Developing sails for the Olympics with Freddy Loof

WB-Sails shares here the development work behind Freddy Loof & Max Salminen's Olympic winning sails, and gives at the same time a perspective to modern sail development work in general.

In the past, sail development used to mean eye-balling the sails on the water, looking where creases & wrinkles would form, attempting to iron them out to get a profile as smooth and neat as possible. With the computer age, the game has changed: Now you can simulate the flying shapes of the sails, estimate forces produced, analyze cloth stress & stretch, measure the motions of the boat in a seaway, to optimize the sail shape over a wind range. It is still to some extent a trial and error game, but much less so than in the past.

Any sail development work is usually based on a previous, existing model as a starting point. We had worked with Loof earlier for the Beijing Olympics, but those sails were designed for very different conditions from what we could expect in Weymouth 2012. The English Channel is much windier, tides make the waves shorter and steeper, and as an additional feature of Weymouth, the wind usually blows over a coastline making it more turbulent. Also, the temperature difference between the water and the air influences the structure of the wind, which affects the optimal sail shape.

For London 2012, we were working with the Finn and the Star. We had no customers for 470 this time, and the rest of the Olympic classes are monopolies with no development work allowed.

Mikko Brummer (left) discussing the Star design with Martin Gahmberg (right).

The development team

WB-Sails is a tiny loft by comparison to other Olympic players (North, Doyle, Quantum), with three sail designers and 15 employees altogether. The sail design team comprises of Mikko Brummer, besides manager and owner, also head of R&D, Mikko's brother Otso, our Chief designer, Martin Gahmberg, the sail designer who was in charge of design work for Freddy's sails, and Joakim "Jocke" Wilenius, our senior sail designer in charge of the FInn and general development work. Martin was also coaching Fredrik Lööf and Max Salminen in many events and regattas, followed up with their training to record sail shapes and test rig trimming features, and provided all the on-the -water data for Mikko for computer analysis. Jocke assisted Martin sometimes in the data collection and design, although his main interest during the Olympiad was in the Finn sails, as he was also coaching in Finns. Practical matters concerning production are dealt by Pelle Kindberg, our one-design production manager.

Besides the WB-Sails staff, we should not forget about the sailors. The Star champions were mentioned earlier, on the Finn we had Tapio Nirkko, coached by Jocke Wilenius, likewise the Swedish Finn entry Daniel Birgmark, and also to a large extent French the Finn sailors Jonathan Lobert and Thomas Breton. The sailors' input is always crucial in a project at the top level.

Re-cutting the luff curve of a mainsail in Freddy's basement at lake Garda. Freddy eyeballing the curve, in the background sailmaker Pelle Kindberg and Max Salminen's blond hair. Pelle is in charge of the production of all the One Design sails at WB.

Shape analysis

The sail shape on the water, the flying shape in sailmaker's jargon, is recorded with video cameras, either in the mast head or on the deck.

The wind speed and direction is recorded simultaneously with the video taping, best with another synchronized video camera, focused on the wind instrument display in the coach boat following near by.

Sometimes a small, hand held wind meter is taped right under the camera, to show the wind speed in the same display with the sail. Video is necessary, to register the ever changing shape of the sail with boat pitching in the waves, and the wind data is needed to be able to compare different sails with exactly the same pressure on them.

The smallest difference in pressure bends the mast, sags the stay or opens the leech, affecting the shape of the sail. When comparing sails, still frames are picked from the video with similar wind data, for computer analysis. This time consuming job requiring tedious accuracy is often performed during the night-time after sailing sessions.

The shape of the sails is analyzed from the stripes glued on, either manually in a shape plot software, or more recently with the help of VSPARS. VSPARS is a software especially developed for the purpose by the David Le Pelley, manager of the famous Auckland twisted flow wind tunnel.

VSPARS does the scanning of photos automatically, provides an average shape of hundreds of frames (if you like) and what's best, provides direct 3D-coordinates of the sail & rig for the computer study. A real bonus to have if you have lots of analyzing to do and hundreds of 3D sail models to create.

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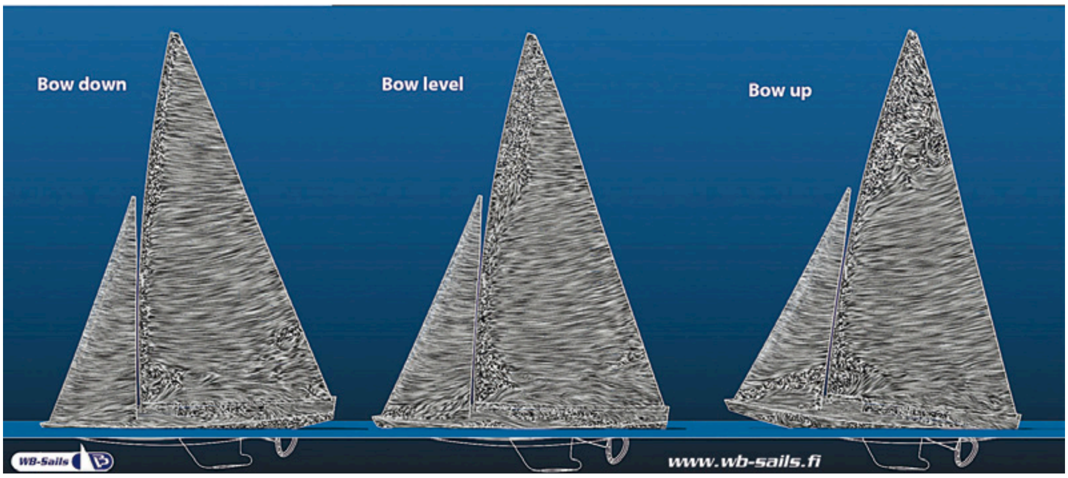
Aerodynamics & simulation

All this preparatory work is needed to get to the point: The aerodynamical optimization of the sails. CFD ((Computer Fluid Dynamics) is used to calculate the flow field around the sails, and from the flow field the forces & moments applied to the rig & boat.

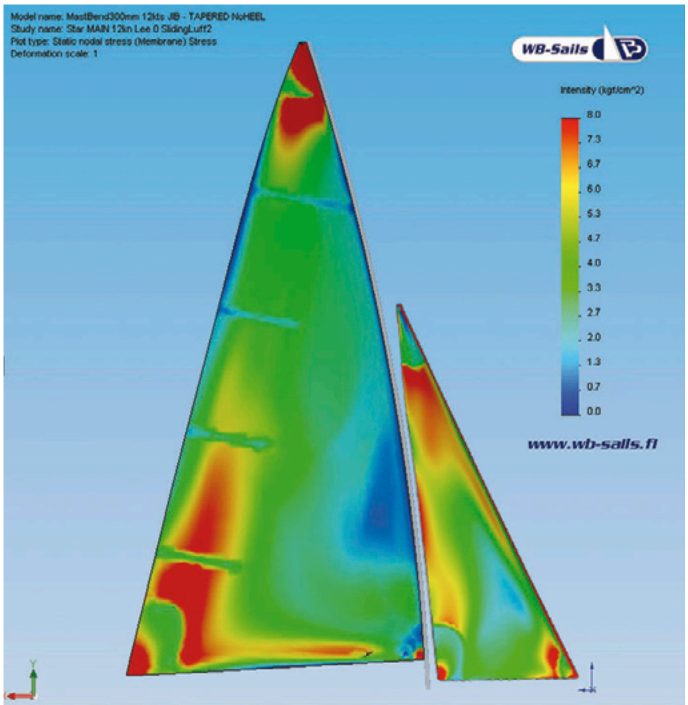
The progress in the field of computer flow simulation has been remarkable during the last decade. For the London preparation, we added the boat's motion in waves into our simulation toolbox, and effects of the motion on the sail airflow - previously within reach of supercomputers only. The demand on computing resources has increased: at WB-Sails, we have in practice one workstation running 24/7 on aero-analysis, year in and year out, for the whole Olympiad, while another is used for analyzing the results and preparing the next model for a run. Most of the work is focused on the Finn and the Star. Allowing for the motion also requires more data collection: The simulation needs the pitching, heaving and rolling motions around all axes as input. The motions are measured with a device called IMU (inertial motion unit), made by Cosworth and similar to the one used for monitoring G-forces on Formula 1 racing cars. The simulation can be used for studying the effects of different wave driving techniques, in addition to the aero-work.



Computer simulation of the boat passing over a wave. Orderly, more or less horisontal patterns on the surface of the sail depict attached flow, the chaotic regions represent areas of flow separation. This kind of simulation allows us to study also the effect of steering over the waves, and the average forces as well as the instantaneous force available to drive the boat. The way to present the flow pattern mimics that of a wind blown sand. When the bow is climbing up the wave (on the right), the mast head swings back, the local apparent wind angle increases towards the head and the head is momentarily stalled, as witnessed by the chaotic flow region. There is also a separation vortex forming from the tack of the jib. When the bow is level at the crest of the wave (middle), the sails are less loaded with a more orderly flow. As the bow goes down (on the left) the apparent wind goes further forward and flow is attached but on the narrow region along the mast.

Stress and strain - material choices

The choice of sailcloth is crucial to the design of the sail. WB-Sails has been working since mid-70s with Contender, a Dutch cloth supplier. We tested many different cloth weights and finishes in different parts of the sails, and also countless different cuts, from small variations to a completely new radial design, which Max Salminen eventually picked for his jib in London 2012. The sailcloth needs to be stiff, but not too stiff, since its stretch is exploited in controlling the shape of the sail from light winds to heavy. The stress and the strain (stretch) is also simulated in the computer, with the help of FEA (finite element analysis). Cloth properties vary from one roll to another, and even within one roll. We also simulated the effect of batten stiffness: It is important for the leech roundness, and the top batten influences the mast bend. The FE-analysis also tells the corner loads of the sails and the loads transmitted into the rig - this knowledge is used in evaluating rig trim effects. In case of the FInn, we developed a whole new cloth prior to Beijing 2008, MAXX, for the sail. For 2012, we had a new version made, a little stiffer yet still as light, and it did prove itself as a more allround material than the old one, increasing the wind range of the sail.



Computer simulation of the stress intensity in Star sails
Red= highly stressed areas, blue= lightly stressed areas.
You can clearly see the effect of the corner reinforcements and the battens.

Espionage and practical work on the water and in the loft

Despite all the technological advances (and hype), the most important factor in sail development is still the human factor. There can be no successful development without on-water testing and interaction between the sail designer and the sailors. WB-Sails has been lucky to have had such a long term relationship with Olympic sailors. With Freddy Loof we started in 1994, when he was still sailing Finns. Freddy's sail designers, Martin and Joakim, were also more than occasionally his coaches, following on the race course and during practice sessions, at the same time taking photos and watching what the competition was doing. Besides the shape, the optimization work includes plenty of technical details, such as fittings, rings, luff-tapes and ropes etc., and here rival sailmakers' innovations are quickly copied. The sailors always have the last word on what is working and what is not. At the Olympic level, they have an amazing feel for the smallest variations and can give feedback at an amazing accuracy, they have such a good understanding of their boat. For Freddy and Max, we cut 121 sails during the 4 years Olympic cycle… 50 mainsails and 71 jibs. Out of the mainsails, there was 24 variations - some smaller details, others (15) larger variations in mold shape or luff curve or panel layout. 15 sails were identical, of the "workhorse" model, but the final main was one of the last variations. Also, for the jibs, Max wanted a 15 mm adjustment only 6 weeks before the London 2012 regatta, and it was one of those jibs he picked for the races.

In addition of the shape, there's a lot of other tweaking and optimizing work that goes into the design of a state of the art sail. The structural detailing, reinforcements, rings, luff tapes & cords, batten fixation etc. all need to be carefully evaluated and tested. So Pelle Kindberg, who is in charge of our one-design sail production, spends yearly a week at Lake Garda or other sailing resort, discussing all these details with the sailors. Industrial espionage belongs to the picture: we photograph, video and analyze our competitors sail trim and manufacturing details from time to time.

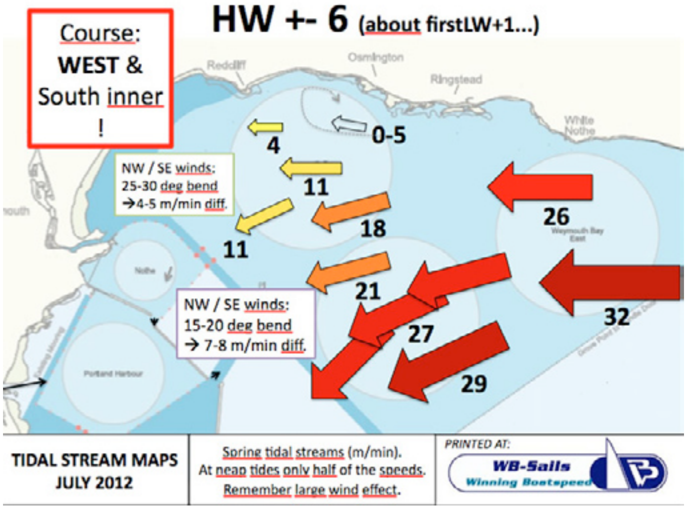
Two boat testing with Flavio Marazzi in Perth 2011.

Taming the wind and the waters

WB-Sails did an extensive wind study on the Weymouth Olympic waters with the help of the French Olympic team and its tecnical staff. The tubulence intensity of the wind - gustiness - varies a lot, depending amongst others on location, wind direction (sea breeze - off-land breeze), and the temperature difference between the air and the sea.

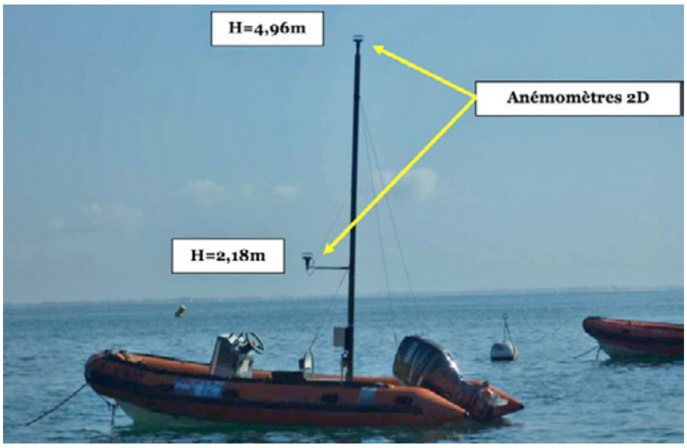
The turbulence intensity governs almost completely the wind shear, the difference in wind speed up from the surface to the top of the mast. This wind shear profile is an important factor in the shape of the sail: When there's more wind low down, you need a sail fuller in the foot, and vice versa. This knowledge is useful to the sailor, too, for choosing the sail and rig trim for the day, and even his tactics.

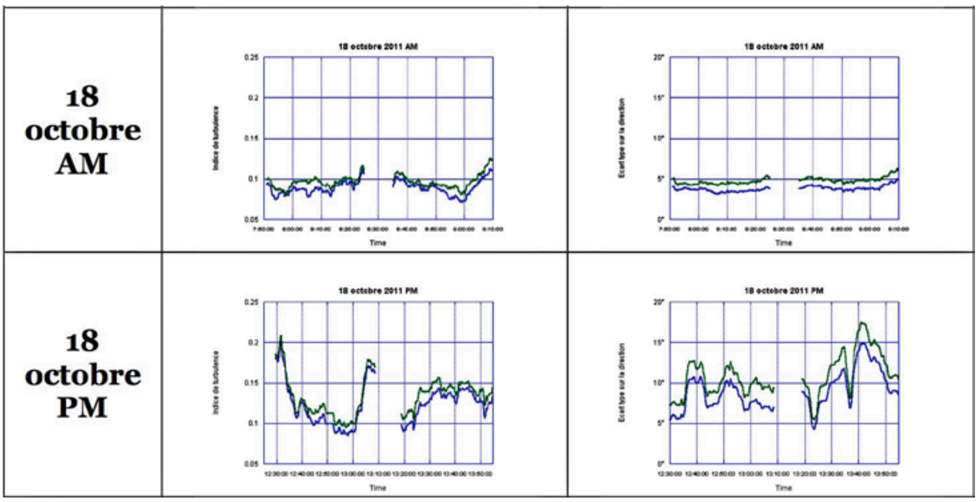
For London 2012 and Weymouth, the current (tides) was a big factor as well. Besides influencing the tactics, we had to allow for the current in sail design as well. Knowing at what dates and time to racing would take place, we knew how long the sailors would be spending sailing upwind and running downwind. Especially in lighter winds this can make a difference: beating upwind against the current, you can end up spending twice as long on a beat as normally, and on the other hand downwind legs go in a flash. We would allow for this when assessing the upwind vs. downwind properties of the sails, always a compromise between these two.



Above: A tide chart over the Olympic waters by Martin Gahmberg, for the help of the sailors

Below: The French rib used for wind data collection, equipped with ultrasound anemoters at different heights to assess the wind shear





Sample output of the wind data, collected on the same day in the morning and the afternoon. On the left, turbulence intensity, on the right wind direction variation. You can clearly distinguish the different wind regimes and the significance of the turbulence on the wind.

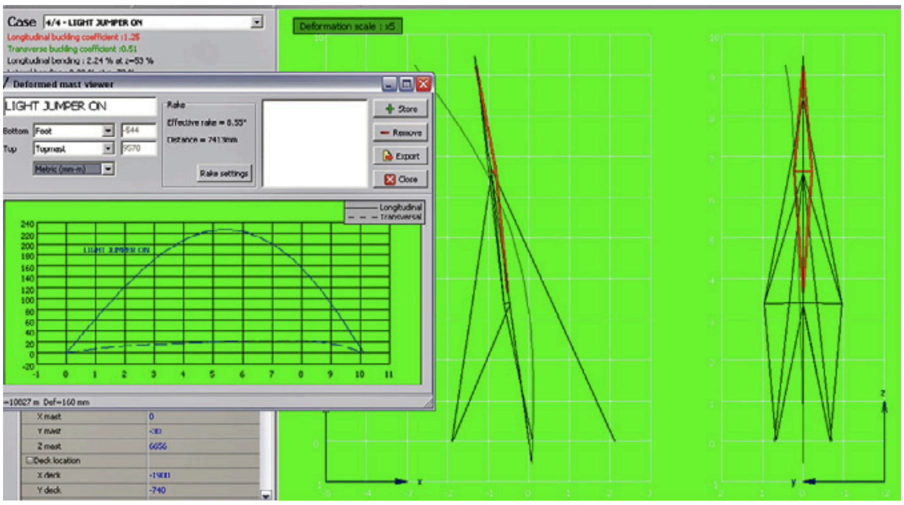
Mast work

For the Star, a considerable amount of time - maybe a whole season - was spent in experimenting with different mast stiffnesses, shroud attachment points, jumpers and so on. Even a whole new mast section was developed, but in the end nothing could better the standard Emmetti.

The mast development program was not in our hands, we felt it was on a wrong trail, and it certainly did consume a lot of expensive time: Weeks of computer simulation and countless luff curve adjustments to fit the different configurations. Not that it would all be wasted, we did learn a lot in the process, and we think there may still be something in a new mast section with a different concept.

In case of the Finn, we knew better where we were, with the long experience Jocke has in the class. Nevertheless, Jocke did a lot of testing, planing carbon off in one place and laminating more in others, to explore all limits of the cat boat rig. In the end, we learned a valuable lot on different demands in different weathers - as much as the wind, the waves or "chop" have a big influence on the optimal mast stiffness and bend curve. Rig is for the sailboat what suspension is for the car - when the road gets bumpy, you need a very different suspension from that of a smooth asfalt.

Testing the Star rig with jumpers.



Simulating the Star mast bend, equipped with jumpers.

We now understand how relatively small adjustments in rig stiffness and sail shape can make a big difference in the optimal wind range of the boat. The compromise is, surprisingly enough, usually between good in light and heavy air, or good in medium winds. To get it optimal through the whole range is not possible.

WB-sails development work has been supported during the years by TEKES, the Finnish Funding Agency for Technology and Innovation, directly or indirectly within several research projects. We have also received support from the Finnish Olympic Committee, and this time around from the Swedish Olympic Committee instead, thanks to Jocke Wilenius close contacts Swedish team.

“The effort WB-Sails put in the Star and the Finn sails for London 2012 was remarkable,” Mikko Brummer sums up, “Especially considering the size of our loft. When we started the London project with Freddy back in 2009, we concluded that this would probably be his last shot for the Olympic gold, and together we agreed to leave no stone unturned”. In the long run, this will come down to all sails we make - in fact it already has, since the tools and the methods developed during the Olympic preparations have recently been used in a two boat X-35 project.