FAST WIRE SCANNER CALIBRATION

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Abstract

The fast rotating wire scanners installed in the PS and the PS booster are used for the precise transversal profile measurements in horizontal and vertical planes. The scanners may show large position measurement errors if no special treatment is applied to the acquired data. The aim of the calibration is to obtain a correction algorithm for the systematic position measurement error due to mechanical and electronic offsets.

A new calibration system has been developed and introduced in CERN for the scanners implementing position feedback control. The calibration method is based on a substitution of a particle beam by a laser one where the laser beam position is well known. According to the previous experience the following crucial requirements to the system have been taking into consideration: heavy and mechanically stable design of the calibration bench to reduce mechanical oscillations of scanner parts; automation of the calibration procedure to exclude human errors in data taking, storing and analysis; high precision of the laser positioning; minimization of the total amount of scans and calibration time for each scanner.

SYSTEM OVERVIEW

The setup consists of a massive vacuum tank that can receive either a horizontal or a vertical scanner with 2 viewports at the position where normally the vacuum chamber is situated. A laser beam, split into two parallel beams of nearly equal intensity distant by 2.7 mm by means of special optics, through which the wire travels at high speed, is mounted in front of one viewport. Behind the second viewport a large fixed mirror is positioned.

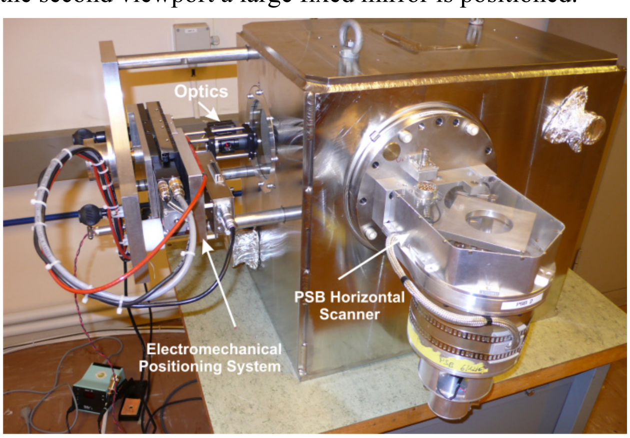

Figure 1: Calibration bench with a horizontal PS booster scanner.

The carbon wire scanning through the beams creates thus twice a shadow detected by one single photo-detector, resulting in 2 negative peaks and otherwise constant signal. Correlating the measured peak positions with the real laser beam position allows the creation of a correction algorithm. For the automation purposes the laser and photo-detector are mounted together on a translation table and moved by a stepping motor (Parker MX80S, stepping motor driven linear stage.).

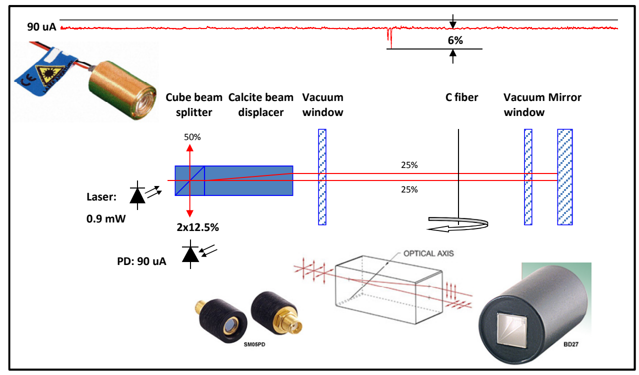

Figure 2: Measurement principal.

An expected and observed signal from the 30 µm C-fiber travelling with a speed of 10 to 20 m/s through a 200 µm (σ) laser beam (1mm diameter) only has a modulation depth ~6%. A precise adjustment of the optical subsystem is required to provide conditions at which a peak detection algorithm works stable. One should note it impacts on the total number of scans which is needed to be done during the calibration of a scanner. A minimal number of bad scans, when peaks cannot be detected precisely, is allowed to make less repeated scans and to extend the life-time of bellows and wires.

Motion Control and Acquisition Electronics

The electronics for the acquisition and control of the wire-scanner movement and laser positioning are hosted in a standard VME64x crate. The motion control card [5] is in charge of the scanner positioning and the laser beam acquisition. The laser movement and position acquisition are controlled through a TVME200/IP-OCTAL-422 card connected to a MIDI crate [6]. Two FESA [3] classes running on a RIO3-8064 CPU card control the system. When a scan is launched, the position of the scanner is measured by means of a precision rotary potentiometer. A 16-bit ADC performs the read-out of each position measurement which is then stored in a 256k memory block. The standard wire-scanner installation acquires the signal coming from a photomultiplier using a logarithmic amplifier. The calibration installation has to use the laser detector signal instead. The signal is read with a 12-bit ADC configured to acquire an external input signal. The measurement in both cases is stored in another 256k memory block of the motion control card. The rate of acquisition is

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configurable. For calibration purposes a rate of 200 kHz was used. The laser position is read from the MIDI crate and corresponds to the number of steps the motor displaced from a limit switch with respect to the centre of the chamber.

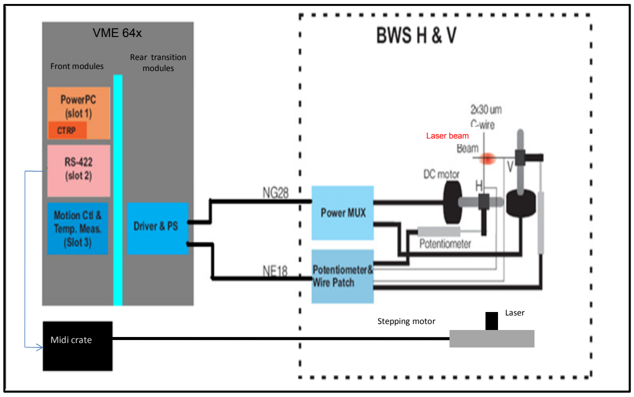

Figure 3: Electronics schematics of the calibration bench.

LOOKUP TABLES

The measured position of the scanner is represented by a signal coming from the potentiometer only contains the information about a motor crankshaft angle (see Figure 3). Because of very high non-linearity of the transmission of the motor rotation to the wire travelling the crankshaft angle cannot be used directly to identify a projected position.

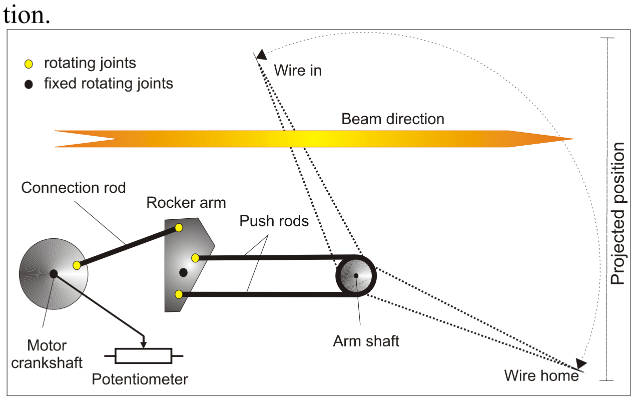

Figure 4: Schematic of a wire movement.

To convert bits into projected positions in the calibration system a method of lookup tables is implemented. Each lookup table contains number pairs $n^p(bits) \Leftrightarrow x^{p.p.}(mm)$ covering a significant range of the projected positions. The calibration system uses the theoretical and correction lookup tables. The correction tables are the final output of a calibration procedure and they have to be uploaded to the FESA servers controlling the operational electronics. The theoretical lookup tables (Figure 5) have been calculated once according to geometrical parameters of an ideal scanner (Table 1) by a method described in [1]. They are used to display the calibration results in a form of human readability and may help to unmask some problems with a scanner during its calibration.

Table 1: Geometrical parameters of the kinematic model

Parameter	PS	PS Booster
Crankshaft radius	11 mm	11 mm
Length of connection rod	84.5 mm	84.5 mm
Horizontal distance of motor shaft to rocker shaft	80 mm	80 mm
Vertical distance of motor shaft to rocker shaft	36 mm	36 mm
Radius of rocker arm, motor side	26 mm	26 mm
Radius of rocker arm, wire side	17 mm	16 mm
Angle between rocker and lever	34 deg.	34 deg.
Horizontal distance from rocker centre to fork shaft	164 mm	167.69 mm
Vertical distance from rocker centre to fork shaft	17.25 mm	17.62 mm
Radius of fork shaft	5.75 mm	6.0 mm
qDistance from fork shaft to wire	164 mm	164 mm
Fork angle at home position	-20 deg.	-24 deg
Distance from fork shaft to beam centre	89.75 mm	92.38 mm
Radius of push rod	6.2 mm	6.2 mm

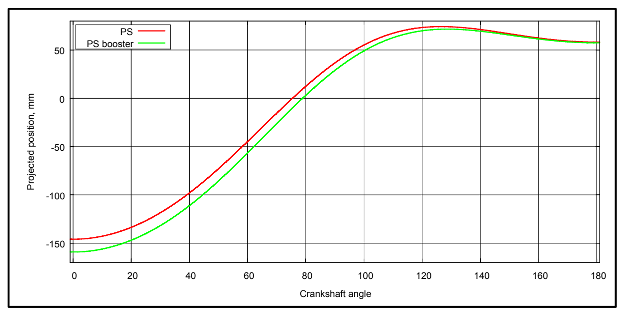

Figure 5: Lookup tables of theoretical projected positions.

CALIBRATION PROCEDURE

A scanner calibration is carried out in 4 steps:

1. A scanner is mounted in the tank and linked-up to the control electronics. To prevent scanner damage the installation integrity and readiness of all the elements in the system have to be verified before the calibration is being started.
2. Verification of the photodiode signal quality and peak visibility by making single scans. Optics adjustment may be required.
3. Automated calibration. At each laser position few scans for each predefined speed (10, 15 and 20 m/s) have to be performed and the detector read out. The acquired data is analyzed and the peaks in the signal accurately located in time scale. An incremental positioning of the laser and a number of repeated scans are set up to perform the minimal needed number of scans for tolerable results. The automated calibration produces 6 correction lookup tables: for each of 3 predefined speeds and for 2 wire movement directions. Figure 6 shows the mismatching between measured and calculated lookup tables of 2 wire scanners for the speed 15 m/s where a laser positioning increment equals to 5 mm.

4. A check of newly created correction lookup tables. The same scans as in the step 3 have to be performed again but already applying the created tables to identify a wire position. An error of a position measurement is defined as $\Delta x = x_{wire}^{p.p}(v_p) - x_{laser}$, where v_p is a potentiometer value of a detected dip(s), $x_{wire}^{p.p}(v_p)$ is a projected position of the wire taken from a correction lookup table, x_{laser} - laser beam position. If the majority of the results are within the range ±0.5 mm the scanner is classified as calibrated and ready to be used for operation. Check results of the scanners from Figure 6 are shown in Figure 7.

Steps 2-4 are executed using a dedicated expert application written in java to handle remotely the calibration task and to process acquired data. The application communicates directly with 2 FESA servers controlling the electronics.

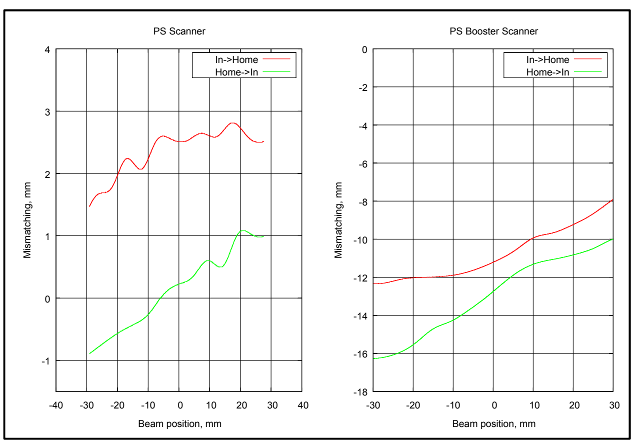

Figure 6: Mismatching between measured and theoretical projected positions of a scanner in PS domain and a scanner in PS booster domain. The wire speed is 15 m/s.

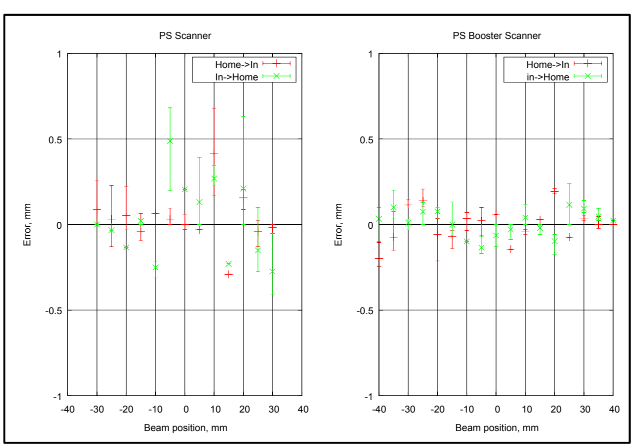

Figure 7: Check results of a scanner in PS domain and a scanner in PS booster domain. The wire speed is 15 m/s.

CONCLUSION

With the new calibration system we achieved the following results: human errors are completely excluded from the calibration task; one scanner full calibration takes only 1 hour if there are no hardware problems (it took half-day formerly); percentage of bad scans is very low when optics are well tuned. During the 2008-2009 shutdown at CERN 13 fast wire scanners including a spare one were calibrated and installed in the PS and the PSB booster at hard time constraints. When the PS and the PS booster started up few comparative profile measurements were done to verify a match of a profile centre-mass with a position measured by a nearest pickup. A Figure 8 shows one comparative measurement.

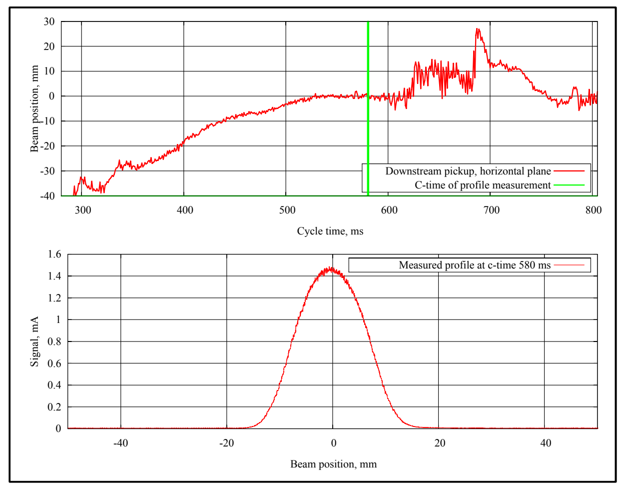

Figure 8: Horizontal profile measurement of a c entred beam in the PS booster: a) beam position from a downstream pickup, b) profile, measured by a wire scanner.

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