PNS03/06 shear probes for microstructure measurements

Product information

March 2010

1 Principle of operation

PNS shear probes are airfoil-type microstructure velocity fluctuation sensors designed for microstructure profiler.

The mean velocity due to the profiling speed **V** of the probe is aligned with the axis of the axially symmetric airfoil of revolution (see figure 1, red tip). While the probe is not sensitive to axial forces, the cross-stream (transverse) component of turbulent velocity **u** produces a lifting force at the airfoil. A piezoceramic beam, connected with the airfoil, senses the lift force in one dimension.

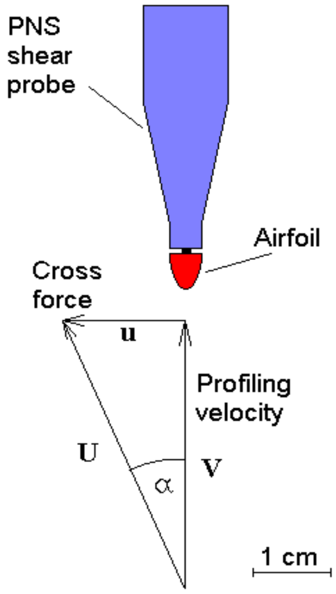

Figure 1
Measurement geometry of PNS shear probe

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The output of the piezoceramic element is a voltage proportional to the instantaneous cross-stream component of the velocity field.

PNS shear probes are sensitive in the plain parallel to the flat at the sensor body.

Shear probes measure the velocity fluctuation relative to the movement of the profiler. Consequently, shear measurements require a low vibration level of the profiler. The vibration level of the microstructure profiler mainly depends on it mass, its shape, and the cable. Free sinking profiler operation with a slack in the cable between profiler and ship is recommended. At rising measurements, special effort is required to keep the vibration level of the profiler at a reasonable level.

To avoid falsification of the measured shear by resonant oscillation of the airfoil/cantilever construction, the profiling speed should not exceed 1 m/s.

2 Construction of PNS shear probes

The basic construction of the PNS shear probes is shown below.

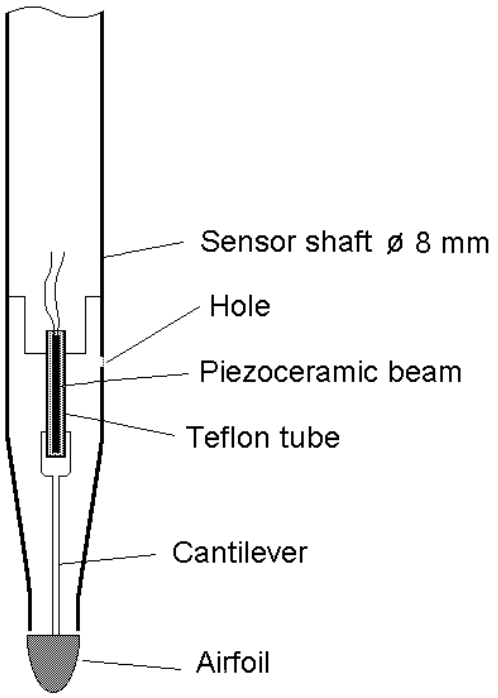

Figure 2
Basic construction of PNS shear probes.

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The piezo-ceramic beam is inside a Teflon tube. The lift force is directly transmitted to the piezo-ceramic beam.

PNS shear probes are available in two versions: PNS03 with an airfoil diameter and length of 3 and 4 mm and PNS06 with 6 and 10mm, respectively. Figure 3 shows the two versions of the shear probe. PNS03 and PNS06 shear probes are available in a compact version and a version with thread M10 (see figure 4). The compact version is used in the MSS profiler delivered since beginning of 2009. The older versions of the MSS profiler has been delivered with the thread version of the PNS shear probes.

There are no differences in the electrical and hydrodynamical properties between the compact and thread versions. The thread version of the PNS shear probes will be available as spare parts for existing MSS profilers. If the new compact version is used instead of the thread version, a new sensor shaft has to be used.

Figure 3
PNS03 (left) and PNS06 (right) shear probes.

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Figure 4
Compact version (left) and thread version (right) of the PNS06 shear probes.

3 Spatial response

The spatial resolution of airfoil shear probes depends on the length of their airfoils. The spatial response can be determined using the simple assumption for the transfer function H(k) of a sensor with a length L in profiling direction

$$H(k) = (\sin \pi kL / \pi kL)^2$$

k is the cyclic wavenumber. According to this equation, the transfer functions of the PNS03 and PNS06 have a -3dB point at wavenumbers of approx. 100cpm and 50cpm, which corresponds to a spatial resolution of approx. 1cm and 2cm, respectively.

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4 Properties of PNS shear probes

The properties of PNS shear sensors as described below have been determined during a series of laboratory tests and field measurements. The general behaviour of the sensor is described. Individual probes can have somewhat deviating properties.

4.1 *Pressure rating*

The standard version of PNS shear probes have a pressure ration of 100 bar (1000 m water depth). All sensors are pressure tested at 100 bar before calibration and delivery. On request, PNS06 shear probes for depth ranges up to 4000 m can be delivered. These sensors have a metallic pressure bulkhead in its shaft (see figure 5). The deep water version of the PNS06 shear probes are pressure tested at 400 bar before calibration and delivery.

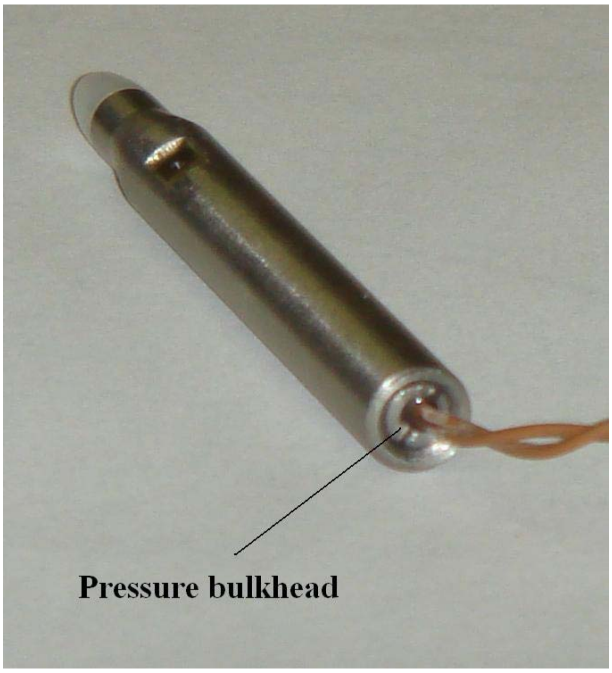

Figure 5
Metallic pressure bulkhead in the shaft of a PNS06 shear probe

4.2 *Sensitivity*

The sensitivities are in the order of $1 \cdot 10^{-4}$ (Vms^2)/kg for the PNS03 and $4 \cdot 10^{-4}$ (Vms^2)/kg for the PNS06. Individual calibration is necessary.

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For the calibration of shear sensors, a special shear probe calibration system has to be used. ISW Wassermesstechnik provides a calibration service for shear probes. The following calibration arrangement is used: The probe rotates about its axis of symmetry at 1 Hz under an angle of attack **α** in a water jet of a constant velocity **U**. At different angles of attack, the rms. voltage output **E** of the probe is measured. The probe sensitivity is the slope of the regression (best fit of a cubic approximation) obtained from the equation $E/(qU^2) = S \cdot \sin 2\alpha$. q is the density of water, and S is the shear probe sensitivity in $(Vms^2)/kg$.

4.3 *Thermal drift*

Exposed to temperature changes, shear probes show an offset in its output voltage (as shown in figure 6). The low frequency thermal drift (time scale several seconds) has to be filtered out in the procedure of shear computation.

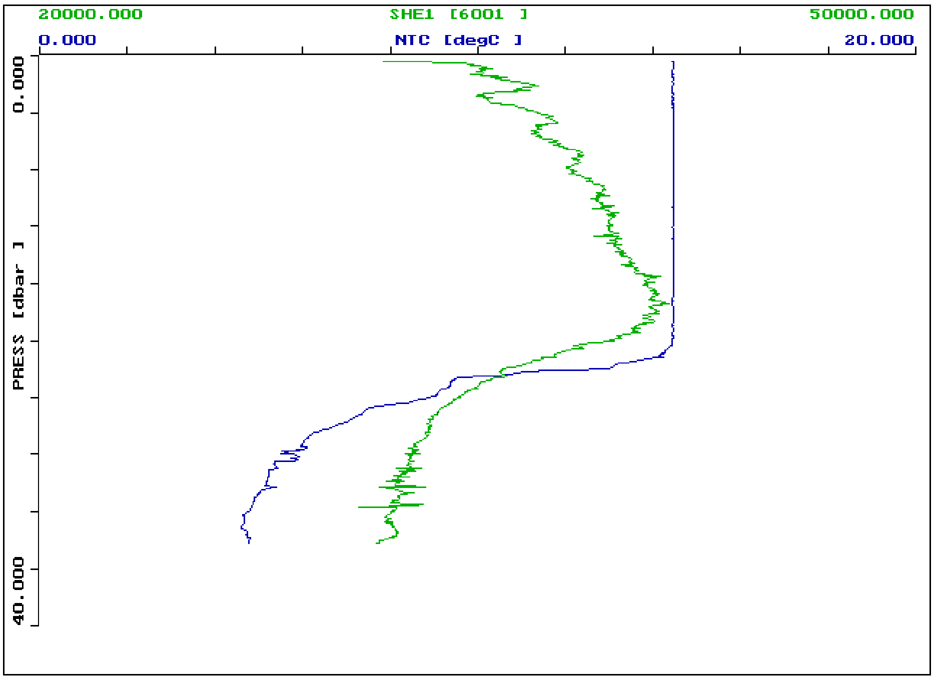

Figure 6
Shear measurements with a rising MSS profiler across a strong thermocline. Blue - temperature (measured with fast FP07 sensor). Green - output of shear sensors (raw data). The PNS shear probe shows a pronounced offset of the output voltage when crossing the thermocline. The low frequent oscillations near the surface are caused by waves.

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4.4 *Temperature dependency of sensitivity*

The sensitivity of PNS shear probe is dependent on the temperature: it decreases with sinking temperatures. This effect is shown in figure 7.

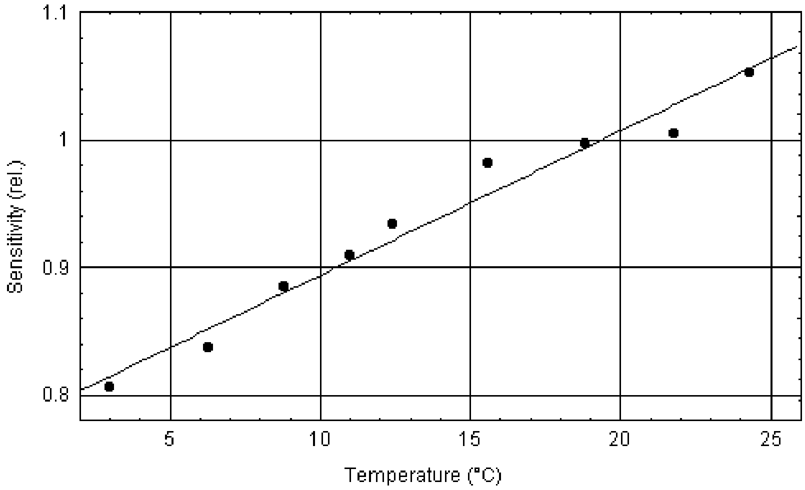

Figure 7
Typical dependency of the of PNS shear probe sensitivity (in relative values) on the temperature.

The drop of the sensitivity with decreasing temperature can be approximated by the function

$$S_M/S_C = 1 - 0.011\,(T_C - T_M).$$

T_C and T_M are the temperatures (in °C) during the calibration and the shear measurements at sea, respectively. S_M and S_C are the sensitivities at the temperatures T_M and T_C. T_C belongs to 21 °C (for shear sensors calibrated by ISW Wassermesstechnik). The resulting correction factor for the dissipation rate is

$$1/(1 - 0.011\,(T_C - T_M))^2.$$

4.5 *Long term stability*

Piezo-ceramic beams as used in the PNS shear probes to detect lift forces have an extreme high impedance in the order of 10^{10} Ω (100 GΩ). If moisture penetrates through the isolation

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(during long term exposure of the shear probes to water), the impedance decreases. This leads to a decrease of the shear probe sensitivity.

At PNS03/06 shear probes, the Teflon tube effect an excellent isolation against water. Even under high pressure the impedance of the piezo-ceramic beam remains for a long time above 100 GΩ (see figure 8).

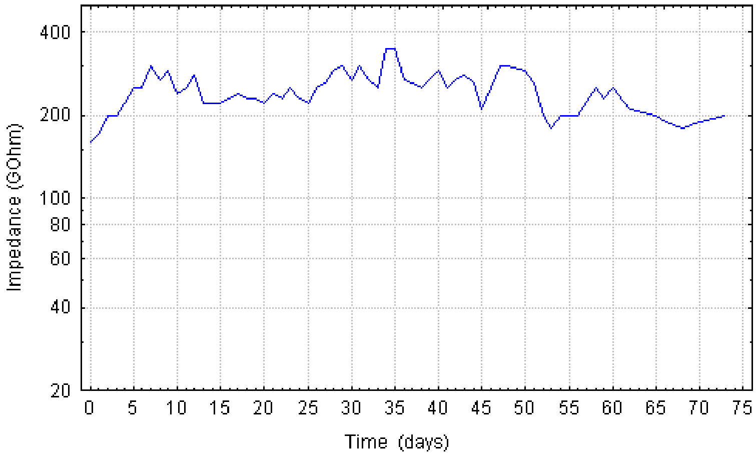

Figure 8
Measurement of the impedance of the piezo-ceramic beam of a PNS shear probe in a pressure tank at 300 bar. There is no decrease of the impedance during the 75 days test period.

5 Maintenance

Don't let dry out salt water in the inside the shear probe. After usage of the profiler, the shear probe should be flushed with fresh water. As shown in figure 9, a soft rubber tube is pressed sideward to the sensor socket at the position of the hole for flushing the sensor. After flushing, blow out the remaining water in the interior of the shear probe using the plastic bottle and rubber tube without water (profiler in vertical position).

In situations with high particle concentration, the PNS shear probes should be cleaned from time to time by additional flashing with fresh water.

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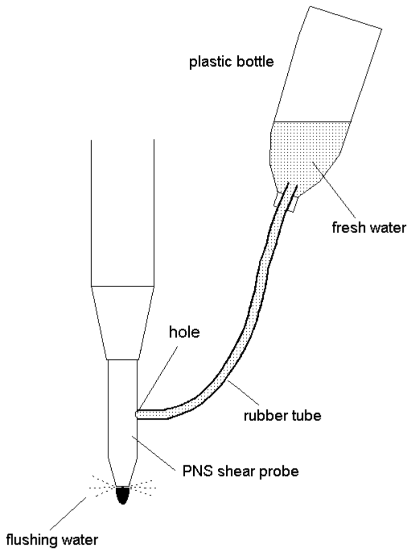

Figure 9
Arrangement to flush the PNS shear probes

6 Technical parameters

Impedance (piezo-ceramic beam)	typical 100 GΩ
Capacity (piezo-ceramic beam)	typical 1.6 nF
Piezoceramic beam isolation	Teflon
Resonance frequency	approx. 420 Hz
Depth range	max. 1000m (4000m on request)
Airfoil dimensions	
PNS03	Ø = 3.0 mm, L = 4.0 mm
PNS06	Ø = 6.0 mm, L = 10.0 mm
Sensor dimension:	
Length (total)	77 mm
Diameter	8 mm
Materials:	
Housing	Titanium
Airfoil	Plastic

Please note: The piezo-ceramic bending element in the shear probe can easily break. Shear sensors are consumables!

Technical parameters can be changed without notice!

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