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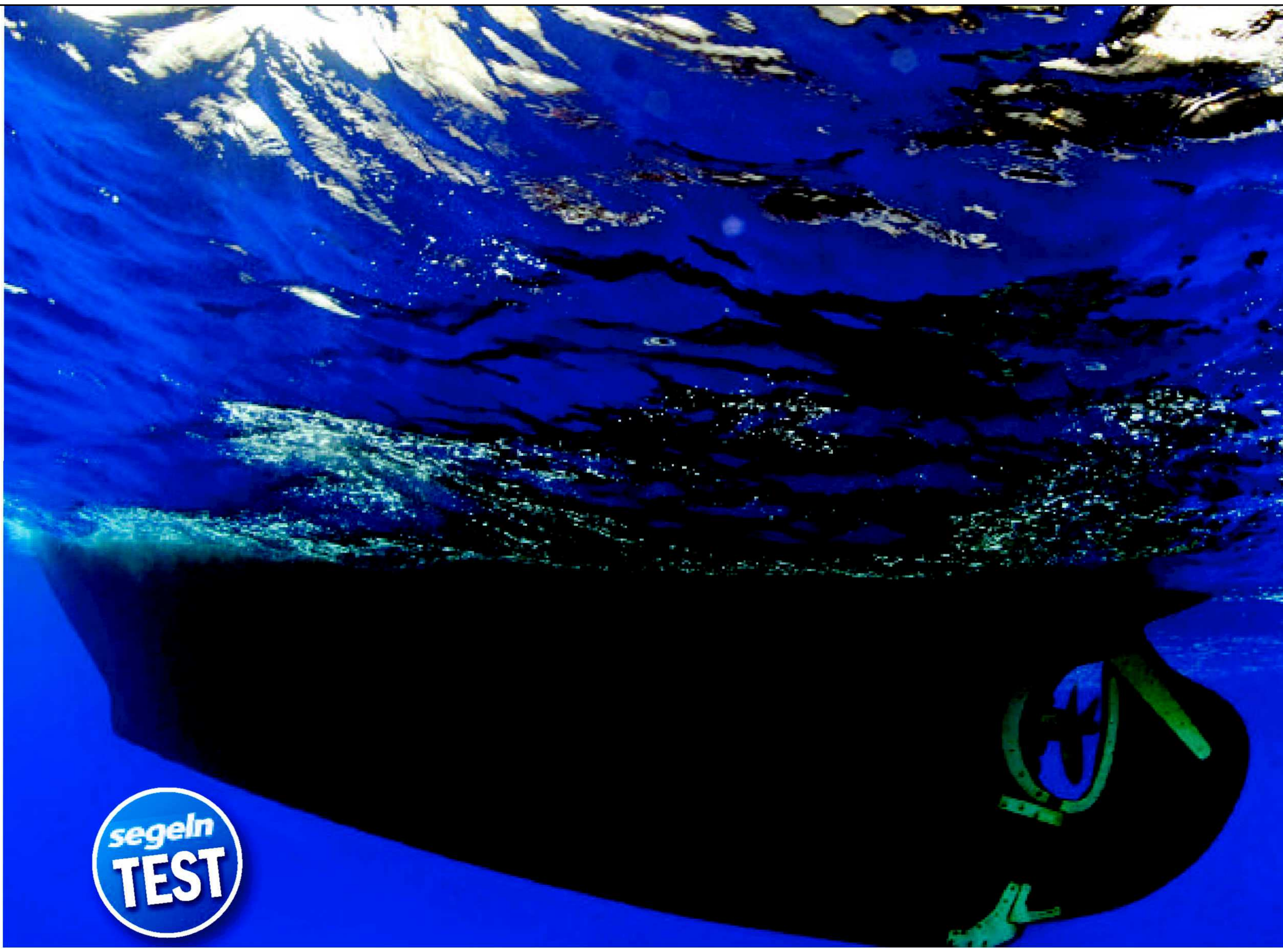


11 Streamlined propellers under test

P(r)op art

A fixed blade propeller is not the first choice when one wants to extract the last ounce of speed from a yacht. The flow resistance in comparison to a folding or a reversible propeller is considerably higher. How large the difference actually is and what the flow optimised blade can achieve during harbour trials “Segeln” has found out for you at the Naval Architecture Test Centre in Potsdam.

Text: Gerald Sinschek

A sailing boat is a sailing boat, two sailing boats are a regatta. And if the "Opposition", despite having a similar yacht, pulls slowly further ahead the reason may lie under the water. Hanging under the faster yacht is perhaps a streamlined folding propeller which makes a small but significant difference.

Those sailing with a free rotating fixed pitch propeller under the hull could also be towing along a large bucket. The drag is almost the same. Those who should brake the propeller according to engine manufacturer's instructions, may just as well throw a second bucket overboard and tow it behind which spoils greatly the pleasure of sailing.

At least we have made drag measurements in the famous Potsdam Naval Arch. Test Centre (NATC Potsdam) towing tank). There we tried to get to the bottom of a much discussed topic: How much less is the resistance of a two bladed folding or reversible propeller in comparison to its fixed counterpart? How does a comparison look between a modern folding and rotating blade propeller for cruising or harbour manoeuvres, when forward and reverse thrust is rapidly available in order not to bump the edge of the pontoon?

Test configuration and propeller types

Five standard folding propellers, a variable pitch propeller and three reversible screws were in the test programme. As a comparison we tested a fixed two bladed Volvo propeller, "Racing folding propeller", which should have especially low drag, and a three bladed variable pitch screw propeller. Diameter and pitch for our defined yacht configurations were determined by the propeller manufacturers. The task was to select for a Bavaria 34 Cruiser with Volvo engine Dl-20 and Saildrive 130S a suitable blade, considering the given values for engine, gearbox and Saildrive to achieve as far as possible optimum performance. This should be about 7.4 kn at full speed ahead at maximum 3200 rev/min (the maximum engine revs.)

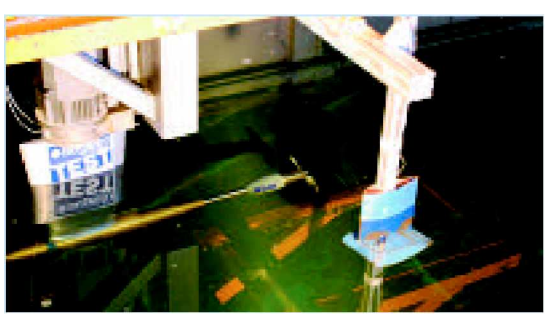
In addition we measured the static thrust (forward and reverse) at a given speed. These so called bollard pull tests allowed conclusions to be made as to the manoeuvrability of the propeller. The more thrust a propeller produces the faster a yacht accelerates or comes to a halt. For harbour trials this is an important criterion.

The main purpose of the test runs in the 280 m long NTCA test basin was however the towing drag measurements. After all this mechanical work of art was only built for one purpose; that of making sailing boats go faster after the engine has been shut down. The blades of a folding propeller open up under engine drive from the resulting

How we tested

A video camera was installed next to the propeller, which showed its behaviour under water

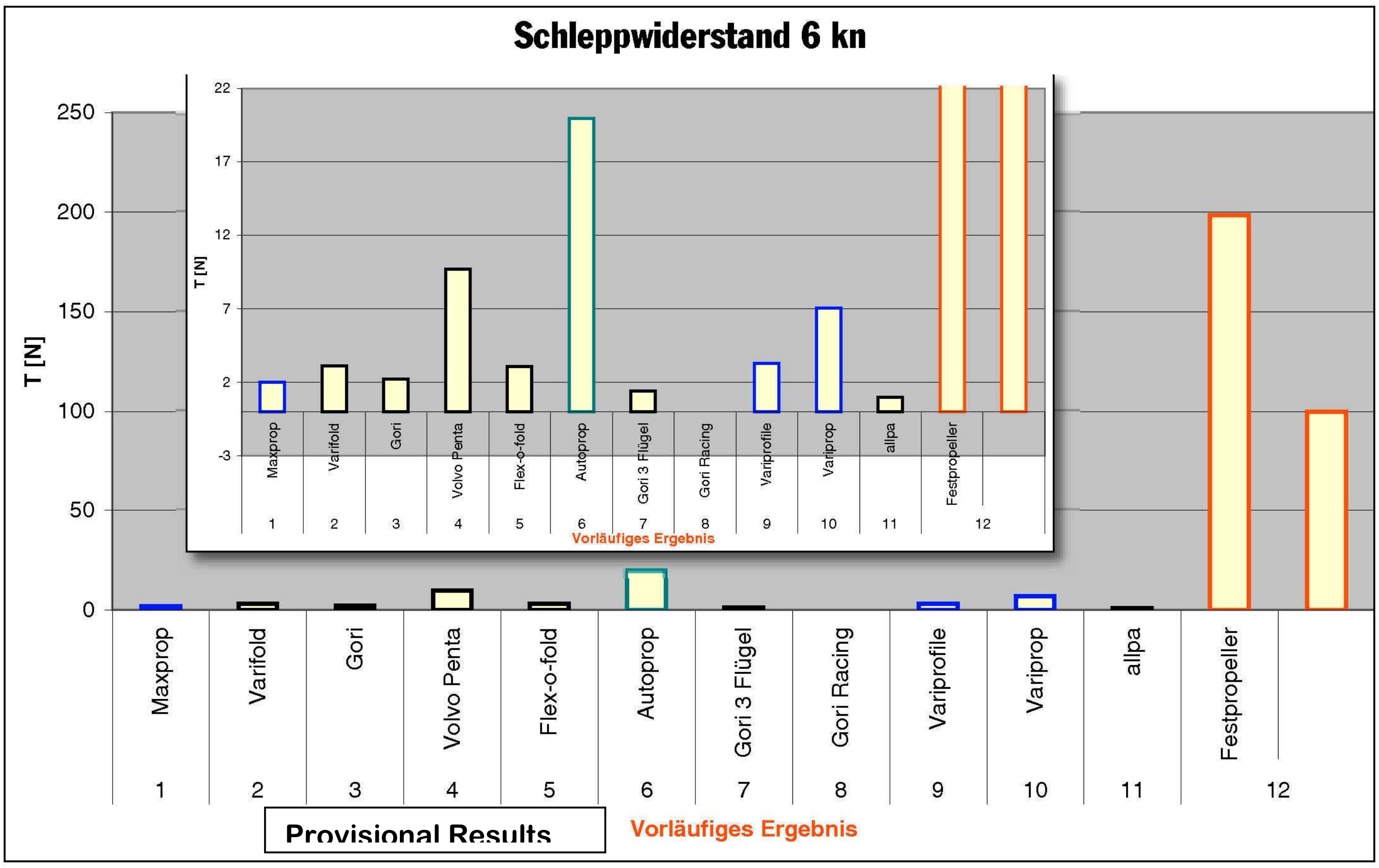
The giant towing carriage travelled at up to eight knots above the test tank



For two days we travelled constantly up and down the NA Research Centre Potsdam test tank with the enormous towing carriage to determine measured values. (Towing drag, bollard pull forward/astern and power at cruise and full speed).
The towing drag of the folding and reversible propeller in the sailing position was determined at a speed of six knots. With the drive shaft of the measuring instruments stationary (Dynamometer H39) static friction occurred, which influenced the measured results. During resistance measurements the shaft rotated at 0.5 1/s. Tests have shown the influence of this very small rotational speed on the drag affected the measured accuracy.
For the measurements we assumed that the total engine power was available for driving and that no power was taken to drive the alternator.
The evaluation for the reference yacht was converted for the density of Atlantic sea water at 18°C.

The propeller was mounted on a shaft as a dummy based on the Saildrive of the Volvo 130 S. Mounted in the blue section, front right, is a video camera and underwater lighting.

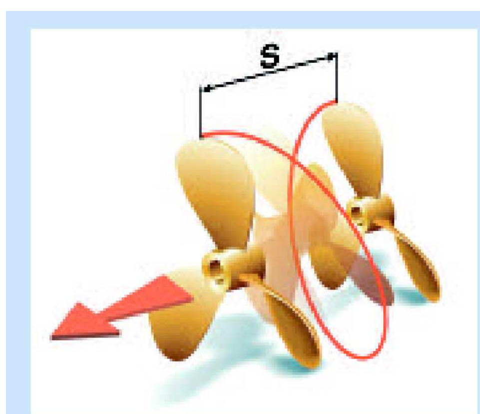
Towing Resistance at 6kn



In the large bar chart the differences in resistance between the folding and feathering propeller and the Volvo (upper bars: braked, lower bars: free rotation) are easily seen. The small differences can be seen better in the detailed chart. Here the Autoprop gives a drag value of just over 20 Newton, the Gori Racing on the other hand is so well shaped that it produces no drag.

Propeller pitch

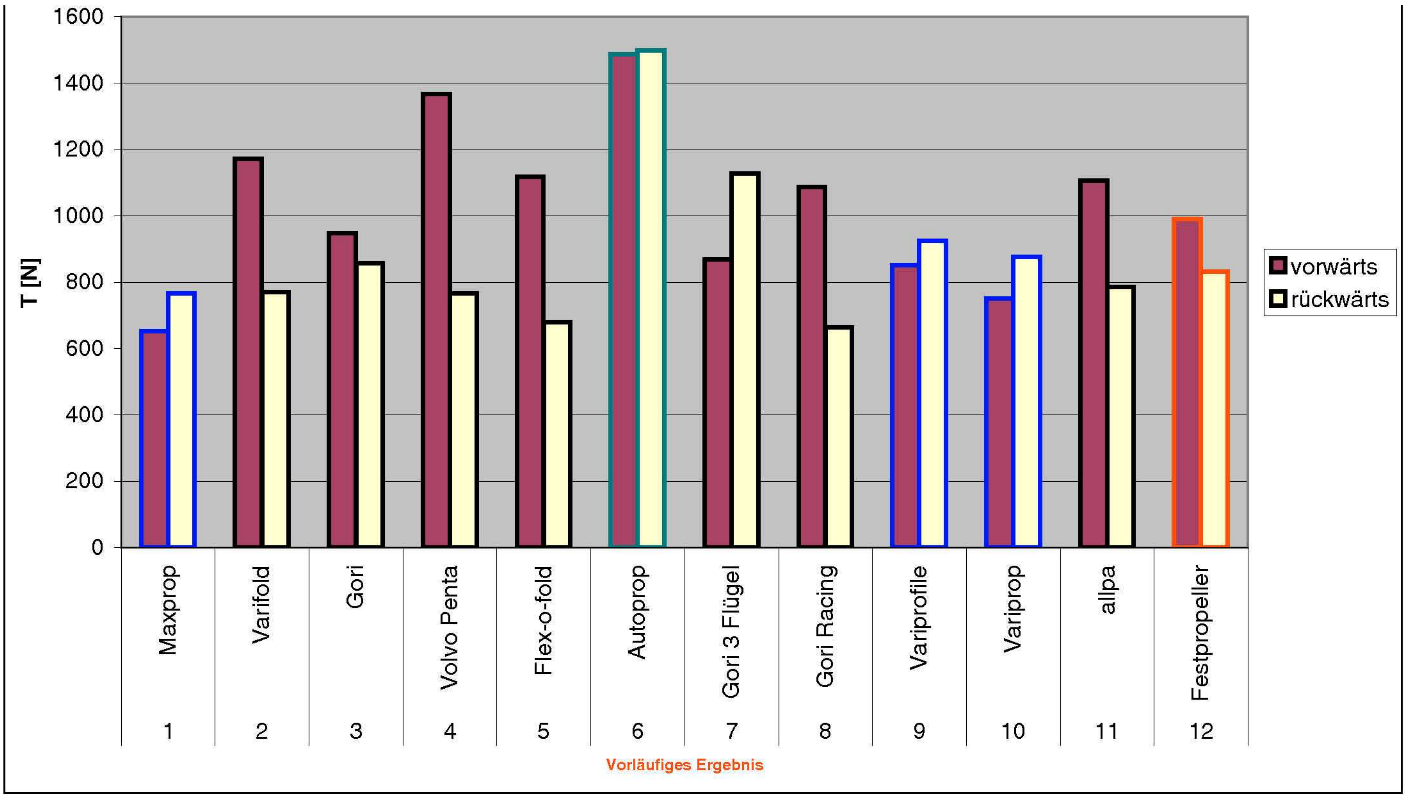
A ship's propeller is characterised by two dimensions (in inches) : Pitch and diameter. The pitch describes the theoretical travel in the water of the propeller for one revolution. To illustrate this one may think of a ship's propeller as a wood screw, which with a turn of the screwdriver travels a certain distance in the solid material. A propeller with a small pitch similarly does not go as far through the water for a single turn as a propeller with a large pitch. The diameter is calculated by the experts and depends on the space under the hull and the required blade area. These determine first of all the amount of water that is accelerated astern to achieve the required speed. With the feathering propellers under test the pitch could be varied to achieve optimum conditions.



5" **is theoretically the distance in inches which a propeller travels for one revolution**

Centrifugal force and torque. Because the blades are geared together they open and close synchronously. When the Diesel is shut down both blades fold in due to longitudinal water flow stream thus reducing the drag considerably. With feathering propellers the blades are not turned by centrifugal force but through an integrated gear drive active in the prevailing situation for forward or astern. If the engine stops the blades are turned to the horizontal position by the water flow where they offer the least resistance. A special form is the "Autoprop". The two highly

Maximum achievable bollard pull



This chart shows the value of maximum achievable bollard pull in Newtons. The two bars per propeller represent the forward thrust (violet) and reverse thrust (beige). The small "Maxprop" value can apparently be optimised by careful variation of the pitch, without overloading the engine. Especially high values are shown for the "Autoprop" whose free rotating blades are set in the optimum position depending on rotational speed and torque.

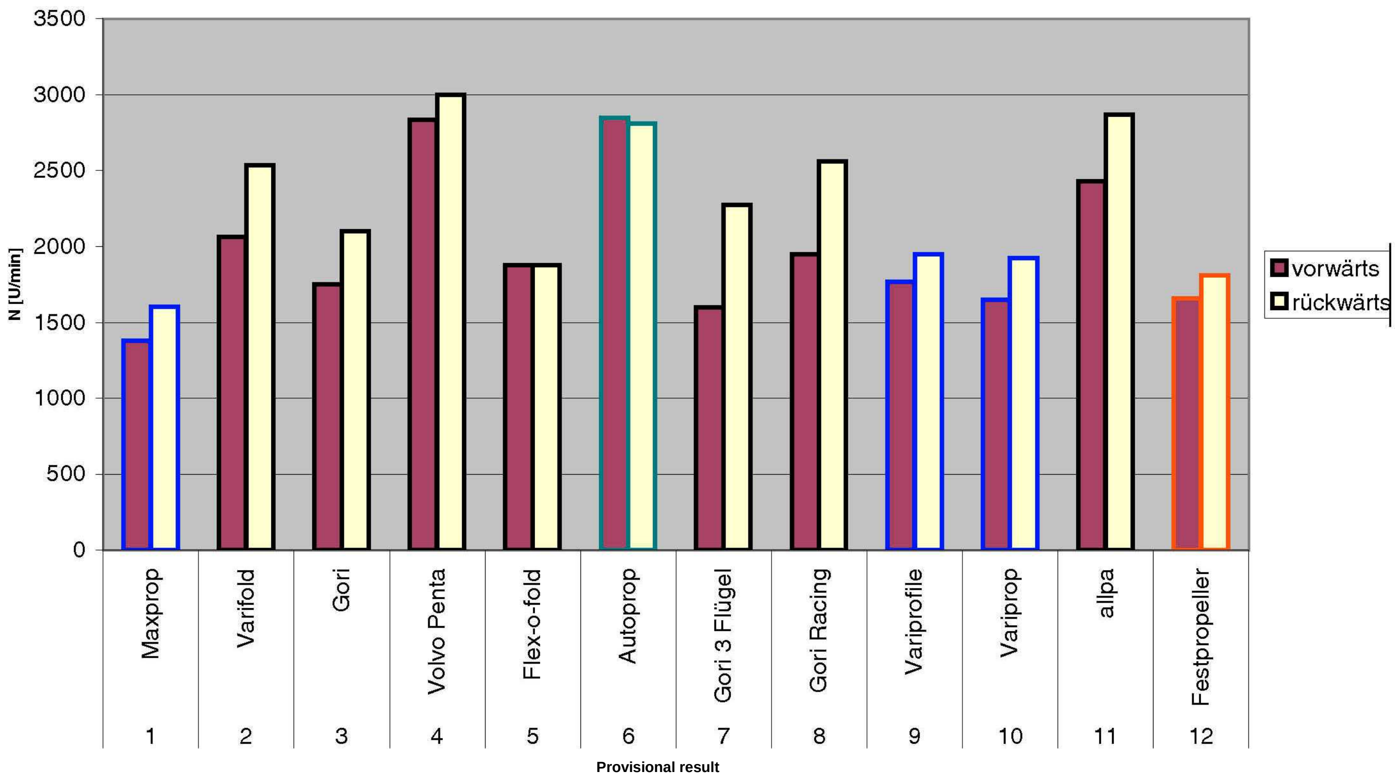
profiled blades are mounted on a transverse axis in the boss. Depending on engine rotational speed and torque they arrange themselves independently in the ideal position. When there is no drive, the blades turn through 180^0 about the transverse axis to the new position.

Test results and special features

The situation described at the start for towing drag one can see in naked values: The Volvo held fixed blade propeller decelerates - theoretically - the yacht from six knots under sail with over 200 Newton. To the measured total drag (approx. 550N) of the yacht at this speed, one must then still add 40% ."Braking contribution". With the propeller free to rotate the drag is reduced by at least 50% to 100 Newton. However this value still corresponds to about 20 >-

Left the "forward position" for the "Autoprop", in middle are the free rotating blades in the position "astern" and the right hand picture shows the blades in the sailing position. For this model they offer the least drag in the flow.

Maximum achievable revs/revs for maximum bollard pull



As the propeller blade profile is optimised for good forward travel performance, not only are the majority of propellers considerably better for "forwards" than "astern" thrust values (compare with diagram "Bollard pull" p.?). For travel astern, in addition much higher revs are required to achieve maximum thrust. The "Autoprop" is again in a special position: Not only are the thrust values almost identical, but also the necessary revs required.

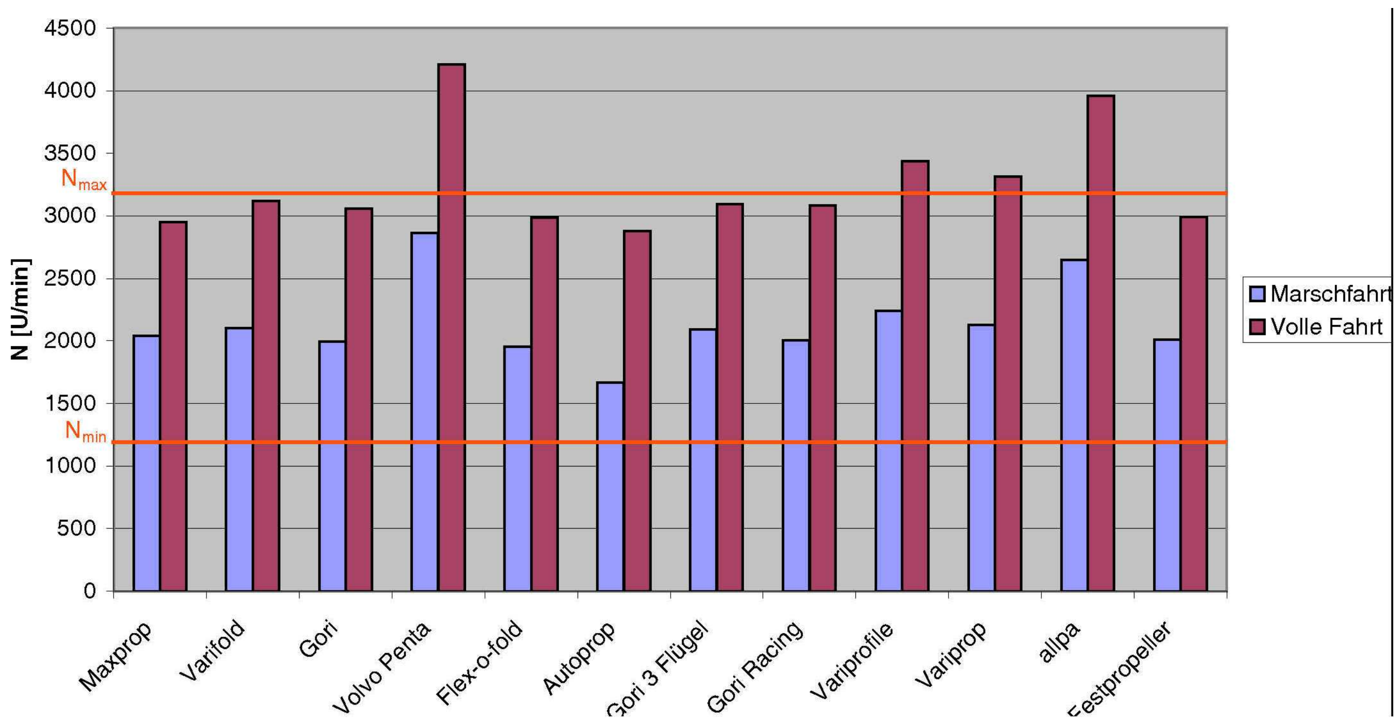
Percent of total ship's drag. As the drag curve for a yacht increases sharply with speed and is not approx. linear, this relationship becomes even worse at low speeds. The bollard pull values for fixed blades was 1000 N forwards and a good 800 N reverse, cruising speed was at 2000 rev/min, for 7.4 kN the engine ran at 3000 rev/min.

With a robust bronze alloy manufactured folding or feathering propeller the drag relationship of the yacht propeller changed dramatically. The hydrodynamically polished propeller develops just between 1 and 20 Newton drag, which corresponds to a proportion of between 0.2% and a maximum of 4.2% of the total drag. The hydrodynamically optimised screws also display their strengths at low speeds.

As the most streamlined propeller from the standard test programme was the Allpa folding type. The drag is only a single Newton so small

The majority of propellers tested were fitted with a zinc anode. The "Maxprop" (l) gives in addition a more streamlined transition between boss and Sail drive. Allpa (r) without anode

Engine speed



Provisional result

In the yacht configuration (see text) the Volvo-Penta "D1-20" delivers maximum power at 3200 rev/min. The propellers represented by the four violet bars that are above the line, would have only attained the maximum speed of 7.4 knots with considerably higher revs. They are too "light", the chosen pitch is too small. The Volvo folding prop was the most unsuitable for our boat, with the "Variprofile" and "Variprop" one had to adjust the pitch bolts

that it can almost be neglected. The Italian foundry Eliche Radice have done a good job which goes unseen. At the same time the prop gave for the bollard test measurements 1100 N forwards and 800 N reverse thrust, which were good results. For this comparatively higher revs were required. However, Allpa had incorrectly calculated the dimensions. The 15 inch diameter was given to all manufacturers, and the pitch was to be calculated individually based on the ship's specification. For the cruise and full ahead test runs it was shown that the Allpa prop the required maximum speed with the maximum available revs of 3200 rev/min (see above) could not be achieved. Theoretically this propeller would have needed 4000 rev/min to achieve 7.4 kN. The propeller was "too light" as the pitch for the nine inch from Allpa was dimension too small.

Similarly streamlined with a drag value of only two Newton was the feathered pro- >-

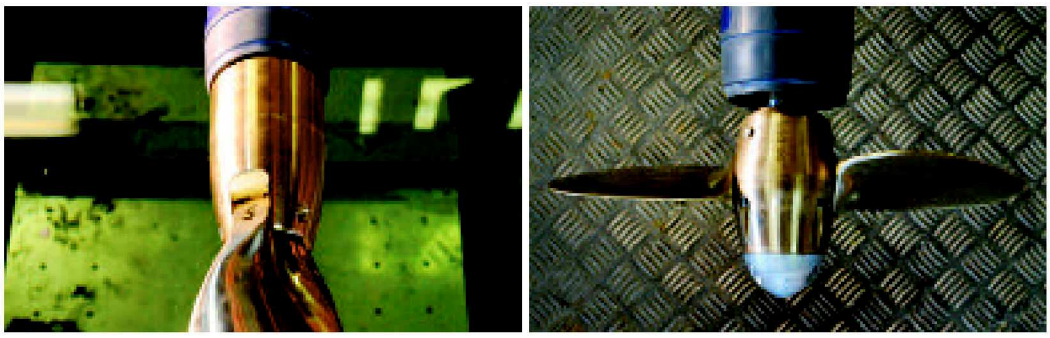
Propeller installation

Research Ldr. Dipl.-Ing Dr. Stefan Helma (r) assembling prop.

Installing a propeller is comprehensible if one adheres strictly to the instructions. Necessary special tools such as a hook spanner and others are generally supplied. With both folding propellers one cannot do too much wrong, the number of parts to assemble is manageable. Allpa and Flexofold could, however, have made the operating instructions more comprehensive and also in German.

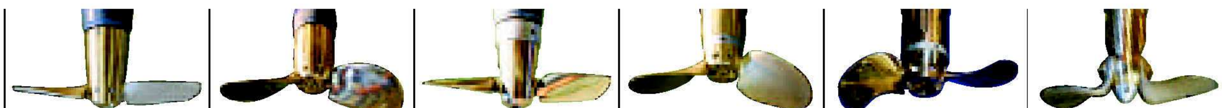
Somewhat complicated and requiring more than two hands is the installation of the "Maxprop". The correct choice of pitch is somewhat complicated and requires concentration. All safety screws must definitely be secured with a thread locker e.g. "Loctite" , which is supplied with all propellers.

peller from "Maxprop". The static thrust measurements for it were 653N forwards, the lowest value, and also 767 N for astern travel are not spectacular values. For tight harbour manoeuvres it can be noticeable. Because with the "Maxprop" the pitch can be varied, the thought comes to mind simply to increase the pitch, in order to achieve better values. The required torque for this cannot be provided by the engine for our test configuration. With the manufacturer selected pitch the engine is already



The change over from boss to sail drive occurs very differently. With "Flex-Q-Fold" (l) the region is very streamlined, with "Variprop" (r) yawning unfavourable gap

at full speed on its power limit.
In third resistance place revolving with only 2.2 Newton towing resistance is the Gori folding propeller. The bollard pull values indeed occupy the lower third of the test results, but with 857 N astern and barely 1000 N forwards the harbour performance should be acceptable. The 12 inch pitch selected by the manufacturer is correct: The speeds



Model	Allpa	Flex-o-Fold	Gori	Varifold	Volvo	Autoprop
Manufacturer/Distrib	Eliche Radice/ Allpa, Tel. 0031-24/377 77 73, www.allpa.nl	Flexofold, Tel. 0461/481 56 10, www.flexofold.com	Gori/Bukh-Bremen, Tel. 0421/535070, www.bukh-bremen.de	Bruntons/SPW, Tel. 0471/77047, www.spw-gmbh.de	Volvo, Tel. 0431/399 40, www.volvo-penta.de	Bruntons/ SPW, Tel. 0471/77047, www.bruntons-propellers.com
Price	588.35 €	1044 €	1082.90 €	1008 €	1328€	1875 €
Guarantee	2 years	3 years		2 years	1 year	2 years
Weight	5.6 kg	6.9 kg ???	6.7 kg			
Type	Folding prop	Folding prop	Folding prop	Folding prop	Folding prop	Automatic Variable pitch propeller
Diam/Pitch.	15 x 9	15 x 12	15 x 12	15 x 9	15 x 8	15 x variable
Anode available	no	no	yes	yes	yes	yes
Installation/ instructions	Very easy install -ation; few instructions only in English	Very easy install -ation; few instructions only in English	Very easy install -ation, good instructions many pictures	Very easy install -ation, good instructions German	Very easy install -ation, instructions in German	Very easy install good instructions in German
Tests						
Towing drag /Newton	1	3.1	2.2	3.1	9.7	20
Bollard pull/Newton forward / astern	1106 / 786	1118 / 681	948 / 857	1172 / 771	1368 / 766	1486 / 1499
Engine speed max. Bollard pull	f/2430 r/2870	f/1880 r/1880	f/1750 r/2100	f/2060 r/2540	f/2840 r/3000	f/2850 r/2810
Engine speed Cruise 6.4 kn / Full speed 7.6 kn	2650 / 3960	1950 / 2990	1990 / 3060	2100 / 3120	2860 / 4210	1670 / 2880
Sail load at/kN	1.4	1.9	2.3	1.7	1.9	No measurement available
Comments	For the cost conscious regatta sailor is the "Allpa the very best : As a sail prop it scored with the lowest drag in the regular test series, the bollard pull-values are reasonable the price is considerably less than the competition.	This sail prop excels due to small drag. The bollard pull value for travel astern is however modest, one must be careful in narrow harbours	Gori delivered the second best drag-value. With the good bollard pull values especially for travel astern, make the Gori a very good compromise for racing sailors, who also want relaxed manoeuvres in harbour	The sail prop distinguishes itself with with small towing resistance. In harbour the performance could be better, the reverse thrust is not spectacular	In comparison with fixed pitch propeller the drag value is small other folding and blade props have better values. The reverse thrust could be better, all in all the prop is an acceptable compromise	The strengths of the Autoprop lie definitely With its performance Under power. The Motorprop gives almost 1500 Newton thrust fwds and rev. However the drag value is high and propeller is Expensive too
Assessment	⊙⊙⊙⊙⊙	⊙⊙⊙⊙⊙	⊙⊙⊙⊙⊙	⊙⊙⊙⊙⊙	⊙⊙⊙⊙⊙	

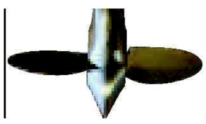
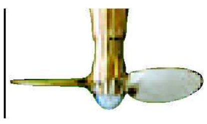
are available in a healthy speed range and the engine is not over loaded.

Each with 3.1 Newton drag the two folding props "Varifold" and "Flex-O-Fold" lie together. They also have similar bollard pull values, the "Varifold" can both in forward and reverse travel produce more power. The "Flex-O-Fold" produces for reverse travel the worst test values: With only 681 Newton the virtual ship went astern. One can approach the edge of the landing stage very rapidly. The revs for both are close to optimum, in other words: The pitch is correct, the manufacturers have the knowledge.

A shade more drag is produced in the water by the rotating blade propeller with variable "Variprofile", and the word "braking" is seen as relative: measured with the total drag for the yacht the "Variprofile" would have had only a partial resistance of 0.7 %. At maximum r evs the expected top speed was not attained with delivered setting, the prop is too "light". The owner of the virtual test Bavaria yacht must once again crane his ship from the water and adjust the pitch screws to a better setting. Here one should proceed with care to reach the perfect pitch setting and not straight away by turning the adjusting screw a complete turn. Even if it could mean an additional appointment with the crane.

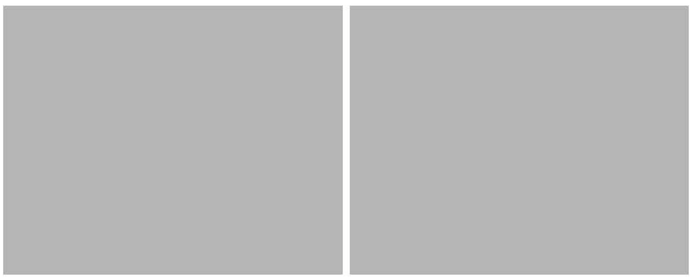
The "Variprop" with three blades stands out considerably in the line up of streamlined propellers. The dynamometer measured seven Newtons, which amongst other things is due to the ungainly construction and the large gap between the propeller boss and Saildrive leg. It does not depend on an especially effective blade profile that would stick out like a lump in the flow, apparently not if one examines the bollard pull values. With 752 Newton under test it got off the mark, it pulled with 877 N. As a result the stipulated maximum speed was not attained and here also the pitch should be carefully readjusted.

Curiously enough the Volvo folding propeller does not go so well with the Volvo engine and Volvo Saildrive. For the towing resistance - >-

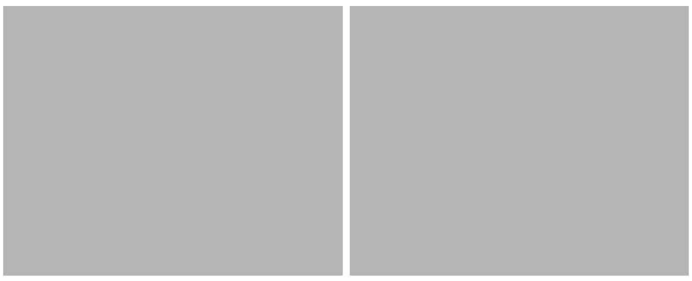





Model	Maxprop	Variprofile	Variprop	Gori Racing	Fixed Prop	Gori 3-bl
Manufacturers/ Suppier	Maxprop/Boattec, Tel. 0431/3990060, www.boattec.de	Tel. 0471/770 47, www.spw-gmbh.de	Tel. 0471/770 47, www.spw-gmbh.de	Gori/Bukh-Bremen, Tel. 0421/535070, www.bukh-bremen.de	Volvo, Tel. 0431/399 40, www.volvo-penta.de	Gori/Bukh-Bremen, Tel. 0421/535070, www.bukh-bremen.de
Price	1688 €	1457€	1675 €	1558.90 €	292€	2344.30€
Guarantee	2 years	2 years	2 years			
Weight						
Type	Rotating blade propeller	Rotating blade propeller	Rotating blade propeller	Folding prop	Fixed pitch propeller	Folding prop 3-fl.
Diam/Pitch.	15 x 12	15 x 11	15 x 12	15 x 12	16 x 11	15x 12x3
Anode available	yes	yes	yes	no	no	yes
Installation-instructions	somewhat complicated, instructions in German	somewhat complicated, instructions in German	somewhat complicated, instructions in German	simple	simple	somewhat complicated, Instructions only in English
Tests						
Towing drag /Newton	2.0	3.3	7.0	0	99.9 held 198.7 free rotating	1.4
Bollard pull/Newton forward astern	653 767	851 926	752 877	1086 665	990 833	869 1128
Engine speed max. Bollard pull	f/1380 r/1610	f/1770 r/1950	f/1650 r/1930	f/1950 r/2560	f/1660 r/1810	f/1600 r/2280
Engine speed Cruise 6.4 kn Full speed 7.6 kn	2040 2950	2240 3440	2130 3310	2000 3090	2010 2990	2090 3090
Sail load at/kn	3.5	2.7	3.1	2.7		3.3
Comments	The Maxprop Offers a very low value of drag. The performances under power is modest and and gives lowest forward thrust value which cannot be corrected by increasing pitch	The manufacturer's pitch was selected somewhat too low. An adjustment of the sail propeller would definitely improve the bollard pull results and perhaps lead to a good compromise .	With somewhat more pitch the bollard pull values would apparently have been better. Together with the comparatively high towing drag the Variprop makes a good compromise" .	An immeasurable drag distinguishes this perfect sail prop. Those wanting to equip their yacht for regatta Sailing should consider the price Of wiining and buy this prop. The bollard pull values are variable.	The fixed pitch propeller is the "sailing brake" the bollard pull values for this propeller are acceptable	Despite the large jagged areas the three bladed propeller gave a very low drag value performance and very good reverse thrust. This comparision prop is however very expensive
Assessment	⊙⊙⊙⊙⊙	⊙⊙⊙⊙⊙	⊙⊙⊙⊙⊙	⊙⊙⊙⊙⊙	⊙⊙⊙⊙⊙	



A folding prop in the engine drive position (l) and folded in to a more streamlined sailing position (r)



The rotating blade propeller, due to flow, takes up the lowest drag position (r)

measurements the propeller (9.7 N) is in last but one place which can be explained by the extremely long extended blade tips which protrude a long way into the flow. The engineers selected the unusual form for the benefit of good performance which the folding propeller proves by the impressive bollard pull measurements: In "reverse" with 768 N it is placed in the lower middle range, and "forwards" with 1368 N gave the second best result. The pitch is only 8 inch which is too much and in no way compatible with yacht and engine: The hull speed cannot be achieved with this combination. The yacht would not reach 7.6 knots through the water without 4210 rev/min. As the engine only revs up to 3200 rev/min, one must accept a reduction in speed.

Here Volvo would do better to extend the range of this or other propellers.

With 20 Newton drag the "Autoprop" with its free rotating blades is still a long way off the fixed blade brake" (100 N to 200 N), is by far the worst in the towing test. In return the bollard pull values forwards as reverse are solely top class (currently over 1400 N), the revs despite this remain comparatively low and the engine does not have to make available its last ounce of torque.

For the best possible comparison we have also towed an especially flow optimised Gori racing folding propeller and a three bladed rotating blade propeller (Gori) in the towing tank. Looking at the given towing resistance values for the "Racing" we had to rub our eyes a number at times: The hydrodynamically styled master piece offered 0 (in words: zero) Newton drag. And in addition with good bollard pull values and optimum engine speed range at cruise and full speed ahead. However the pitch is a shade too large and under full load the engine may produce clouds of black smoke, because more torque is required than is available and the rotational speed is not achieved. The fuel injector balances this requirement by injecting more fuel. The additional fuel leads however to an over rich mixture in the cylinders and the exhaust clouds become black and sooty.

It is the same picture for the folding propeller with three blades: pitch somewhat too large, but very good bollard pull values and despite the crude shape when folded a very low drag value, with only 1.4 Newtons, within a field of 12 propellers, lay in third place. For the advantages of quiet engine running and outstanding stopping characteristics one must reckon on a two to four times increase in price in comparison with the other screw under test.

Folded/ Open

The propeller blades fold or revolve very quickly to the optimum position. At best 530 rev/min was required, to turn the "Maxprop" to the engine drive position. The blades of the simple folding Gori propeller had already attained its ideal position at120 rev/min. The other way looked entirely different however: Some propellers required under test a comparatively high flow velocity in order to fold or revolve to the ideal position. The "Maxprop" blades only revolved to the ideal sailing position at 3.5 kn and also the "Variprop" and the three bladed Gori only made themselves thin at more than three knots. These observations oppose the actual purpose of the propeller especially at low velocity to produce little drag. It is possible that the frictional resistance in the rotating blade propeller mechanism or the geared folding blade will reduce after longer operation and will work easier. The measured values for the rotating blade propellers can possibly be reduced by following the described operating tips. "Variprop" even produce a single sided sheet on how to get the propeller in to the sailing position. Here is an extract: -sail at three to four knots forward speed. -Select neutral, switch the engine off and >-

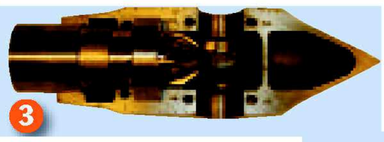
The recommended Volvo fixed blade propeller for our yacht configuration delivered exciting comparative values

TECHNIK im Detail

"Max-Prop"

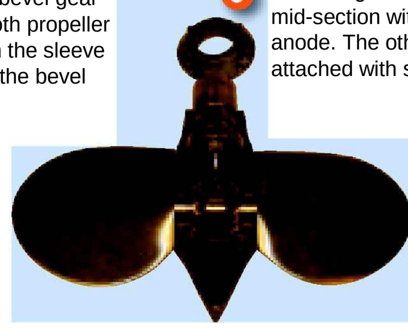
1 Mid-boss with rotatable blade bevel gear. Here the bevel gear engages for pitch adjustment for forward and astern travel.

4 The two part zinc anode is screwed to the mid-section and provides in addition a streamlined transition to Saildrive



3 Centre piece with bevel gear in half housing. Both propeller blades are fitted in the sleeve bearing normal to the bevel gear

2 Both halves of housing (right and left), between them the mid-section with central bevel gear that is bolted directly to the drive shaft.

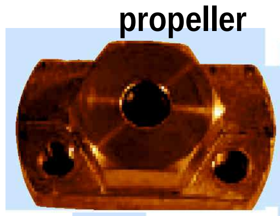


5 A housing half with propeller in place, mid-section with bevel gear and zinc anode. The other half housing is attached with six bolts

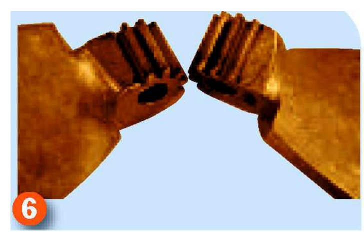
6 The central bevel gear in mid-section, with which pitch adjusted. The position of the punch marks is read from table with ref. to letter.

Rotating blade propeller

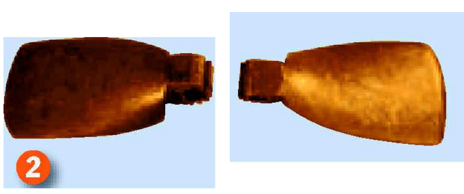
1 Folding propeller boss. It is initially bolted to the shaft



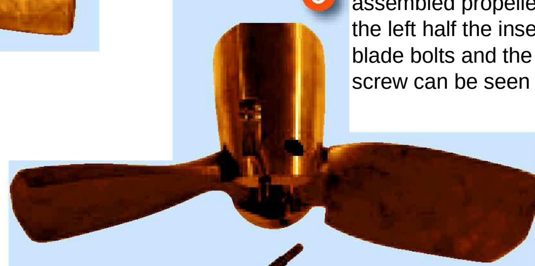
4 Shaft nut safety screw and grub screw, which additional secure the shaft nut



6 Due to gear connection the propeller blades move synchronously when folding in and out

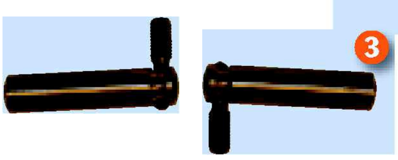


2 The blades are placed in the boss and secured with bolts



5 Almost completely assembled propeller. In the left half the inserted blade bolts and the safety screw can be seen

7 Viewed from behind the inner gearing can be seen in the boss, which engages with the Saildrive shaft gear



3 Two blades with bolts safety bolts, which secure the bolts in position

now put the indicated engine state to reverse for a short period so as to stop the shaft. Now select neutral again.
Whether or not during this manoeuvre the sail should be hoisted, is not in the instructions.

(Almost) all theory is grey

These values and observations cannot be transferred 1:1 to every other yacht-engine-gearbox combination. The individual factors have such different influences on boat performance. If the towing resistance is a comparatively more stable value which cannot be altered positively or negatively, it is seen differently

The Gori "Racing-Propeller" : closed. The non-existent drag can be visualised

in the bollard pull test: Here one can read a definite trend, which is given by the blade geometry and construction, variations can arise due to engines with different torque curves of other drive differences.

Result

How great the actual speed improvement in the water with a hydrodynamically optimised propeller is, one cannot say with scientific certainty if the exact drag curves for the actual yacht are not available. With estimated values based on experience the screws can depending on sailing speed achieve at least another half knot. And that can bring a decisive advantage not only in regattas, but also for sailing trips the greater range alter cruise planning considerably.

Those putting maximum value on sailing performance, cannot bypass these screws.

even if one, in comparison to fixed propellers, one must invest more heavily. Finally the pleasure in sailing is increased at least quadratically with every small increase in speed. We have attempted to put screws in to three categories on the basis of their characteristics:

1) The sail prop: It should firstly have low drag and manoeuvrability is secondary.

2) The engine prop: It should give good performance under power, both forwards and astern and at least 800 N should be developed.

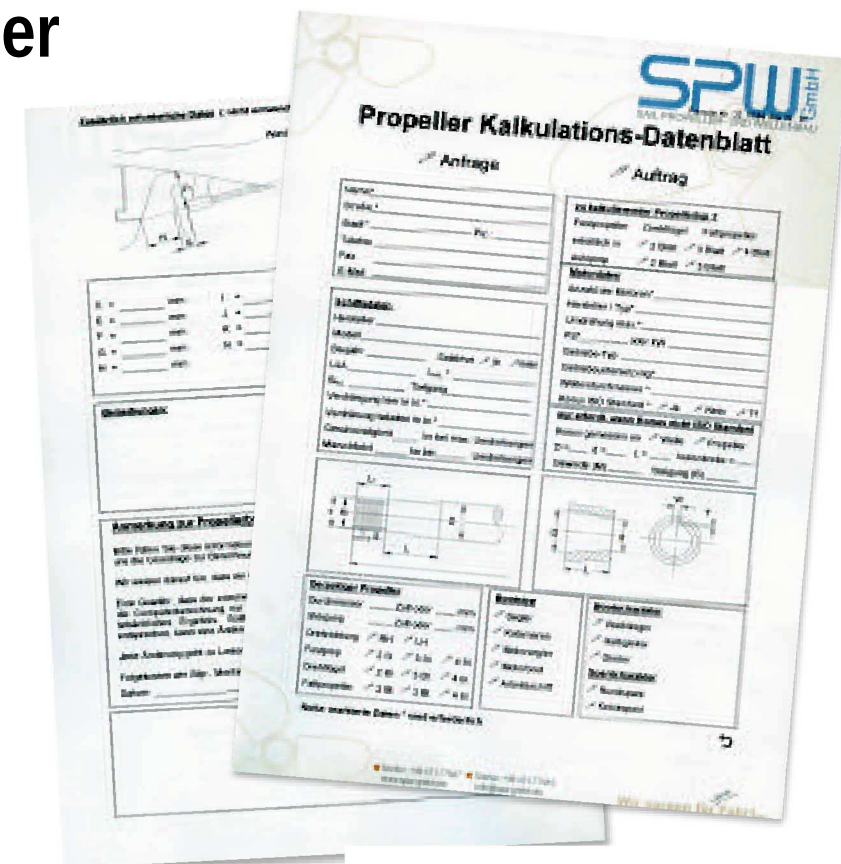
3) The compromise: It is characterised by good engine performance with low drag. X

The correct propeller

If the boat does not attain the specified maximum speed at the specified engine revs or the engine under full load starts to smoke and soot the incorrect propeller could be fitted. An incorrectly specified propeller can also considerably increase the fuel consumption if one has to operate permanently at higher revs to achieve a given speed. In such cases in order to calculate the correct screw the propeller manufacturer must amass a multitude of data on ships. In an ideal case one can find propeller sizing data for popular boat and engine types in a data base. For lesser known boat types the calculation is more difficult. In this case the experience of the propeller expert is important.

As well as type of ship and boat character (round hull,) ship's data such as overall length, length and beam at the water line and above all for a yacht, the displacement is important.

For boats with shaft, the position of the propeller relativeaddition several other distances must be known: The blade tip distance to the underside of the hull is just as important as the distance to the rudder or skeg. The propeller must be able to fit in to such a tight space.



To calculate the correct propeller masses of data must be obtained.