Novel System for Pressure Measurements on Yacht Sails

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CSEM has developed a novel pressure-measurement system with Politecnico di Milano and North Sails based on MEMS sensors and pressure-strip technology. The system was developed for the Lecco Innovation Hub Sailing Yacht Lab [1] and has been tested in an extensive wind tunnel campaign [2].

Pressure measurements on thin shapes like sails are very challenging. Knowing the effective pressure distribution over the sail plan is of great interest for its aerodynamic and structural design. The system developed enables such measurements and is therefore a valuable tool for the selection and the optimal use of materials and sail production techniques.

The system is based on 9 pressure scanners (Figure 1) each providing 16 sensors connected to pressure strips distributed on different sections of the main sail and the jib of the test yacht. The MEMS pressure dies integrated in the scanner are a new generation of piezo-resistive differential low-pressure sensor membranes that reach very low full-scale ranges below 1000 Pa. The MEMS sensors are cost efficiently bonded to a FR4 substrate using innovative die bonding techniques based on elastic adhesives.

Figure 1: Pressure scanner with CAN cable (1) and strip adapter (2).

Scanner key specifications

FS pressure range	±1000	Pa
Measurement resolution	0.01	% FS
Static accuracy after zeroing	0.25	% FS
Sample rate	1 - 100	Hz
CAN Interface	1	Mbit/s
Size	65×55×6	mm
Weight	50	g

The pressure strips are made of thin polymer films with integrated micro-channels, which enables pressure propagation from the tap to the respective sensor of the connected pressure scanner. The main advantage of the strips is their low weight and the flexibility of this foil, which allows fast and non-invasive application to the sails.

The performance of the measurement system was evaluated in static and dynamic tests as well as in wind tunnel tests in upwind configuration on a 1:10 scale model of a 48 foot cruiser-racer. A set of pressure strips with a total number of 144 pressure taps was mounted (Figure 2). The strips were attached on both sides of the main sail and the jib in order to measure differential pressure between the leeward and windward sides. The scanners were placed in the hull of the model. In addition, flying shape measurements based on time of flight (TOF) technology were performed.

Figure 2: Pressure-strips (in white) applied to the main sail of the 1:10 scale model during wind tunnel test.

The wind-tunnel test results gave relevant insight explaining the dependency of sail-plan trimming on sail pressure, driving forces and flying shape measurements (Figure 3). Further measurements on the full-scale sailing yacht lab on Lake Como are planned for the end of 2016.

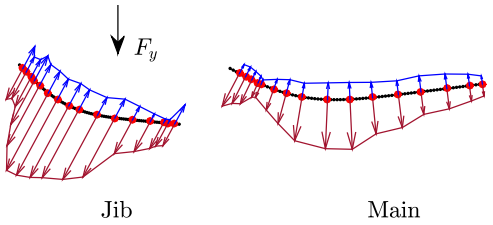

Figure 3: Visualization example of pressure distribution based on wind tunnel measurements at an apparent wind angle of 20°.

The system is a major improvement compared to state-of-the-art pressure measurements on flexible sails. It is expected that in the future such measurements on scale models and full-scale yachts will provide a reference database for validating CFD simulation models and further optimize the structural design and aerodynamics of sails.

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• Politecnico di Milano

•• North Sails

[1] Fossati, *et al.*, "A Novel Full Scale Laboratory for Yacht Engineering Research", Ocean Engineering 104 (2015) 219-237.

[2] Fossati, *et al.*, "Pressure Measurements on Yacht Sails: Development of a New System for Wind Tunnel and Full Scale Testing", 22nd CSYS (2016) 84-96.