WIRE SCANNERS AND VIBRATIONS MODELS AND MEASUREMENTS

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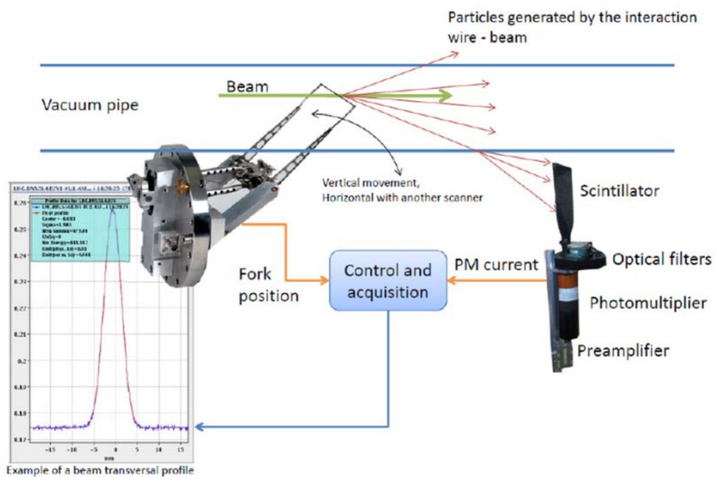
Abstract: *The new fast wire scanner foreseen to measure small emittance beams throughout the LHC injector chain will have a wire travelling at a speed of up to 20 m/s, with a requested wire position measurement accuracy of the order of a few microns. The vibration of the thin carbon wires used has been identified as one of the major error sources on the wire position accuracy. In this project the most challenging and innovative development has been the wire vibrations measurement strategy based on the piezo resistive effect of the wire itself, while the deflection of the fork supporting the wire has been measured by semiconductor strain gauges. Dynamic models of the wire and fork have been created to predict the behaviour of the fork-wire assembly and will be used for optimisation of the wire-fork assembly. The contribution will discuss the measurement setup and the model development as well as their comparison. In addition it will show that this technology can easily be implemented in current operating devices without major modifications.*

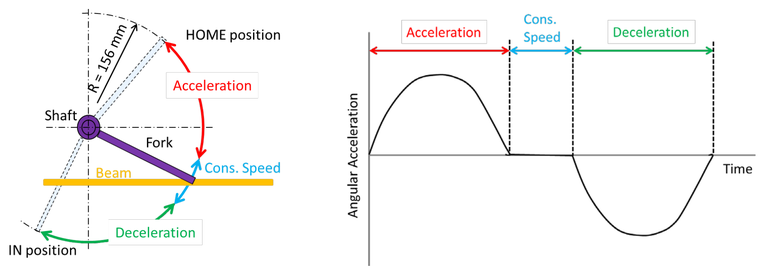
Motivation

Rotating Wire scanner



In order to reconstruct the beam transversal profile, the position of the fork is combined with the photomultiplier signal. Therefore profile accuracy depends on the wire and fork position accuracy determination.

Scan cycle

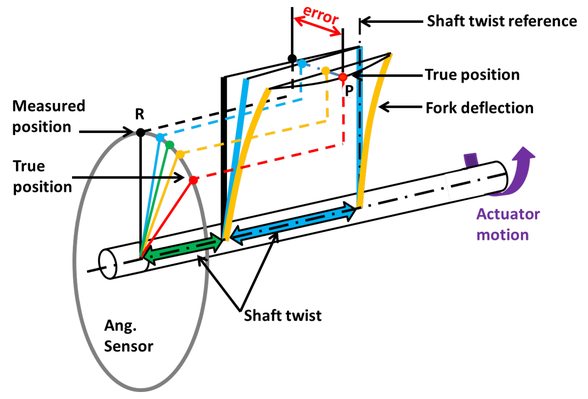


The typical scan cycle of a rotating wire scanner consists of an angular rotation motion showing an acceleration phase, a constant speed phase and a deceleration phase. Depending on the peak speed required, the length of the fork, the angular travel and the motion pattern design, the pick acceleration values can vary. Typical values for the new CERN vacuum wire scanner are:

Peak speed	20 m/s
Fork length	156 mm

Peak angular speed	128.20 rad/s
Peak angular acceleration	6700 - 10000 rad/s^2
Tangential acceleration	**95 – 159 g**
Normal acceleration	260 g

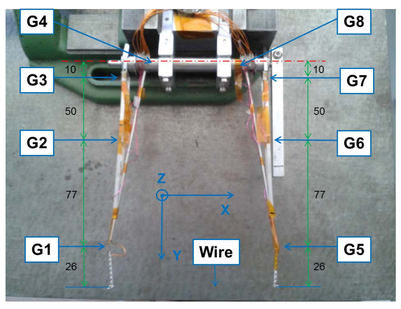
Deflections

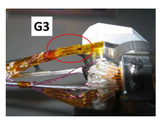


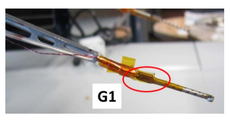
The acceleration induces deflections on the measurement chain (shaft, fork and wire) that provoke an error between the real position of the wire midpoint (P) and the position measured by the angular sensor (point R). In addition due to the variations of acceleration these deflections become in oscillations, thus increasing the uncertainty for the wire position determination. For the new CERN vacuum wire scanner the position accuracy requirement is in the range of **2 µm**.

Experimental setup

Strain gauges location

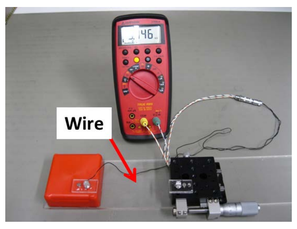






The fork has been equipped with semiconductor strain gauges. Gauges G4 and G8 are mainly sensitive to the twist of the shaft. Gauges G2, G3, G6 and G7 are sensitive to the deflections in Z direction (transversal deflections). Gauges G1 and G5 are mainly sensitive to the deflections in X direction (longitudinal deflections).

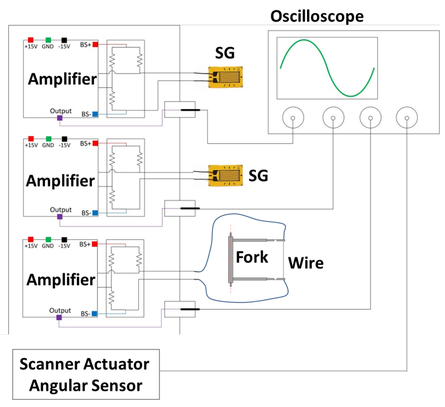
Wire piezorestive effect



Experimental measurements show that in the standard carbon wire used in CERN's operating wire scanners, a variation of resistance appears under wire elongation.

Wire diameter [um]	34
Wire length [mm]	114
Resistance [Ohm/mm]	31
Gauge factor	0.64

Acquisition system



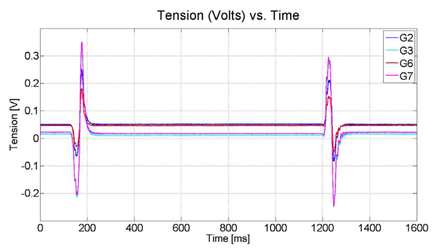
The acquisition systems for the strain gauges and the wire are based in a Wheatstone bridge combined with an amplifier. The amplified tension is read by the a oscilloscope. The acquisition system records also the angular position of the fork by means of an angular sensor.

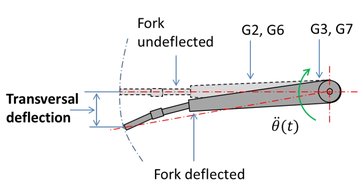
Calibration factors

Sensor	Factor [mm/V]	Measured parameter
G1	0.140	Tip longitudinal deflection
G2	1.329	Tip transversal deflection
G3	0.652	Tip transversal deflection
G5	-0.158	Tip longitudinal deflection
G6	1.329	Tip transversal deflection
G7	0.652	Tip transversal deflection
wire	-0.35	Wire elongation

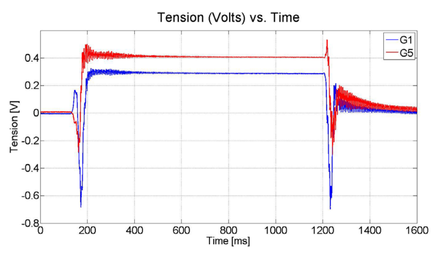
Deflection and Vibrations Measurements

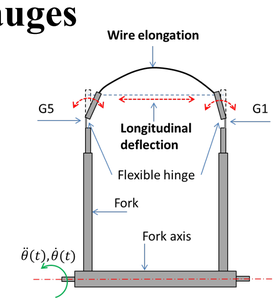
Transversal deflections





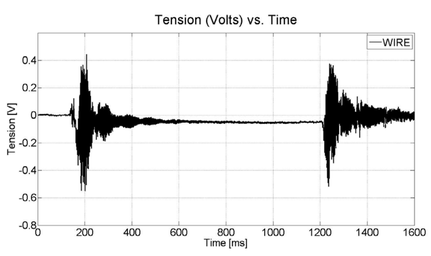
Longitudinal deflections, gauges

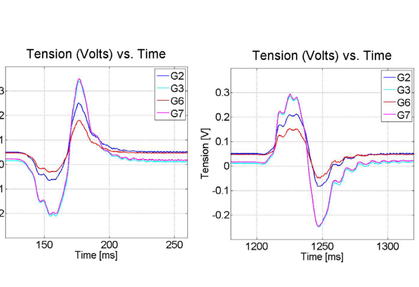


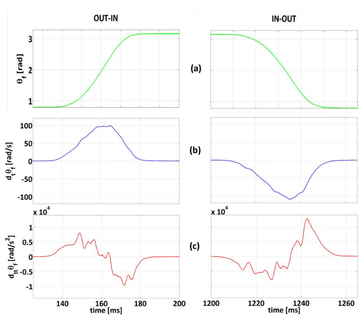


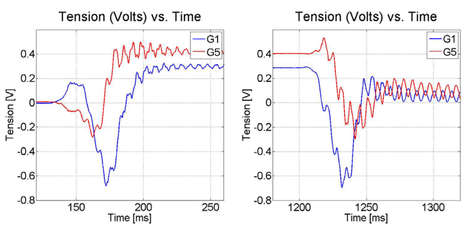
Longitudinal deflections of the fork tips and motion forcers acting on the wire provoke wire elongations that change the wire resistance.

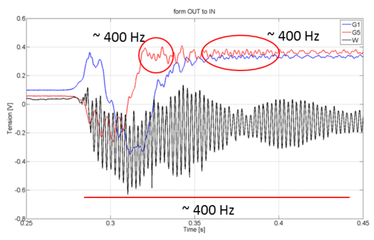
Wire elongation



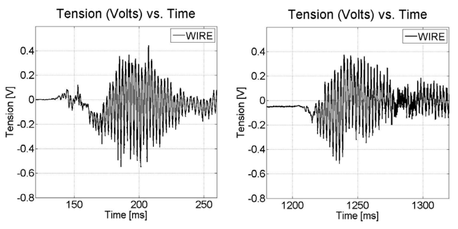


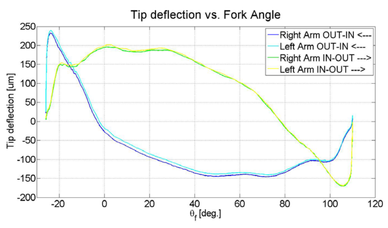




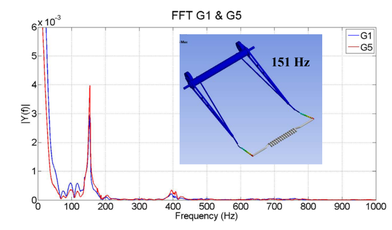


Transversal strain gauges and wire signal show the ~ 400 Hz frequency which corresponds to the second natural mode of the fork.

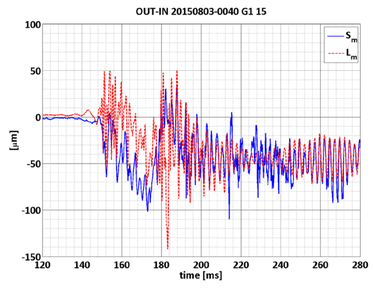




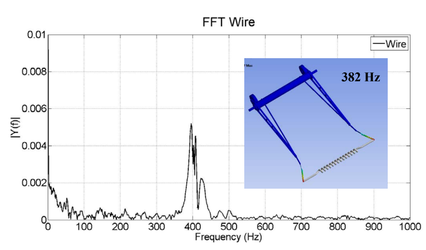
Angular acceleration provokes the deflection of the fork arm. The resistance of the strain gauges bonded to the arm varies proportionally as result of this deflection.



FFT performed in the signal of G1 and G5 show two peak frequencies which correspond to the first and second natural modes of the fork (~150 Hz and ~400 Hz respectively.



The same trend of the longitudinal deflection (Lm) and wire elongation (Sm) is observed applying experimental factors to G1, G5 and the wire signals.



FFT performed on the wire signal shows only the second mode (~400 Hz) as the first mode (~150 Hz) does not provoke elongations on the wire.

The transversal deflections on the fork tip can be estimated applying experimental calibration factors.