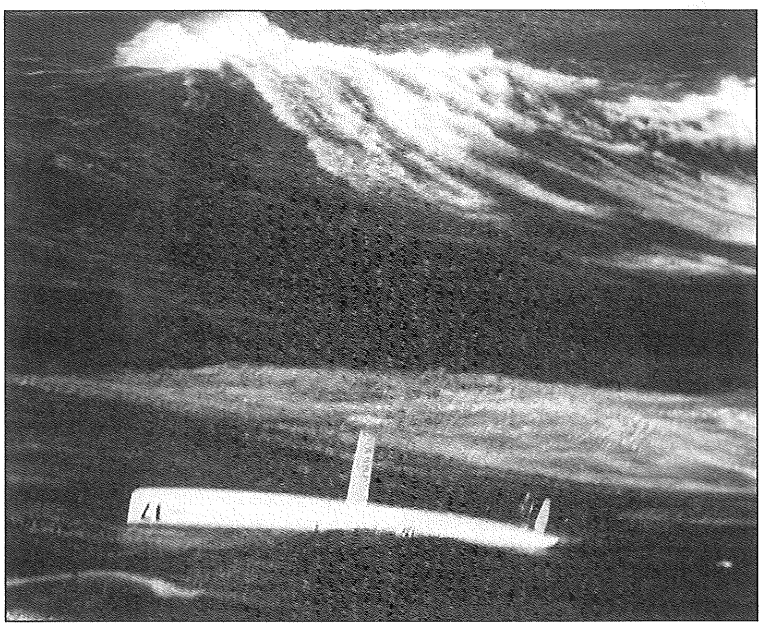
As Vendee Globe sailors learned to their peril in the Southern Ocean, modern yachts are becoming increasingly less stable. Researcher Barry Deakin asks: are we learning?

The Search for Stability

Yacht designers have traditionally been concerned with the provision of a comfortable and seaworthy cruising vessel with adequate sailing performance and ease of handling. Yachts evolved initially from working craft such as fishing or pilot vessels, the characteristics of which were well known. Designers have modified these forms gradually and, by changing parameters a little at a time, remained confident of their stability and seaworthiness. Many rules of thumb have developed over the years to guide decisions on such parameters as ballast ratio and sail area.

With the growth of racing as a sport alongside advances in materials technology, yacht design has progressed in the direction of performance, often at the expense of the other qualities sought in a cruising yacht. The design of racing yachts is dominated by the rating rules and these have influenced designers to produce the familiar modern shapes. The traditional rules of thumb are obsolete in the racing yacht design office and are sometimes neglected when modern cruising yachts are considered. Modern racing yacht forms have many benefits in terms of internal arrangements as well as performance, and market pressures have brought about their use as cruising yacht hulls.

Designs have therefore diversified considerably in recent years and, to the surprise of many people, their stability properties are equally diverse. Various regulating authorities have come to realise this and have sought ways of assessing the safety of yachts in terms of stability. Methods of calculation and stability requirements have both come under review in recent years, and numerous discussions have taken place on what constitutes "good stability" or "sufficient stability" for a yacht.


Pic courtesy RAAF

Is this the ultimate logical conclusion to current racing yacht design rules?

The yachting press has contained a wealth of articles on the subject, but much of what has been said has been based around data on just two yachts which sailed in the 1979 Fastnet race. The stability curves of the Contessa 32 and the 1/2 tonner "Grimalkin", which were presented in the race inquiry report, have been used many times to illustrate the difference between a traditional cruising yacht and a contemporary racing yacht. The yachts were of similar size with a length of just under 10 metres. The Contessa, with a reputation as a seaworthy yacht, had a range of stability of 156 degrees, whilst the 1/2 tonner, which capsized during the race, and remained upside down for some minutes, had a range of 117 degrees.

A considerable amount of research was carried out in the 1980's, prompted by the 1979 Fastnet Race casualty list, which led to a much improved understanding of capsize mechanisms. The work concentrated on capsize as a result of an encounter with a breaking wave, since this was the principal mechanism reported by the casualties. The work included extensive model tests conducted in the UK by the Wolfson Unit, and by a number of researchers in the USA. The results of the research were well publicised around the world. One of the important conclusions of this work was that yachts with a range of stability greater than about 150 degrees would not remain inverted following a capsize, the inertia of the roll of subsequent wave motion being sufficient to return the yacht to upright.

Traditionally, small cruising yachts had a range of stability of at least 150 degrees and would therefore always return to upright if capsized. Such a range requirement is generally considered by modern designers to be unnecessarily conservative, and is certainly not readily achievable with a modern hull form. In general, traditional forms with narrow beam and a deep hull were more resistant to capsize, but breaking wave height in relation to boat size is the overriding factor. Larger yachts are therefore safer in a given sea state, since they are less likely to encounter a breaking wave of sufficient size to result in capsize. This fact has led to proposals for stability requirements which vary with size.

All who studied the data, from an impartial position, were in agreement that the design characteristics which have adverse effects on safety in breaking waves are: large beam; shallow canoe body draft; high aspect ratio keel (since it leads to a high centre of gravity of the ballast, and poor directional stability); light displacement; low ballast ratio; and low coachroof volume. All of these, with the possible exception of the coachroof volume, will be recognised as characteristics of the contemporary cruiser-racer.

It is common in our societies for the safety of some aspect of our lives to be degraded gradually in the name of "progress", until some disaster occurs which claims an unacceptable toll. Regulations are then introduced or modified to reduce the risk of recurrence. In view of the widespread alarm created by the 1979 Fastnet race, it is reasonable to assume that representative bodies would have acted at that time to ensure, or at least encourage, a reversal of the design trends which were identified as being so undesirable for offshore yachts.

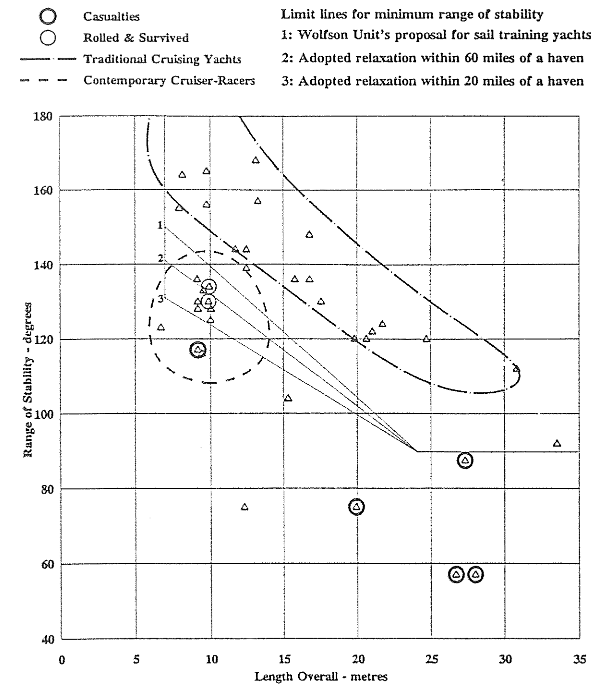
The conclusion of the Fastnet Race Inquiry Report was the sentence: "...provided that the lessons so harshly taught in this race are well learnt we feel that yachts should continue to race over the Fastnet course."

Unfortunately the lesson about stability was not well learnt by all. During the 1980s the IMS statistics indicated a general reduction in the stability of the fleet. In the 1992 Japan - Guam Yacht Race, the yacht Taka, with a range of stability of 114 degrees, capsized in Force 8 conditions and remained inverted for about three quarters of an hour with the subsequent death of six crew. The report of the enquiry into that tragedy concluded with the sentence: "We hope to receive further assistance and advice to ensure that such accidents never happen again."

In addressing that desire the Japanese authorities appeared to disregard the research of the UK and the USA. They commissioned a thorough, and expensive, programme of models tests which replicated those conducted previously. The results aligned well with those of the researchers in the west, and the conclusions and recommendations were the same, that is that a large range of stability is essential to ensure safety in large breaking waves.

Figure 1

Sailing Yacht Stability Data on Wolfson Unit Files in 1989



In 1994 a Pacific storm took a heavy toll on a fleet of yachts sailing from New Zealand to Tonga, with six yachts rolled through 360 degrees, and another lost, with its crew. The latter was advertised as a "serious cruising boat", and was classified as a Category 1 yacht. Whilst it was typical of contemporary cruising yachts, it had substantially higher beam than traditional ocean going yachts. Following an investigation into this incident, New Zealand's Maritime Safety Authority recommended in its report that the New Zealand Yachting Federation should "...consult with the Authority and other interested organisations to assess what steps can be taken to help prevent similar accidents in the future."

The common theme in the responses of those charged with investigating these incidents is clear. They all wish to prevent further losses at sea, and they all seek information on what can be done. The information is well documented however, and there is no excuse for any authority involved in yachting being ignorant of the facts.

When the UK Department of Transport's Code of Practice was developed in 1989, stability for sail training yacht requirements were recommended by the Wolfson Unit. At that time there were few well documented casualities for which reliable stability data were available, since full range stability calculations rarely were conducted.

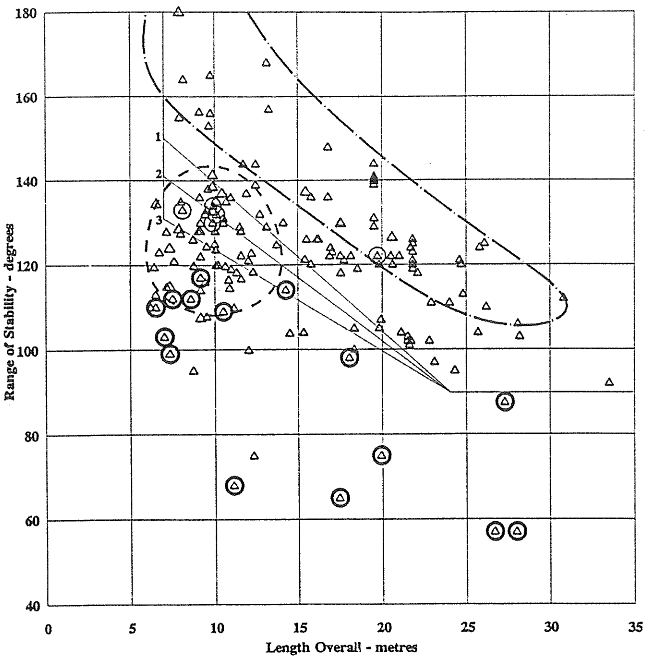
Figure 1 illustrates the data which were on file at the Wolfson Unit at that time. Some of the yachts were recognisable as traditional cruising yachts with narrow beam, a long keel with ballast located low down and hence a low centre of gravity. Small yachts of this type exhibit a large range of stability. The Contessa 32, and a number of recent designs for cruising, fell within the envelope of data provided by these examples.

Contemporary cruiser-racers, influenced to a significant extent by rating rules, and concentrated around the popular 10 metre length, exhibit a generally lower range of stability. Some of these had earned poor reputations as a result of their performance in the Fastnet race, apparently being susceptible to capsize, though they did not remain inverted for prolonged periods.

Two such 10 metre yachts are identified in Figure 1 with ~~squares~~ circles around the data points. Five casualties are identified with bold circles (one of these being Grimalkin), the others

Figure 2

Sailing Yacht Stability Data From Various Sources in 1996



were larger vessels which were capsized by the wind. On the basis of these data the limits for minimum range of stability were derived as shown. Since that time further data have become available from studies by the Wolfson Unit and others, and for yachts submitted for approval as UK sailing school or charter yachts. These have been added to the database to monitor the validity of the Code of Practice, and to gain some impression of current design trends.

Figure 2 illustrates the currently available data. Most importantly, though unfortunately, many new casualties have been documented. These all appear outside the limits required for UK sail training or charter yachts, apart from one which would have been eligible for operation within 20 miles of a safe haven.

Three new cases of yachts being rolled and returning upright, albeit with some damage, have been added. These all had a range of stability between 120 and 140 degrees. Some new data have been added within the envelope drawn previously for traditional cruising yachts, but by far the majority lie below that region, some within the region in which the casualties appear. There is therefore no doubt that there are many yachts which are vulnerable to being rolled by breaking waves, some of them unlikely to return to upright despite being in storm conditions where further large waves will be encountered. It would not be fair however, to deduce from these data that the majority of yachts on the market today are of the latter type, since some of the yachts have been studied specifically because they are known to be marginal cases.

The casualty data appear to validate the standards developed, and suggest that the lessons of the 1979 Fastnet race may not have been taken to heart by the industry or the authorities, despite further high profile casualties around the world. Unfortunately, as we all know, those characteristics which have an adverse effect on safety in survival situations make the yacht fast, spacious and comfortable in favourable conditions. They are valuable assets in the modern yachting market, and authorities will be reluctant to try to enforce unpopular restrictions.

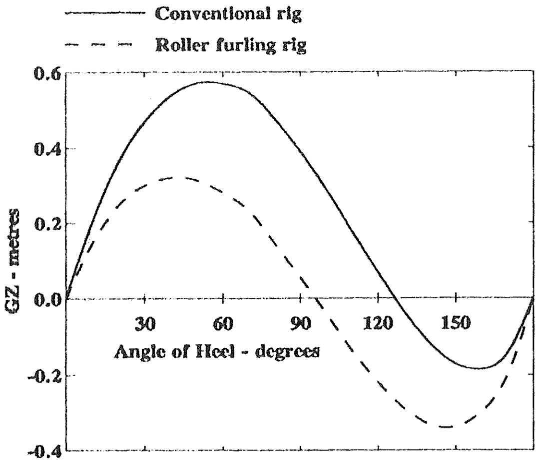
Buyers of sailing yachts should be provided with information to indicate realistically the type of operation for which they are suitable. It would be irresponsible to market yachts as ocean cruising yachts if they are vulnerable in terms of stability, or indeed any other aspect of safety. Every individual is entitled to take measured risks, but one should not be misled by marketing strategies into underestimating those risks. This is the principle behind the European Community Directive on small craft which is being developed. Boats will be assigned a category based on wind speed and wave height to indicate the conditions for which they are considered suitable. At present however, great difficulty is being found in reaching agreement on the stability standard required for each category. It appears likely that the resulting standard will be more complicated than that illustrated in Figure 1, and that commercial pressures will force agreement on low requirements. These may yet mislead the buyer into believing his new coastal cruising yacht will carry him safely through ocean storms.

Most yacht design offices now have facilities for computing the stability characteristics of new designs and many incorporate a calculation of the range of stability into the design process. Not all of these computer programs are able to include the effects of coachroof and cockpit however, and these are of course fundamental to the stability at very large angles. There are many individuals and small companies

Range of Stability

The range of stability of a yacht is the range of angles through which it can be heeled, in still water, and when released, will return upright. If it is heeled to an angle greater than the limit of its range, it will capsize. A yacht with a range of stability of 120 degrees will have an inverted range of stability of 60 degrees. That is, if released at any angle with 60 degrees of upside down, it will return to the upside down position, 180 degrees.

Figure 3
Stability curves for two yachts of the same class with different rigs



involved in yacht design who do not have such facilities. If they are involved only in cruising yacht design it is unlikely that they will commission a consultant to produce stability data, since there is no legal requirement nor public demand for such information.

Yacht designers tend to rely on their calculations for displacement and centre of gravity location. Inclining experiments, which are used to measure these values accurately, are virtually unheard of for cruising yachts, unless of course the yacht is also to be raced and undergoes an inclining experiment as part of its rating measurement. Since there have been no stability regulations for yachts, some designers have adopted their own targets and generally they appear to regard a range of stability of about 120 degrees to be the basic requirement. This value may have been selected as a result of considerable publicity given to the USYRU recommendations in the mid 1980's, rather than being arrived at independently by the individuals.

There has been a reluctance on the part of rating authorities to demand detailed stability calculations from the designers of racing yachts. Until perhaps 20 years ago the technology was not readily available but more recently, with numerous computer programs available, specific stability requirements could have been incorporated into their rules. Fears of additional cost to the designers and problems associated with approval of results have perhaps deterred them. This attitude has led to an increased tendency to rely on approximate methods of assessment, based on a small number of principal dimensions. An alarming illustration of the dangers of approximate assessments is given by a comparison of the stability curves for two examples of a class of 8.7m production cruising yacht (Figure 3). The yacht with a range of 127 degrees has a conventional rig as designed. The other with a range of only 96 degrees has a mast furling mainsail and roller furling headsail fitted. The additional weight aloft on this yacht has reduced its range by 31 degrees. The only way to identify such effects accurately is with an inclining experiment and a conventional stability calculation. Thus there are two aspects to stability assessment: the range needs to be determined properly; and there needs to be a sufficiently conservative minimum requirement. If an approximate method must be used an increased factor of safety should be introduced, for example by increasing the minimum requirement.

Yacht racing will never be 100 percent safe, but if the authorities wish to minimise the likelihood of such incidents as these, the knowledge and techniques are there to be used, and they are now available at an acceptable cost. It appears that the result of existing racing rules has been to keep existing fleets competitive rather than to encourage increased safety in new designs.

Improvements have now been made in the Whitbread Rule and if this example were followed by other race authorities, with a sufficiently stringent requirement, the general standard of safety would be raised. The researchers are making progress but the authorities seem to be hesitant about incorporating their findings.

Barry Deakin is a researcher with the University of Southampton's Wolfson Unit, which studies marine technology and industrial aerodynamics. The unit offers commercial consultancy to yacht and small ship designers, builders, and operators and is well known for its work on sailing performance and safety.