Weather and boat speed

It’s an obvious fact that the boat speed depends on the wind speed, direction and water temperature. Thanks to Klaus Filter (1) we can analyse experimental data, which was obtained in 1970-s in DDR. Klaus wrote: “The physical property or water changes depending on the temperature. … The mobility of water molecules decrease at lower temperatures”, which increases the frictional resistance. Fig. 1 shows that **<u>the boat speeds decrease by 1.3% (~4s over 2k), when the water temperature drops from 20^{o} C down to 5^{o} C</u>**. If the water gets warmer, up to 30^{o}, then the boat goes 0.6% faster (~1.8s over 2k). The power trend fits very well to the experimental data (R^2 = 0.99).

The wind resistance data was obtained using a wind tunnel. Klaus wrote: ”The system crew-boat above the waterline causes a resistance of approximately 13% of hydrodynamic resistance.” This means that the wind resistance comprises 11.5% of the total resistance. Boat and riggers contribute 15% to the wind resistance (1.7% of the total resistance), rowers’ bodies – 35% (4.0%) and oars – 50% (5.7%). “These shares can increase up to 4 times under headwind conditions and decrease to zero with a sufficient tailwind.”

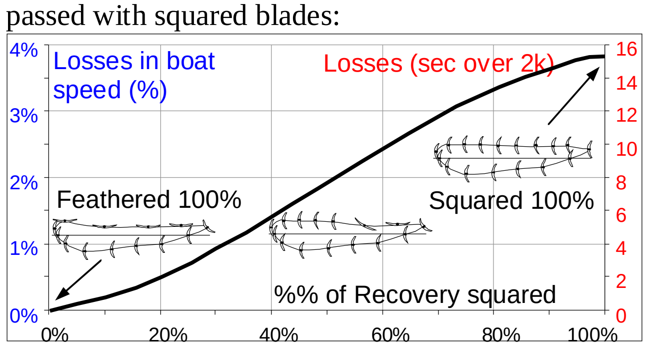
Fig. 2 shows that straight winds and winds at an angle of 30 deg to the boat have a higher effect on smaller boats: 5 m/s head wind makes singles 17.4% slower and eights 12.2% slower, tail wind of the same speed makes singles 7.5% faster and eights 5.1% faster. According to Klaus’s data, a cross-head wind at 60 deg has a similar effect on all boat types (about 10% slower at 5 m/s) and a cross-tail wind of the same speed is more favourable to smaller boats. Cross winds have a higher effect on bigger boats: 5 m/s cross wind makes singles 1.6% slower and eights 4.1% slower. The second order polynomial trends fit quite well to all experimental data (R^2>0.99) except 60 deg and cross winds in eights (R^2=0.93 and 0.53 respectively).

How can we check above data using results of World regattas? Fig. 3 shows that the winners’ speed normally lie within the range of ±5% from the average speed in the event. The slowest speeds (typically 8% slower than average) and the fastest speeds (3.9% faster) correspond to head/tail wind of 3-4 m/s according to Klaus’s data. Unfortunately, statistical data on weather conditions is not available, but we could estimate that the strongest winds had higher speeds (e.g. 5m/s wind is classified only as “a gentle breeze” n=3 on Beaufort scale). Therefore, it is possible that the presented charts slightly overestimate the influence of the wind. It is noticeable that the head wind has the highest effect on lightweight events, which is understandable due to their lower mass and power. Also, it looks like doubles are less affected by wind than pairs.

Above data allows us to build a model, which can predict the boat speed at various wind and water temperature conditions. The model was implemented as a Web application in combination with a rigging chart (http://www.biorow.com/RigChart.aspx).

What we can do to decrease wind resistance? Klaus recommends the following: “In crews where the height of the sitting athletes noticeably is different, the tallest should be in the bow to give the best coverage. … Crews should wear caps where they can cover their hair under stronger headwind conditions. The clothing has no influence as long as it does not flutter.”

We can add that **<u>the technique of the blade squaring/feathering is very important</u>**. During recovery the blade moves with a speed of up to 15 m/s (50 km/h), which is a sum of the boat velocity (it has the highest value during recovery and could be up to 7 m/s in M8+) and handle velocity (up to 3 m/s) multiplied by gearing ratio (2.3-2.4). The air drag of the blade is very significant because it increases with the square of the speed. If a rower squares the blade early during recovery, it increases the area affected by wind, which creates extra loss of the boat speed. The chart below shows the losses at various shares of recovery passed with squared blades:



<u>If the blade squared early at the middle of recovery, a crew can lose up to 10 s over 2k race at calm conditions and up to 30 s at head wind 5 m/s.</u>

References

1. Filter K.B. 2009. The System Crew – Boat. Lecture during FISA juniors’ coaches’ conference, Naples, 15-18 October 2009 (also on http://www.scribd.com/doc/21984934/klaus-Filter)

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Appendices.

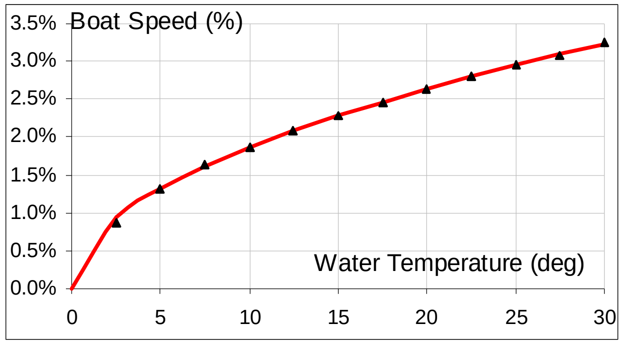


Fig. 1. Dependence of the boat speed on water temperature. Points – experimental data of Klaus Filter (1), line – fitted power trend.

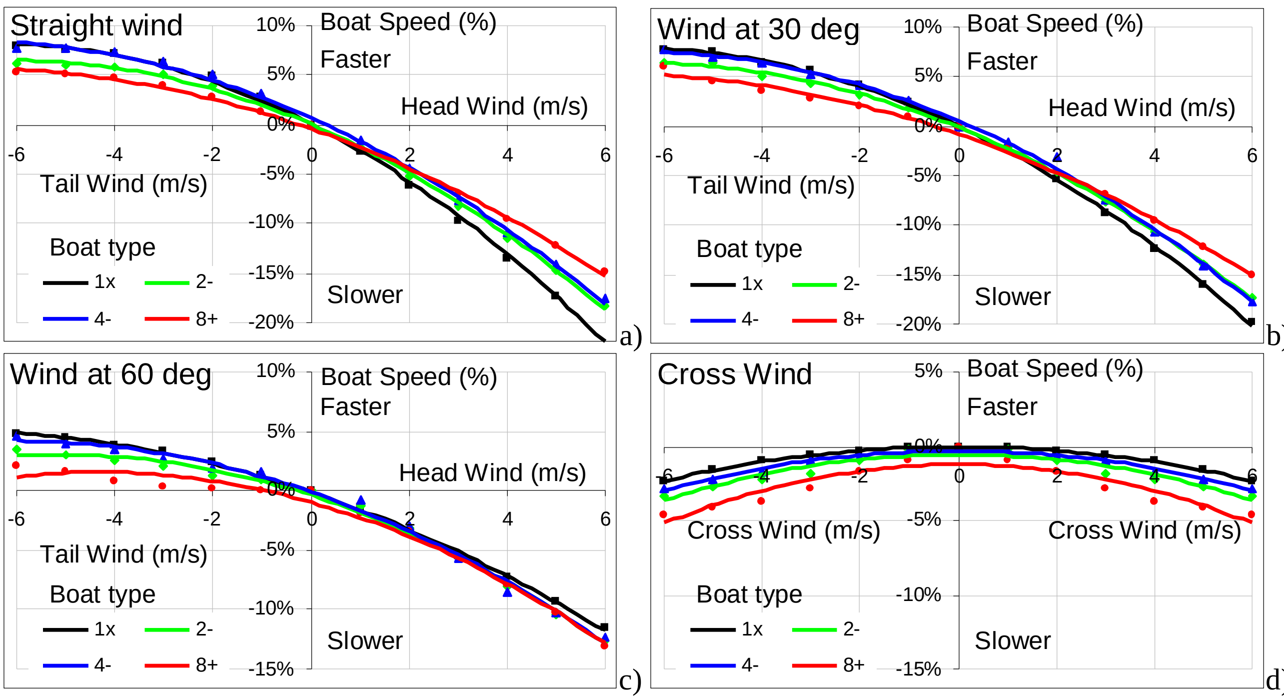
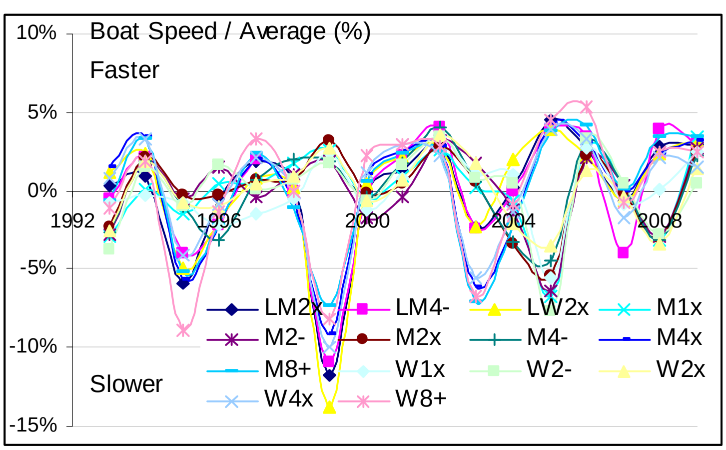


Fig. 2. Dependence of the speed of various boat types on wind direction and speed. Points – experimental data of Klaus Filter (1), lines – fitted second order polynomial trends.



Boat	Min	Max	Range
LW2x	-13.8%	3.9%	17.8%
LM2x	-11.8%	4.5%	16.3%
LM4-	-10.9%	4.1%	15.0%
W8+	-8.8%	5.3%	14.2%
W4x	-9.9%	3.9%	13.9%
M4x	-9.2%	4.2%	13.4%
M8+	-7.3%	4.1%	11.4%
W2-	-7.7%	3.5%	11.2%
M1x	-6.8%	3.4%	10.2%
M2-	-6.4%	3.1%	9.6%
W1x	-5.5%	3.5%	9.0%
M2x	-5.5%	3.2%	8.6%
M4-	-4.5%	4.0%	8.5%
W2x	-3.6%	3.5%	7.1%
All boats	**-8.0%**	**3.9%**	**11.9%**

Fig. 3. Variation of the boat speed relative the average in the boat type in the winners of World Championships and Olympic Games during 1993-2009.