forward of the mast, developing a very heavy compression *B* on the battens while the drive of the sail makes the boat heel to starboard.

In the above paragraph force *P* is the horizontal component of the pull of the sheet. There is also a vertical component acting downwards, but this is not relevant to the present discussion. The downward pull is transmitted through the leech to the yard, and thence to the halyard.

The attitude c shows why, in smooth water, the most severe batten-bending occurs when running hard-pressed under full sail, but (as with the mast) it is the snatch loadings induced by steep waves and swell that may momentarily produce heavy additional loads, and these may arise on any point of sailing. Even if the waves are running true to the wind, the wash of a passing ship may hit you straight on the nose.

The battens must be strong and stiff enough to withstand such accumulative loading, and this inevitably means that the sail will set very flat in light airs. The sails in China seem to do the same, giving a rig that reaches its full efficiency in a hard breeze, the harder the better.

Another source of batten compression is leech tension, but only if the leech changes direction at that batten. In Fig. 1.7, the leech at A is exerting no compression, whereas that at B is. Any unsheeted battens, such as the top battens on many sails, take less bending load than a sheeted batten but throw additional loads on to their neighbours. When close-reefed in a gale, however, unsheeted top battens may tend to bend the wrong way when off the wind. Fig. 1.8 shows such a batten supported in its middle by the topping-lifts but bent to leeward at its leech end. This may be described as 'S-bending'. A similar effect could be induced by double sheets (see p 72), if these sheets were attached to the battens at points well forward of the leech.

S-bending may also be detectable at the luff of the sail if there is a large amount of balance forward of the mast.

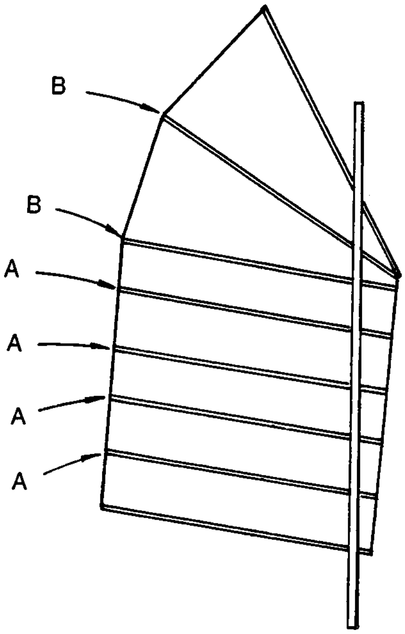


Fig. 1.7 Leech tension

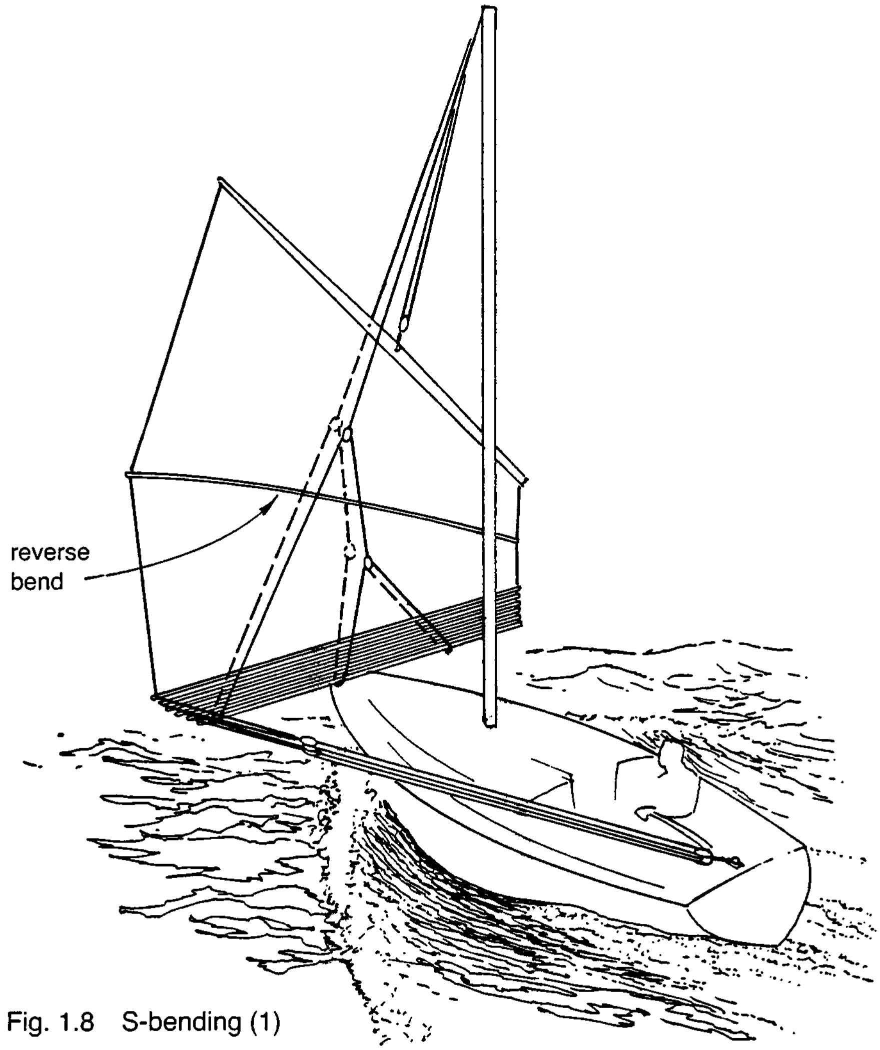


Fig. 1.8 S-bending (1)

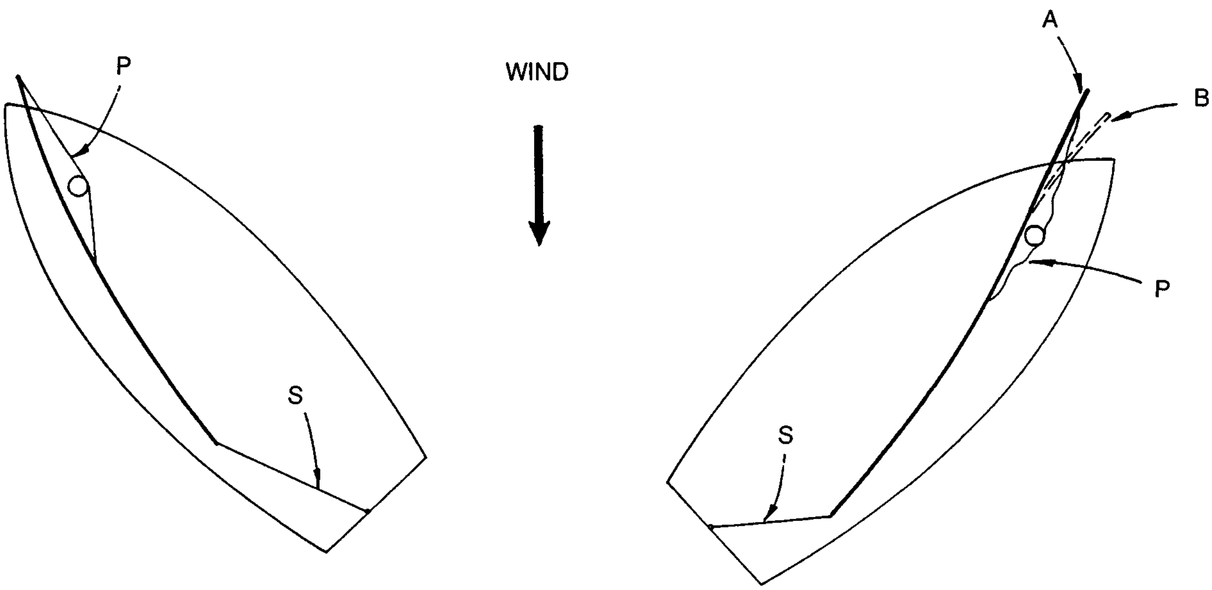


Fig. 1.9 shows one batten of such a sail with its curvature exaggerated. On the starboard tack it hangs clear of the mast on a taut batten parrel P and the sheet S, and will take up a fair continuous curve. On the port tack the batten presses against the mast and the batten parrel is slack. There is no external force capable of curving the forward end of the batten to windward. Normally, with stiff battens and a moderate amount of balance, the forward end of the batten will appear to be straight, as at A, but with a soft batten and/or too much balance it can show an S-bend as at B. Quite apart from any aerodynamic objections, S-bending when close-hauled is undesirable because the sail becomes unstable and the boat will no longer carry a steady amount of helm. If she luffs a little the batten snaps back to line A and the luff of the sail is relieved of wind pressure, whereupon the boat develops more weather helm and tries to luff further. If she is made to pay off again, the batten snaps back to line B and the luff of the sail catches more wind, whereupon she loses weather helm and tries to pay off further. This can be even more perplexing to a vane steering gear than it is to a human helmsman, but luckily no S-bending is normally detectable in rigs designed to the guidelines laid down in this book.

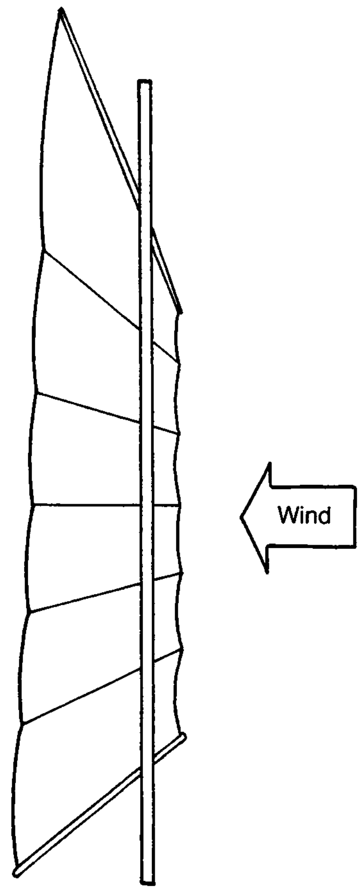


Fig. 1.10 Scalloping (1)

The Sail

So far the curvature of the sail has been discussed only in relation to the bending of the battens, i.e. curvature along the line of the batten. The sail also curves in a plane at right angles to the battens, i.e. by 'scalloping' between battens as shown diagrammatically in Fig. 1.10. Scalloping becomes more significant in a sail with relatively few battens and wide panels. It is reduced by any vertical tension in the sailcloth, and therefore tends to be greatest in the lowest panel, which is supporting less weight. It will be least in the top panel, which is supporting the weight of all the panels below it.

Scalloping may be reduced by pulling downwards on the sail, by means of a tackline when under full sail or by batten downhauls when reefed, as discussed in Chapter 3, but in fact it does not seem to do much harm to the boat's performance if allowed to develop naturally without any such restriction, as in China. A possible exception is the situation mentioned earlier as being the rig's worst point, namely ghosting to windward in a lop. Here it may be that the scalloped sail disturbs the smooth airflow when pitching, in which case reducing the scalloping could be beneficial.

On the port tack the sail presses against the batten, and if the sail's scalloping is greater than the thickness of the batten it will press lightly against the mast in the middle part of each panel. This effect is presumably undesirable, but does not seem to cause any detectable inefficiency. Indeed, several owners feel that their boats sail to windward better on the port tack, particularly in fresh winds. If true, this may be an effect of having the windage of the mast on the lee side.

Much could no doubt be learned by 'tufting' Chinese sails in order to study the airflow near the surfaces. Tufting consists in passing pieces of wool about 8 in (20 cm) long through the sail with a sail needle, middling them and tying an overhand knot each side of the cloth so as to retain them in position with about 3½ in (9 cm) hanging free each side. Tufts could be placed about 12 in (30 cm) apart right along the middle of each panel.

A sail stretches somewhat with use, and the bunt of the sail stretches more than the luff or leech, particularly if these edges are taped or roped. The effect of this stretch is that the luff and leech scallop less than the middle of the sail, so that a plan view of one panel would show that the middle of the panel has greater fore-and-aft arching than that of the battens above and below it, as shown diagrammatically in Fig. 1.11. It would be possible to cut a sail with this fullness built into each panel, thus achieving more arching in ghosting weather without requiring the battens to bend at all, but the implications