CALIBRATION OF NON CONTACT VELOCITY SENSOR USED IN AUTOMOTIVE INDUSTRY

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Abstract.- This paper includes a description of the calibration method used at CENAM to calibrate non contact velocity sensors, which are used by the automotive industry for velocity measurement of vehicles, and distance measurement calibration also used to perform odometer testing. The calibration system development at CENAM consists of a rotor steel of 400 mm diameter with an inertial mass that keeps a constant velocity at the system, a photoelectric probe, a stroboscope and a universal frequency counter. The rotor is driven by an electromechanical control. The velocity measurement is performed in the range from 10 km/h to 190 km/h, distance measurements from 50 m to 2 000 m are also carried out. The final obtained results and the associated expanded uncertainty are reported.

Keywords: non contact velocity sensor, frequency counter.

1. INTRODUCTION

Automotive industry faces continuously the challenge to preserve the high quality standards of their products. To achieve this goal car manufactures carry out validation tests specially designed to know performance, breaking, acceleration, vehicle velocity, fuel consumption, emissions, safety, etc.

The mentioned tests involve a variety of magnitudes sensed with transducers located inside and outside the car and around the test place. In most of them it is necessary to monitor velocity, for this task fifth wheels, optical sensors, radar sensors and microwave sensors are commonly used.

Despite of the fact that GPS (Global Position System) is growing quickly in the market for the measurement of velocity and distance, optical velocity sensors are still widely used and it is necessary to give them traceability to National Measurement Standards for reliable results. In the linear velocity Lab at CENAM, approximately fifteen optical sensors are calibrated every year from different manufactures and using different operation principles. The sensor used for this work is the Correvit Aqua L350 from Corrsys Datron.

2. REFERENCE SYSTEM

It is integrated by a reference measurement system and an excitation system.

Figure 1. Reference system of linear velocity

2.1 EXCITATION SYSTEM

1. Steel rotor with a diameter of 400.058 ±0.025 mm traceable to the Length National Standard of México (CNM-PNM-2).With estimated mass of 236 kg and smooth surface.

2. Support structure: It is made from structural steel plate with welding junctions and thermal treatment. it also holds the rotor aligned to the motor shaft.

3. The propulsion system is a servomotor coupled to the rotor shaft by an elastic coupler. The servomotor is special for high inertial applications and is controlled by a programmable power drive that includes a dynamic braking resistor.

4. The Human Machine Interface is touch screen type.

2.2 REFERENCE MEASUREMENT SYSTEM

5. Photoelectric probe Brüel & Kjær, Model MM-0024. Detects the reflective tape in one side of the rotor and send pulses.

6. Universal frequency counter Fluke and Phillips, model PM6669. Read the detected pulses by the photoelectric probe and display them as revolutions per minute (r/min) or events in totalizing mode. Traceable to the National Time & Frequency Standard of México(CNM-PNE-1).

7. GPIB-USB card, National Instruments. Communication bus between the universal frequency counter and the Laptop.

8. Acquisition software developed by CENAM in LabView platform to record and visualize the measurements of the universal frequency counter.

9. Laptop. Data processes and run the program.

3. OPERATING PRINCIPLE OF CORREVIT® L-350 Aqua

Utilizing a high-intensity light source to illuminate the measurement surface, the optical component of the Corrsys-Datron Sensor observes the stochastic microstructure of the surface via an objective lens. [1]
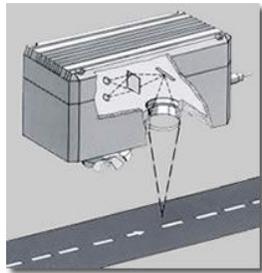

Figure 2. Correvit Aqua L350 with inner prismatic grating *(image courtesy from Corrsys-datron web page, view References)*.

The acquired optical signal is projected onto a periodic prismatic grating within the system, where it is multiplied as details of the surface microstructure move across the grating. Resultant spatial frequencies are integrated over the sensor field to generate a correlated average value. [1]
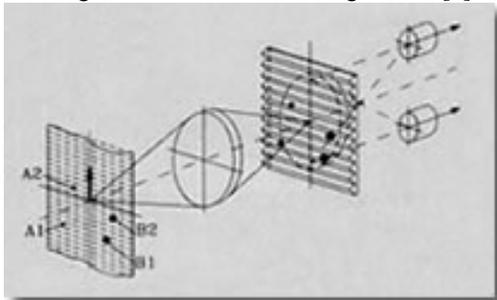

Figure 3. Function principle of Optical velocity sensor Correvit Aqua L350*(image courtesy from Corrsy-sdatron web page, view References)*.

The electronic signal-processing component of the system utilizes tracking filters to determine the representative centre frequency, which is derived by calculating a mean value based on variance in the frequency spectrum. This representative centre frequency allows reliable counting of signal periods, which are directly proportional to the distance that the observed surface has travelled

relative to the sensor. Using this information, speed data can be derived for a gated length measurement. [1]

4. ALIGNMENT OF THE SENSOR HEAD ON CALIBRATION

Once the sensor is positioned in front of the rotor it is important to control the different parameters of influence on the sensor calibration results. The positions are: vertical angle (A1), vertical angle (A2), horizontal Angle (A3), horizontal distance (D1) and height (H1). The next diagrams show the five positions mentioned before. D1 is specified by the manufacturer of the equipment while A1, A3 y H1 are correct when the velocity detected by the sensor is the closest to the reference velocity of the system. A2 does not affect the measurement results.
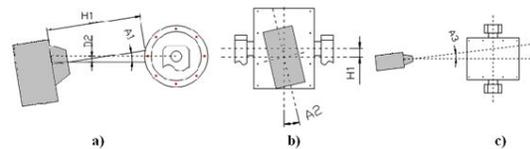

Figure 4. Measurement setup for the calibration of a non contact velocity sensor. a) Side View, b) Back View, c) Upper View

5. ADJUSTMENT OF THE SENSOR HEAD BY POSITION MOUNTING

Once the sensor head was positioned using the guide from figure 4, the possible errors attributed to position are diminished performing this test to generate a correction factor of position to get better results. One side of the rotor has a reflective tape of 3.5 mm that triggers the photoelectric probe. The software of the L-350 CeCalWin Pro, display a window to compare a well known distance against the distance measured by the sensor in the same time interval. The reference eligible distance can be from 50 m to 2 000 m, 1 889 meters are used in order to get the distance the rotor has to turn 1503.0005 times. According to the following equation:

$$Revolutions_{Total} = \frac{Length_{ref}}{P} \qquad (1)$$

$Revolutions_{Total}$ = Number of turns needed to get the reference length in meters.

$Length_{ref}$ = Reference distance for calibration, is the one that completes as much as possible exact revolutions (m).

P = Perimeter of the rotor (m).

The reflective tape on the rotor is the trigger for the photoelectric probe; the tape is positioned in front of it taking as reference the position where the probe flashes to ensure a complete revolution of the rotor.
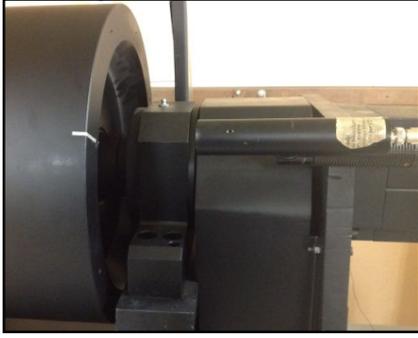
Figure 5. Reflective tape and photoelectric probe

The universal frequency counter totalizes the number of times rotor turns at 10 km/h, the counting stops when the counter displays 1503 events. The software generates a window with the information of Table 1 (valid only for the results presented in this paper). The new factor 1.0234 is written in the sensor to adjust it and the measurement is repeated to verify the factor already found as Table 1 shows.

1 889.000	Entered
1 889.354	Real
1.0236	Old factor
1.0234	New factor

Table 1. Adjustment factor generated after distance comparison.

Using the factor of 1.0234, the error of measurement is about 0.02%, specifically for the results presented in this paper, the factor can change because it is related to the mounting deviation that the sensor head has against the rotor.

6. REFERENCE VELOCITY DETERMINATION AND MEASUREMENT VELOCITY ERROR

An indirect method is used to determine the reference linear velocity of the excitation system. The diameter of the rotor previously measured let us know a perimeter of 1.256819 m ±0.025 mm, the control of the excitation system ask the user to introduce revolutions per minute to operate. The next equations are used to generate the reference velocity values.

$$v = [(v_r * 1\,000)/60] \qquad (2)$$

$$\frac{r}{min} = \left[\frac{v}{P}\right] \qquad (3)$$

$v =$ Velocity in meters per minute $\left(\frac{m}{min}\right)$

$v_r =$ Reference velocity to perform the calibration $\left(\frac{km}{h}\right)$

$\frac{r}{min} =$ Revolutions per minute $\left(\frac{r}{min}\right)$

P = Perimeter of the rotor (m)

The next equation is used for determination of **measurement velocity error** which is the difference between the linear velocity measured by the reference and the sensor on calibration:

$$e_v = v_t - v_r \qquad (4)$$

$e_v =$ Measurement velocity error $\left(\frac{km}{h}\right)$

$v_t =$ Velocity of the sensor in calibration $\left(\frac{km}{h}\right)$

$v_r =$ Reference Velocity $\left(\frac{km}{h}\right)$

7. MEASUREMENT OF VELOCITY

The velocity calibration is performed from 10 km/h to 190 km/h and is measured at nineteen different velocity points. One measurement per second is recorded by the CeCalWin Pro and the software of the frequency counter, until complete one hundred measurements for each velocity point.

Figure 6. Calibration of non contact velocity sensor

All the recorded data is processed on spreadsheet, the measurement velocity error is estimated using equation (4) as well as uncertainty according to GUM to be finally shown in a graph.

8. RESULTS
The measurement results of the performed calibration are shown in the Table 2 and Figure 7.
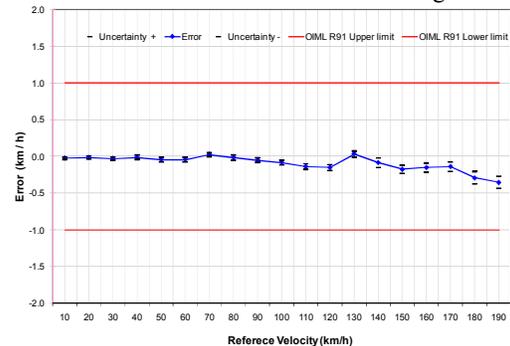

Figure 7. Calibration results of non contact velocity sensor, model: Correvit Aqua L350

In Figure 7 is observed the behaviour of the measurement error velocity in the nineteen calibration points. Despite the fact that error sensor response increases at high velocities, the maximum

measurement error does not exceed the 0.4 km/h at velocities under 100 km/h the error is smaller than 0.2 km/h.

According to OIML R91, all errors under reference conditions shall be less than ± 1 km/h, or ±1 % at speeds above 100 km/h. [2]

Table 2. Calibration results and uncertainty budget.

Reference km/h	Optical sensor km/h	Velocity Error km/h	U k=3 km/h	Velocity Error %
10.00	9.98	-0.02	0.02	-0.22
20.02	20.01	-0.01	0.02	-0.07
30.02	30.00	-0.03	0.02	-0.09
40.08	40.08	-0.01	0.03	-0.02
50.03	49.99	-0.04	0.03	-0.08
60.02	59.98	-0.04	0.03	-0.07
70.03	70.06	0.03	0.03	0.04
80.02	80.01	-0.01	0.04	-0.01
90.04	89.99	-0.05	0.03	-0.06
100.03	99.95	-0.08	0.03	-0.08
110.04	109.91	-0.14	0.04	-0.12
120.04	119.89	-0.15	0.04	-0.12
130.05	130.08	0.03	0.05	0.03
140.05	139.97	-0.08	0.06	-0.06
150.06	149.88	-0.17	0.05	-0.12
160.07	159.92	-0.15	0.06	-0.09
170.06	169.92	-0.14	0.06	-0.08
180.07	179.78	-0.29	0.08	-0.16
190.07	189.72	-0.35	0.08	-0.18

Table 2 shows all the numeric values obtained from the calibration process and uncertainty budget. Velocity error, is shown in percent for easier comparison with the manufacturer declared accuracy of <± 0.2 %. [3]

The measurement error of the optical sensor under calibration is below the specification of the manufacturer but its dispersion is much higher than that shown by the reference measurement standard, see figure 8.
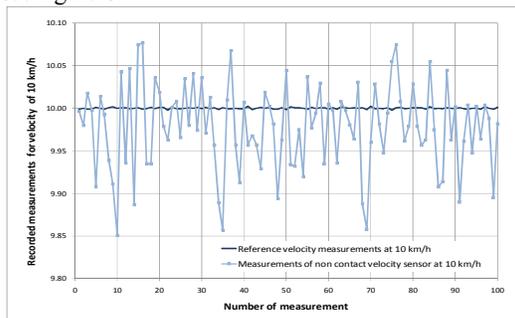

Figure 8. Dispersion of measurements at 10 km/h

9. CONCLUSIONS

The calibration technique used in the linear velocity Lab is reliable enough to preserve the quality of measurements for automotive testing trough the calibration of optical velocity sensors. It is also suitable for legal metrology. The Correvit L350 sensor has been used as working standard on field calibrations at CENAM of traffic radar systems as the model AUTOVELOX® 105 SE, Sodi Scientifica. The obtaining results until 100 km/h were between ±3 km/h according to the IOML R91. The reference velocity system is continuously being improved to try to diminish errors related to synchronization of the system and the sensor in the adjustment of distance.

10. REFERENCES

[1] Information and images from: http://www.corrsys-datron.com/technology.htm
[2] OIML R91. International recommendation. 1990. Radar equipment for the measurement of the speed of vehicles.
[3]Data sheet, Correvit Aqua L350, Corrsy Datron. http://www.corrsys-datron.com/Support/Data_Sheets/CL350A_000-808e.pdf
[4] Guide to the expression of uncertainty in measurement. JCGM 100:2008 (**GUM** 1995 with minor corrections)
[5] 510-AC-P.104. Calibration procedure. Calibration of linear velocity transducers. CENAM, 2011
ISO 80000-3 Quantities and Units- Part 3 Space and time