

Boat optimization and preparation

Karl-Hanne Tagu

About me

- ▶ Boat captain and project manager of Katariina II sailing team
- ▶ ORC national measurer in Estonia
- ▶ Sailing experiences in ORC, Match Race, Melges 24, J70, Star Sailors League and ice-boating



Fast Boat - Sail high average

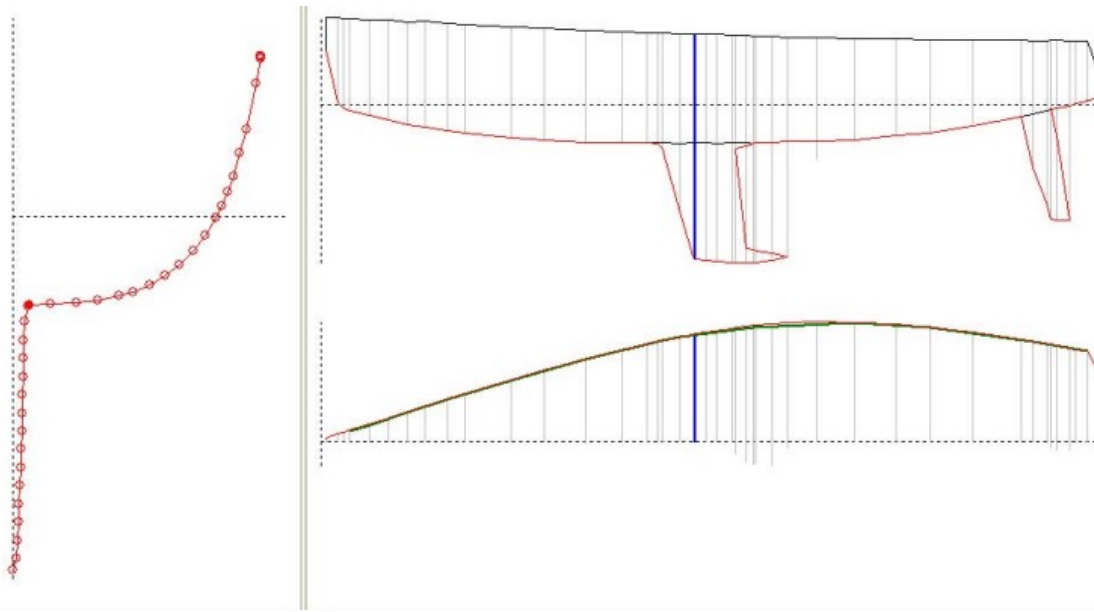
- ▶ Well balanced and easy to trim - get feedback from boat
- ▶ Able to sail fast on all courses, wind condition and sea state - all-rounder
- ▶ Boat is well maintain and take cared. All system works perfectly
- ▶ Good sails with nice/new shape
- ▶ Optimized in two way- relatedly good performance vs rating ratio - not downgraded or rating saver mode and but still fast

ORC international

- ▶ For International regattas, based fully on International measurement system.
- ▶ Based on a complete boat measurement
- ▶ Validated offset file (Hull scan or Designer file with correct FB point)

ORC club

- ▶ For national and club level, administered locally to keep it simple
- ▶ Data may be declared by the owner or obtained (might be worse than ORCi data)
- ▶ Can be used with not validated offset file, sometimes even from similar boat.



ORCclub data and optimization at first level

- ▶ Certificate include alldata, no empty boxes:
 - ▶ Righting moment and if possible add unit trim
 - ▶ Mast weight, center of gravity and cross section
 - ▶ One/furling headsail (genoa)
 - ▶ Adjustable backstay or not
 - ▶ Rated SPL shall not be taken less than J. Rated TPS shall not be taken less than $J + SFJ$
- ▶ Boat, rig and sail are measured correctly (both ORCi and ORCclub).
- ▶ Remeasure your brand new sails after couple of use.
- ▶ Get rid of the biggest sails, which you do not use.

Propeller Data

- ▶ Propeller data (folding or solid)
 - ▶ PIPA shall be the propeller installation projected area calculated on propeller type, installation and measurements

PROPELLER					
Propeller Type	Folding 2 blades				
Installation	Strut	PRD 0.452	EDL 1.930	ST3 0.180	
Twin screw	No	PBW 0.117	ST1 0.065	ST4 0.110	
Hydro generator	No	PIPA 0.0040	ST2 0.180	ST5 0.350	

Woven polyester (dacron)

► Rating advantage

LOW TECHNOLOGY SAIL CLOTH

When the sails are made of low technology material, as woven polyester sail cloth, a credit is applied to the mainsail coefficients, by slightly modifying both drag and lift coefficients by the following amounts: The credit has

β	0	7	9	12	28	60	90	120	150	180
dcd	0.0028	0.0028	0.0028	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0
dcl	0.0000	0.0284	0.0284	0.0284	0.0284	0.0085	0.0	0.0	0.0	0.0

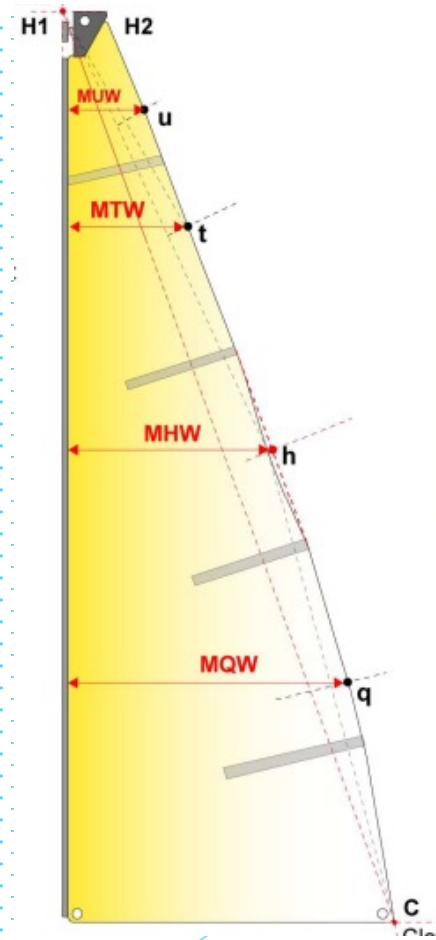
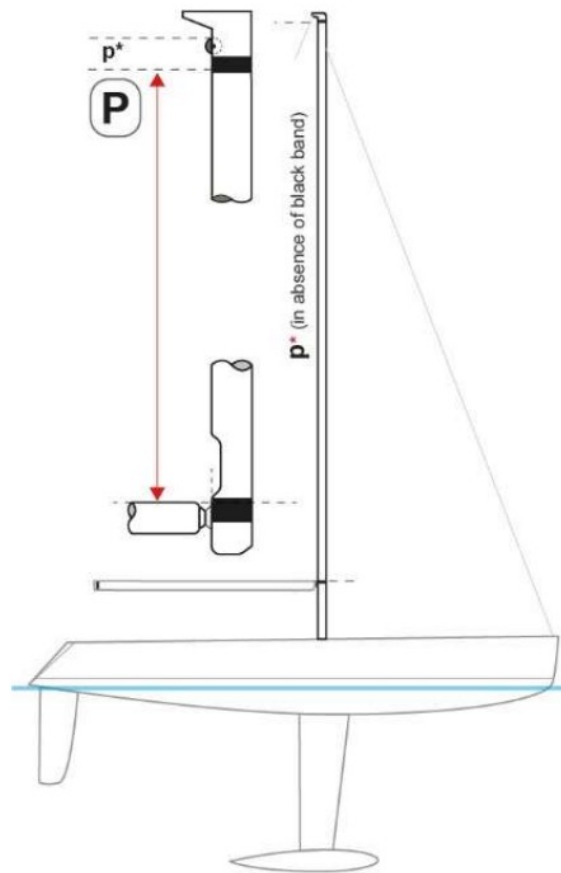
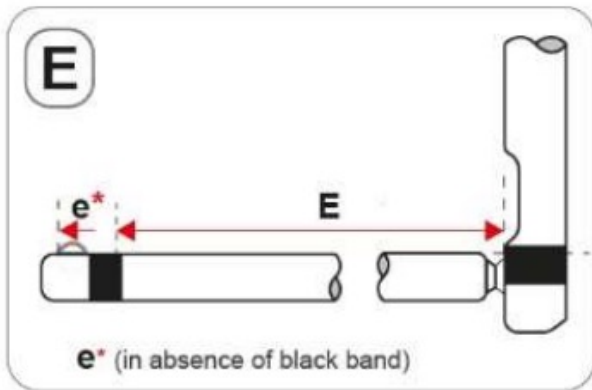
TABLE 5.3: Mainsail low tech material credit

FIGURE 5.9: Alternative Jib Force Coefficient

AWA	7.0	15.0	20.0	27.0	50.0	60.0	100.0	150.0	180.0
Delta Cl	0.0	0.10	0.10	0.05	0.00	0.00	0.0	0.0	0.0

Mainsail area:

$$\text{Area} = \frac{P}{8} \cdot (E + 2 \cdot MQW + 2 \cdot MHW + 1.5 \cdot MTW + MUW + 0.5 \cdot MHB)$$



ORCi for International level

- ▶ What is your target?
 - ▶ Offshore
 - ▶ Inshore
 - ▶ Racing level, where you are aiming
- ▶ What is your budget?
 - ▶ Sails - different type of sails, some spare sails for lower level regatas and good one for high level.
 - ▶ Boat maintenance and upgrade
 - ▶ bottom fairing - long bording, base layers are correctly prepared and bottom has to be smooth as silk.
 - ▶ anti fouling paint needs to be cleaned regulary
 - ▶ Make sure keel and rudder has profile as desinged, if needed reprofile them.
 - ▶ halyards - if you use advanced sail cloths, use good quality ropes for halyards and sheets
 - ▶ trimming systems. Makes sure all systems Works and can be easily use while racing.
 - ▶ Shrouds (wire/rod/composite), make sure you can adjust them and have controll over your mast
 - ▶ Electronics - Works and show correct data.. This most importat data for analysis and improvment or making tactical calls on race the track

Rebuilding

- ▶ Rebuild (hull reinforcement, new foil/keel, mast, rudder, systems).
 - ▶ Stiff hull and have control over your mast or sails
 - ▶ Keel
 - ▶ work with performance vs rating
 - ▶ Increase the righting moment (more stability)
 - ▶ Working with profile to increase the performance (Lift/drag)
 - ▶ Rudder
 - ▶ Better performance, reduce drag or improve boat handling
 - ▶ Work with performance vs rating
 - ▶ Complex systems
 - ▶ Mastjack, hydraulic headstay etc.

Keel re-profile



Comparison for input

- ▶ Compare your boat strenght and weakness against your opponents
 - ▶ Light vs strongwind
 - ▶ Upwind vs downwind
 - ▶ Pointing vs speedmode
 - ▶ Lowmode vs VMG (downwind)
- ▶ Opens first discussion for optimisation
 - ▶ Working with sail plan
 - ▶ Working with ballast
 - ▶ Working with appendages
 - ▶ Working with trim ability

ORCi for International level

- ▶ Understand reasons why you are slow or fast - figures and ratios
 - ▶ RM (displacement/RM) (RM/Upwind sa)
 - ▶ Upwind Sa (Sa/displacement) (Sa/wetted area)
 - ▶ Downwind Sa (Sa/displacement) (Sa/wetted area)
 - ▶ Boat balance (Upwind/ Downwind/ Reaching)
 - ▶ Rating/Performance (Compare your boat different setups and test certificates).

HULL AND APPENDAGES (Lightship Trim)

Class Italia 11.98	LOA 11.650	VCGD 0.169
Measurement 10.06.2022	Max. Beam 3.972	VCGM 0.115
HIN	Draft 2.099	RM Rated (kg·m) 161.3
Plan review	Displacement 6,472	Limit of positive stability(°) 117.1
Hull construction Cored	Wetted area 28.98	Stability Index 115.6
Carbon Rudder Yes	IMS L 10.429	
Light stanchions No	LSM0 10.039	
Trim tab No	Acc. length 11.650	
	Sink (kg/mm) 21.57	

SAIL AREAS (m²)

	Measured	Rated
Mainsail	48.02	49.25
Headsail Luffed	40.73	40.73
Headsail Flying		
Symmetric		
Asymmetric	140.62	140.62

(1 asymmetric(s) with SHW/SFL < 85%)

Comparison of different ratios

YACHT	GPH	CDL	Loa	B max	Loa/B	Δ	Ws	RM 0°	RM/D	Crew	Crew/	MWT	MCG	M inerz.	L	L/Loa	DRAFT	Ws D				
Vesikaar 2019	629,5	9,007	9,99	3,296	3,031	4445	23,1	100,5	2,261	690	0,155	132,5	4,9	3181	9,535	0,954	2,249	8,585				
Vesikaar Suurem groot	-	-	9,99	3,296	3,031	4445	23,1	100,5	2,261	690	0,155	132,5	4,9	3181	9,535	0,954	2,249	8,585				
Jazz	640,1	8,683	9,98	3,372	2,960	4 440	22,13	100,6	2,266	720	0,162	116	4,4	2246	9,051	0,907	1,989	8,230				
SUGAR (ITALIA 998)	624,6	8,827	10,3	3,536	2,913	4 412	23,22	107,7	2,441	630	0,143	120,2	5,09	3114	9,392	0,912	1,898	8,672				
KATARINA II (ARCONA340)	618,2	9,083	10,41	3,476	2,993	4 621	24,98	137,9	2,984	660	0,143	137,9	4,450	2731	9,398	0,903	2,113	9,046				
Cherie	626,1	9,146	10,66	3,636	2,932	5 631	26,12	125,8	2,234	644	0,114	124	4,08	2064	9,716	0,911	2,202	8,291				
Directo	625,2	8,9	10,3	3,536	2,913	4 691	23,7	107,4	2,289	640	0,136	144,1	4,99	3588	9,451	0,918	1,908	8,497				
Silva	629,6	9,201	10,64	3,458	3,077	5 780	25,3	135,5	2,344	665	0,115	149	5,10	3875	9,632	0,905	2,232	7,892				
Matilda 4	595	9,595	11	3,596	3,059	5 170	25,56	117,0	2,263	770	0,149	108,5	4,47	2168	10,038	0,913	2,043	8,589				
YACHT	GPH	LPG %	P	E	P/E	Main measure d area	Ig	J	I/J	J/Loa	Genoa	Spin measured area	Main Genoa	Genoa Rsat Up	Spin Rsat Dn	Sail Area Up	Sail Area Dn	SA Up ▽	SA Dn ▽	SA Up ws	SA Dn ws	RM 0/ SA'H
Vesikaar 2019	629,5	107	12,76	4,45	2,87	33,08	13,37	3,91	13,481	0,391	29,71	86,28	1,113	0,473	0,723	62,79	119,36	70,79	37,24	2,72	5,17	355,6
Vesikaar Suurem groot		107	12,76	4,75	2,69	35,5	13,37	3,91	13,481	0,391	29,71	97	1,195	0,456	0,732	65,21	132,5	68,16	33,55	2,82	5,74	342,4
Jazz	640,1	103	12,5	4,47	2,80	33,38	13,16	3,645	3,61	0,365	26,67	77,81	1,252	0,444	0,700	60,05	111,19	73,94	39,93	2,71	5,02	373,4
SUGAR (ITALIA 998)	617,2	104	13,04	4,8	2,72	37,41	13,66	4,2	3,25	0,408	31,6	94,04	1,184	0,458	0,715	69,01	131,45	63,93	33,56	2,97	5,66	337,2
KATARINA II (ARCONA340)	618,2	105	13,65	4,64	2,94	38,64	14,51	3,95	3,67	0,380	32,51	90,49	1,189	0,457	0,701	71,15	129,13	64,95	35,79	2,85	5,17	413,4
Cherie	626,1	105	13,88	4,73	2,93	39,35	14,39	3,98	3,62	0,373	31,15	90,04	1,263	0,442	0,696	70,5	129,39	79,87	43,52	2,70	4,95	371,5
Directo	625,2	105	13,08	4,8	2,73	36,63	13,72	4,215	3,26	0,409	31,46	88,84	1,164	0,462	0,708	68,09	125,47	68,89	37,39	2,87	5,29	340,7
Silva	629,6	132	13,5	4,6	2,93	36,21	14,09	4,01	3,51	0,377	36,66	87,95	0,988	0,503	0,708	72,87	124,16	79,32	46,55	2,88	4,91	388,3
Matilda 4	595	104	13,65	4,73	2,89	40,86	14,94	4,27	3,50	0,388	34,52	113,54	1,184	0,458	0,735	75,38	154,4	68,59	33,48	2,95	6,04	314,3

Time Allowances

- ▶ Make test-certificate (sailor service) and compare results
- ▶ Re-calculate the results with test-certificate.
- ▶ Make Time Allowances tabel and add other competitors.

Time Allowances in secs/NM							
Wind Velocity	6 kt	8 kt	10 kt	12 kt	14 kt	16 kt	20 kt
Beat VMG	699.1	586.6	543.1	519.5	504.9	495.6	487.2
52°	456.2	396.5	374.8	360.1	349.3	341.3	331.8
60°	430.0	380.1	356.5	340.7	329.6	321.4	310.8
75°	412.3	365.3	333.9	315.9	303.0	293.2	278.8
90°	417.3	368.6	330.4	302.6	284.4	270.7	251.7
110°	454.4	381.0	344.7	321.4	291.2	263.2	228.3
120°	467.3	385.2	339.2	309.6	288.4	270.2	234.6
135°	521.2	409.4	358.4	315.9	279.9	252.2	220.6
150°	627.0	484.4	409.2	363.1	322.8	285.6	228.3
Run VMG	724.0	559.4	472.6	419.3	372.7	329.8	263.6
Selected Courses							
Windward / Leeward	711.6	573.0	507.8	469.4	438.8	412.7	375.4
All purpose	542.5	448.5	402.2	373.0	349.3	329.7	302.5

- ToD (singel number) coefficients are calculated for the respective course model (Windward/Leeward or All-purpose) with the following wind strength distribution:

<i>TWS (kt)</i>	6	8	10	12	14	16	20
<i>Time Allowance percentage</i>	5%	10%	20%	30%	20%	10%	5%

Time Allowances tabel from certificate

YACHT	GPH	6	8	10	12	14	16	20	Data
Vesikaar	629,5	1029	834,8	719,4	653,8	619,7	599,7	570,6	2019
Jazz	640,1	1050,0	853,1	734,6	664,7	626,8	605	578,5	2019
SUGAR (ITALIA 998)	617,2	1004,4	814,9	705,9	649,4	616,8	597,8	568,9	2019
KATARINA II (ARCONA340)	618,2	1008,2	816,2	705,1	647,4	614,0	594,2	563,9	2019
Cherie	626,1	1026,5	832,4	718,3	653	617,0	596,7	569,0	2019
Directo	625,2	1025,7	832,7	718,3	655,6	621,5	601,5	573,9	2019
Silva	629,6	1022,2	833,8	721,2	654,2	617,4	509,3	463,7	2019
Matilda 4	595	967,3	783,8	678	625,8	595,5	576,3	545,2	2019

El

Advanced optimization with designer

- ▶ Explain to him what you want to achieve and how do you feel on the boat. Designer has never sailed with our boat.
- ▶ Get some data/log. Later you can do simulation with different VPP-s.
- ▶ Boat drawing is a must. Get it from yard or scan the boat.
- ▶ Make sure your boat is fully measured and data is correct
- ▶ Turning the building process, scale old and new equipment (make sure you are in the target).
- ▶ Involve your sail designer or someone who has been worked with you already.
- ▶ Make sure and know, what are you doing, otherwise the project will fail.

2023 changes

- ▶ Hydrodynamics - new residuary resistance model
- ▶ Aerodynamics - There is an updated de-powering scheme with removal of default righting moment
- ▶ Sail coefficients are updated for headsails set Flying (mid girth ratios from 50% to 85%)
- ▶ Internal ballast, if any, shall be permanently fixed below the cabin sole, or as low as possible.
- ▶ Default righting moment is removed from Rule 107.4 and is replaced with an estimated righting moment that is used where righting moment is not measured or is obtained from another source.
- ▶ Maximum number of mainsails allowed aboard while racing is increased from 1 to 2 (Same P and E)

HSF- Headsail set flying

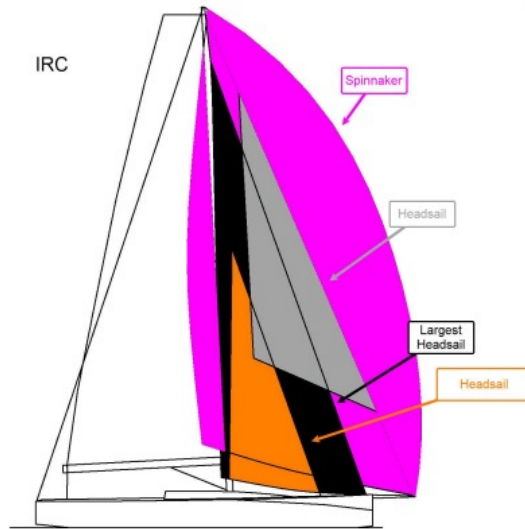


Headsail set Flying: ORC vs. IRC

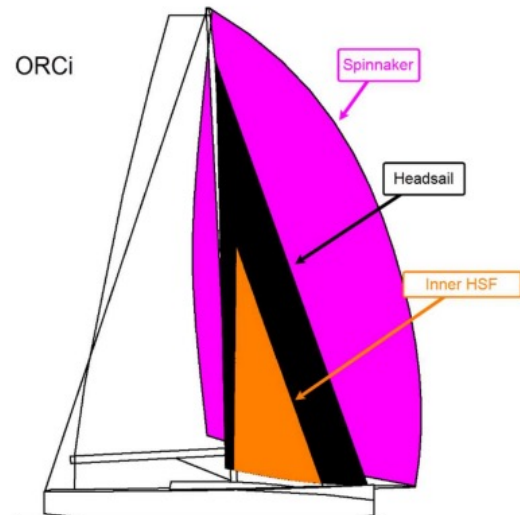
ORC:

- Symmetric spinnaker/ A-symmetric spinnaker - mid-girth at least 75%
- Inner stay (spinnaker staysail and genoa staysail)
- Headsail set Flying, can be use front of headstay (rating increase)

Whilst a **Spinnaker** is set, **IRC** permits any number of **Headsails** to be set.
(See Appendix B)



Whilst a **Spinnaker** is set, **ORCi** permits any number of **Headsails** and **Headsails Set Flying** to be set on or aft of the forestay. (See Appendix A Rule 208.2)

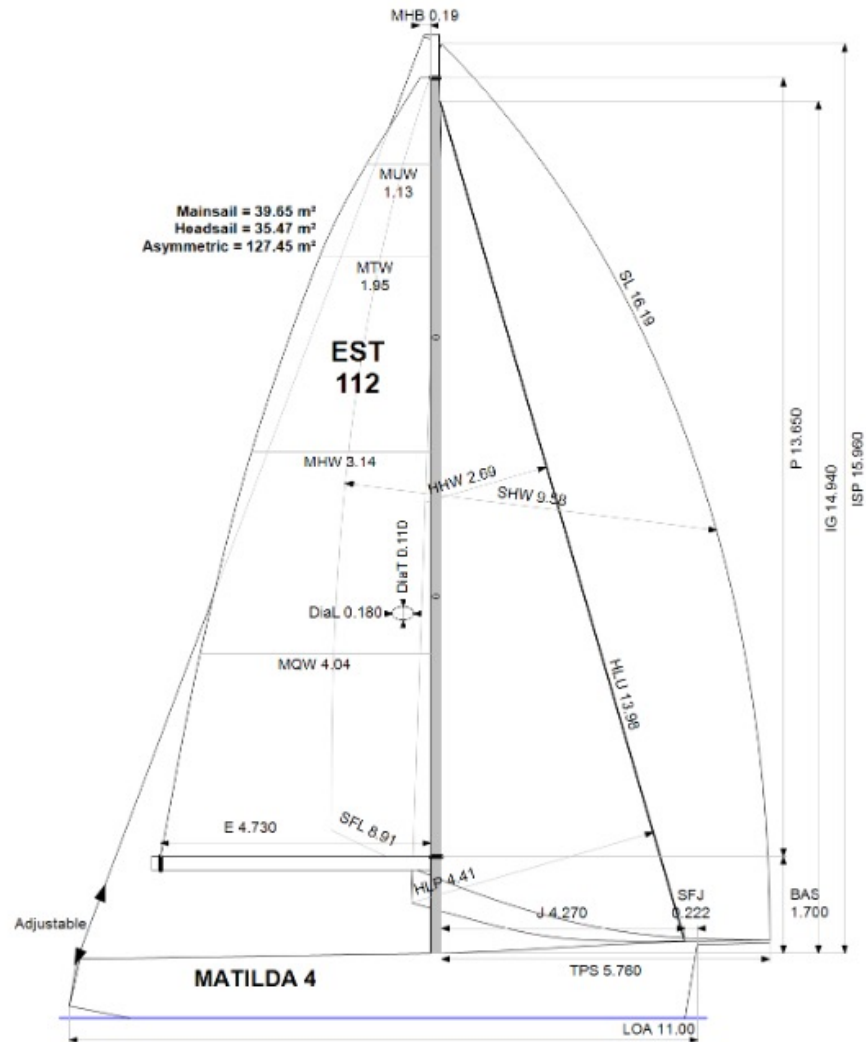


Square top vs Pin tip

- ▶ The roach will proportionally increase the rated area from the measured area by giving the exact area and centre of effort height for square top and other high roach main sails.
- ▶ Effective rig height - fractionality, overlap and roach- are determined in order to calculate the effective rig height which determines the induced drag of the sails.
- ▶ Square top pros and cons (theory):
 - Shorter leech, easier to trim and twist
 - Better center of effort against center of lateral resistance. More sensitive rudder balance
 - With double backstay more sail area
 - less effective (shorter span)
 - Stiff and heavy top



- ▶ P + BAS shall not be less than the greater of $0.96 \cdot IG$ or $0.96 \cdot ISP$
- ▶ Matilda: $P+BAS=15,35$; $0,96 \cdot ISP=15,33$



REDUCTION IN DRIVE FORCE FROM LARGE SPINNAKERS IN LIGHT AIRS (SHAPE FUNCTION)

- ▶ The SHAPE function was introduced some years ago as it is an observed effect that large spinnakers are particularly inefficient in light airs. To address this “type-forming” towards smaller spinnakers, a power loss factor for larger sails was developed so reducing the effective area of a spinnaker that is bigger than the “reference area”.
- ▶ The shape function reference area has a head angle relationship as well as being related to ISP and TPS in order to bring in the effect of gravity making it harder to fly a lower aspect ratio sail
- ▶ The formulation ensures that the “rated area” increases slightly with the increase of TPS/SPL or ISP

Some examples, how the kite will fly



A-symmetric vs symmetric

1. Symmetric spinnaker on pole only
 2. Asymmetric spinnaker tacked on CL
 3. Asymmetric spinnaker on pole , asymmetric on CL and symmetric on pole (mix)
- ▶ A-symmetric faster in light wind and reaching
 - ▶ More design sensitive (rig height, sheeting point)
 - ▶ Setting a tack on centerline, will reduce the rating.
 - ▶ In stronger wind rating will reduce, but in light you pay in rating.
 - ▶ Symmetric faster in medium and stronger wind and deep angles
 - ▶ Less design sensitive more option trim (afterguy, down/uphaul and barber)
 - ▶ Spinnaker boom itself will penalize
 - ▶ In lighter wind rating will reduce, but in strong you pay in rating.

Fixed Ballast/lead

- ▶ Easiest and cheapest way to change your rating without cutting and buying new gear. Lead cost euros 2,5-3,5 per kg and it is resellable
- ▶ Internal ballast, if any, shall be permanently fixed below the cabin sole, or as low as possible. Permanently fixed is considered firmly secured by bolting or gluing that prevents any movement while racing (rule).
- ▶ Changes of ballast in amount or location or configuration requires new measurement and issuing a new certificate (rule).
- ▶ Ballast increase boat displacement and wetted area - which reduce your rating
- ▶ Increasing boat displacement will also increase the RM -which increase the rating little
- ▶ Higher the displacement will increase risk to increase stress for hull, mast and sails.

Sailor service - WWW.ORC.ORG

Making a test certificate

► Adjusting the freeboards

FLOTATION AND STABILITY

Calculation method	Boom inclining	SFFP	0.000	SAFP	11.642	W1	110.3	PD1	273.6	WD	5.125
Flotation Date	11.06.2022	FFM	1.239	FAM	0.382	W2	110.3	PD2	273.7	PLM	9000.00
Measurer	FIV-174	FF	1.228	FA	0.398	W3	110.3	PD3	275.0	GSA	1.0
Comment	POZZUOLI	LCFcl	6.391	LCFsh	6.642	W4	110.3	PD4	274.1	RSA	1.0
		SG	1.0260	HBI	1.331	LCFD	6.975			RM	162.5

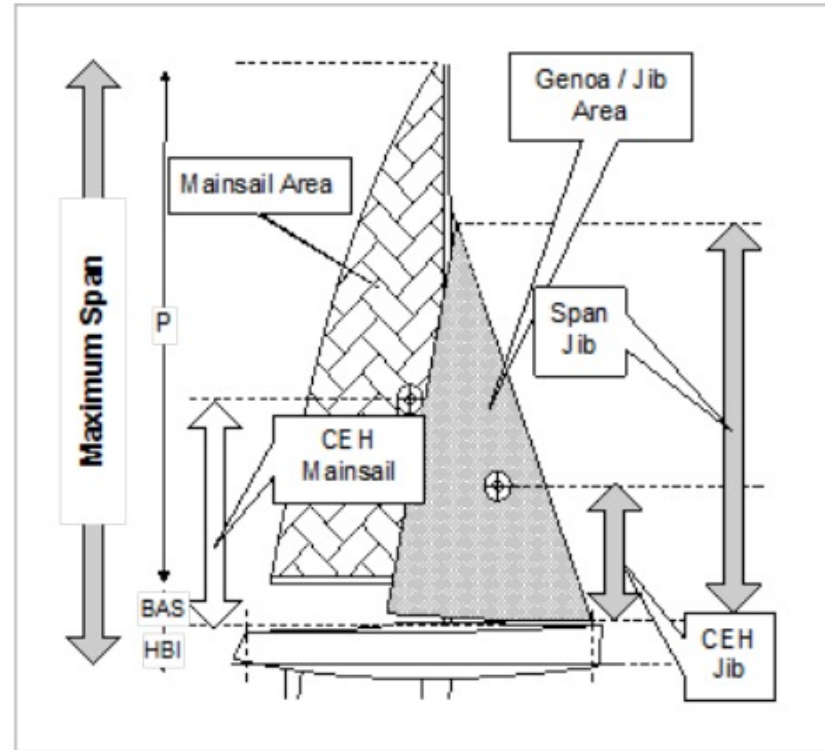
HULL AND APPENDAGES (Lightship Trim)

Class	Italia	11.98	LOA	11.650	VCGD	0.169
Measurement	10.06.2022		Max. Beam	3.972	VCGM	0.115
HIN			Draft	2.099	RM Rated (kg·m)	161.3
Plan review			Displacement	6,472	Limit of positive stability(°)	117.1
Hull construction	Cored		Wetted area	28.98	Stability Index	115.6
Carbon Rudder	Yes		IMS L	10.429		
Light stanchions	No		LSM0	10.039		
Trim tab	No		Acc. length	11.650		
			Sink (kg/mm)	21.57		

Genoa vs Jib

Centre of effort height:

- ▶ Sail area
- ▶ Headsail overlap
- ▶ IG/Sail span
- ▶ De-powering and flating headsails and main sail to be more accurate in different conditions. (according 2022 AMG notes de-powering is bigger with 2023 VPP).



First 36,7 (2022VPP) Genoa vs Jib:

Windward / Leeward	973.8	796.3	694.4	651.1	629.6	606.8	580.8
Windward / Leeward	991.1	809.3	702.7	655.3	633.2	610.3	581.9

Headsails

- ▶ Aerodynamic lift coefficients of the VPP calculation will be selected for different conditions as follows:
- ▶ a) Headsail set on the forestay
- ▶ b) Headsail set flying
- ▶ c) For asymmetric spinnakers with SHW/SFL in range of 0.75 - 0.85 aerodynamic forces are calculated with both coefficients for the spinnaker and for the headsail set flying with one giving faster boat speed taken as final.

Perfromace vs cruising

- ▶ Age Allowance (AA) is a credit for age of 0.0325% of ratings increase for each year from Age or Series Date to the current rule year up to maximum of 15 years (0.4875%)
- ▶ Dynamic Allowance (DA) is a credit representing the dynamic behaviour of a boat taking into account performance in unsteady states. DA is applied to the ratings of all Cruiser/Racers, as well as any Performance boats with a Series Date older than 30 years

Cruiser Racer

- ▶ The purpose of these regulations is to define requirements for categorizing boats as Cruiser/Racers controlling the cost, promoting safety and crew comfort.
- ▶ All systems relating to living, eating, sleeping, and stowage specified in these regulations shall be arranged in a manner suitable for cruising use and shall operate so as to provide the service function normally associated with the system. Items shall be presented as they are intended to be used
- ▶ Before you are going to remove items from board, read „INTERNATIONAL MEASUREMENT SYSTEM“ Appendix 1 - CRUISER/RACER REGULATIONS

CDL

- ▶ Class Division Length (CDL) is the average of the effective sailing length (IMSL) and the rated length (RL) that is calculated from the **upwind speed** of the boat in a **True Wind Speed of 12 knots**. It is used for class divisions as a combination of the boat's upwind speed and length.

The Class Division Length is then calculated as follows:

$$CDL = \frac{IMSL + RL}{2}$$

The transformation in length of the UPWIND12 allowance is obtained with the following formulation:

$$VMG_{UP12} = \frac{3600}{UP12} \cdot 0.5144 \quad \text{where } VMG_{UP12} \text{ is boat upwind speed in m/s at 12 kts wind}$$

$$RL = \frac{VMG_{UP12}^2}{F_n^2 \cdot 9.81} \quad \text{where RL is rated length and } F_n \text{ is Froude number set at 0.28}$$

Crew weight

- ▶ The owner may accept the default calculated weight, but can declare any crew weight which shall be recorded in the certificate
- ▶ The declared crew weight is used to compute increased righting moment while default crew weight will be used to compute sailing trim displacement.
- ▶ The default value for the Crew Weight (kg.) is calculated as follows:

$$CW = 25.8 \cdot LSMO^{1.4262}$$

- ▶ The righting moment balances the heeling moment produced by the sailplan, and is the sum of several components:

$$RM = RM_{\text{hull}} + RM_{\text{crew}} + RM_V + RM_{\text{movableballast}} + RM_{\text{DSS}}$$

Any change of the measurement data requires new measurement and issuing a new certificate. Such a change may be:

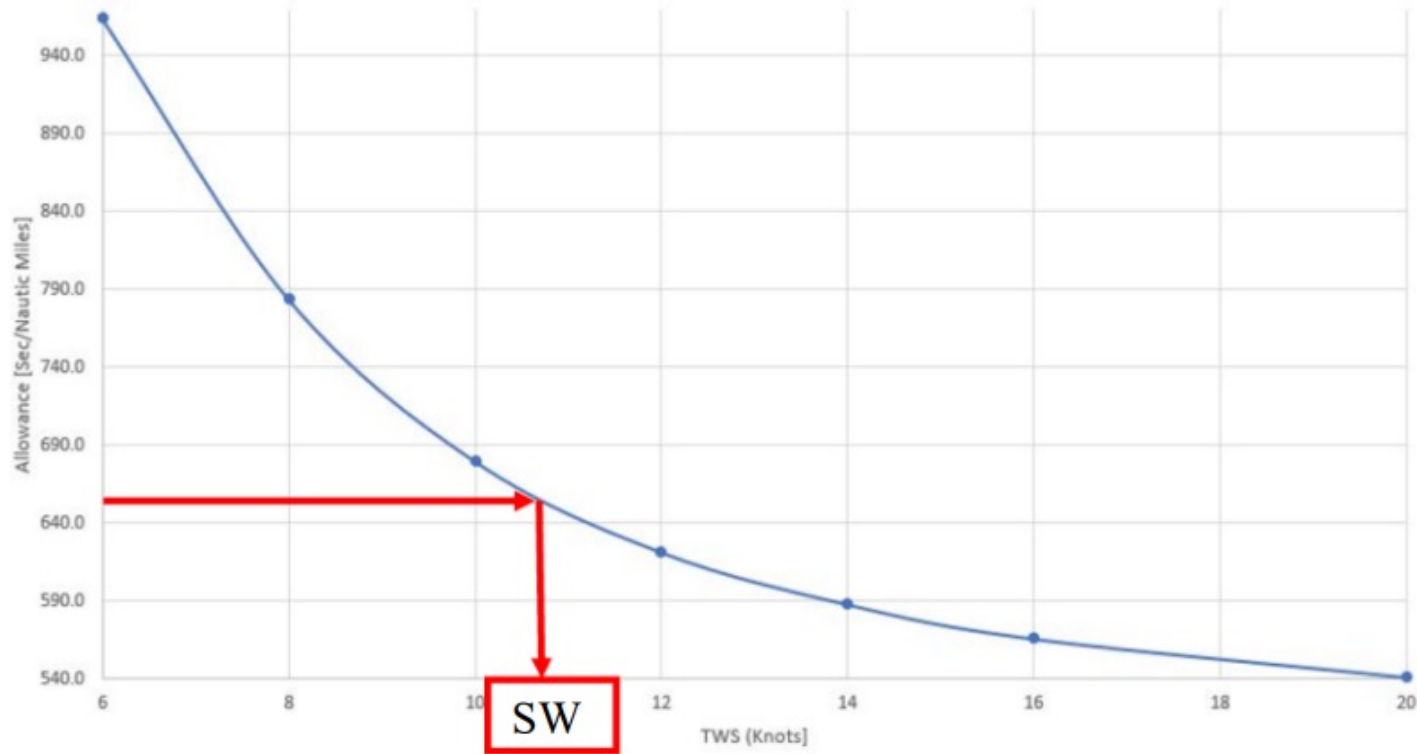
- ▶ a) Changes of ballast in amount or location or configuration.
- ▶ b) Change of tankage, fixed or portable, in size or location.
- ▶ c) Any changes in the engine and/or propeller installation.
- ▶ d) Addition, removal or change of location of gear or equipment, or structural alteration to the hull that affect the trim or flotation of the yacht.
- ▶ e) Movement of any measurement bands used in sail area measurement, or any changes in spars, spar location or headstay position.
- ▶ f) Any change to the size, cut or shape of the maximum area sails.
- ▶ g) Changes to the shape of the yacht's hull and/or appendages
- ▶ h) Changes to spars or standing rigging configuration, including elements of rigging identified as adjustable while racing.
- ▶ i) Changes to the other hull measurements in accordance with the ORC Rule 304.
- ▶ j) Any other change of the data in the certificate that affect any rating.

Scoring

- ▶ Singel Number
 - ▶ One number per mile or hour
- ▶ Triple number
 - ▶ Singel number Ligth/Medium/Heavy
- ▶ Peformance curve
 - ▶ Scoring wind

Single Number Scoring Options		
Course	Time On Distance	Time On Time
Windward / Leeward	650.3	0.9227
All purpose	524.7	1.1434

PCS- Performance Curve Scoring



Conclusion

- ▶ Sail much as possible - as input data
- ▶ Improve your sailing skill, together with that you increase the knowledge, how to make the boat faster (way cheaper than building complete new boat)
- ▶ Analyze your results and performance
- ▶ Try to understand what other boats are doing (optimizing) and analyze it as example
- ▶ Improve your boat and rating to sail faster, not only finding a better rating
- ▶ Try to improve your boat trimming ability, turn it as all-rounder
- ▶ Focus on simplification and high average boat speed