CALIBRATION METHODOLOGY OF A F101-F201 GLOBAL FLOW PROBE USING A LASER DOPPLER ANEMOMETER

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Abstract: *Random uncertainties caused by the environment conditions, system operator as well as the measurement system itself, are factors that interfere in measurements. Concerning the uncertainty generated by the instrument interference, the use of non-invasive instruments, which are not introduced in the environment, is supported. However, these instruments are generally very costly and require specific work conditions which disable their use in certain tests, mainly in the field test. With the objective of correcting the interference caused by the invasive measurement system, its calibration is done using only non-invasive measurement systems as standards. This paper presents the calibration methodology of an invasive flow probe, the F101-F201 Global Flow Probe, with the required correction of the instrument interference on the true velocity measurement in the system. This methodology can also be applied on the calibration of other invasive type velocity measurement systems.*

Keywords: *Flow probe, LDA, calibration*

1. Introdution

Velocity measurement is of large importance in the flow analysis. The use of optical instruments is every day more frequent, as they are non-invasive instruments, and therefore, don't interfere in the measurement result. However, this takes several specific parameters, such as transparent walls of the systems to be studied, insertion of seeding particles in the fluid, among others.

In field studies, most of the times, these parameters cannot be respected, and therefore, the use of invasive instruments is necessary.

With the objective of reducing the uncertainty of measurement reading, caused by the interference of the invasive type velocity measurement system, optical equipments are used, such as the Laser Doppler Anemometer (LDA) which are non-invasive. This paper presents the calibration of a F101-F201 Global Flow Probe, using a LDA as standard.

2. Probes used for Flow Measurement

The rotational sensors, such as the probe, have a propeller that can spin in both directions. The probe can have a horizontal or vertical shaft, with several types of rotors. The two main types are illustrated in Fig.1

The basic relation for the calculus of velocity comes from the counting of the number of propeller rotation, measured by a sensor, leading to the Eq.1 described as follows (Filizola Jr., Guimarães e Gugot, 1999):

$$V = a_h \times N \times t^{-1} + b \qquad (1)$$

where: a_h= propeller pass; b= propeller inertia; t= measurement time; N= number of propeller rotation.

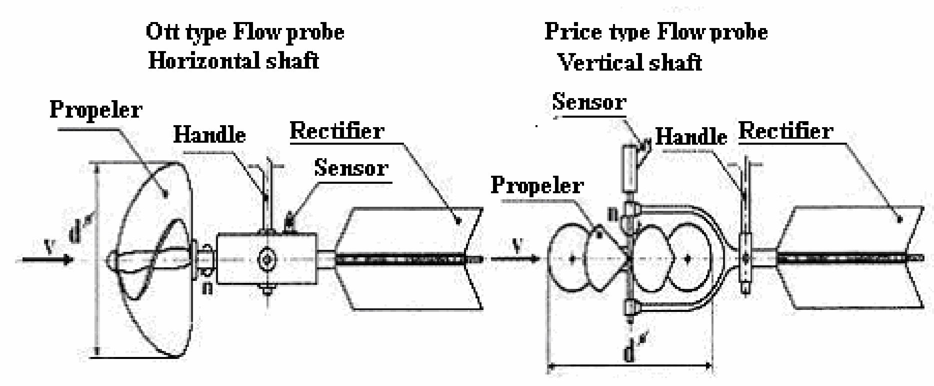

Figure 1 – Horizontal and vertical shaft of rotation sensor probe
Source: Souza, Bortoni e Almeida,1999

These types of probes produces lower head loss and high accuracy, and also do not suffer any interference of water turbidity variation. The most common types of probes are insensitive to an angular slope of ± 5º, relative to the fluid flow. However, there are special types of probes that allow a precise reading for angles up to ± 45º (Coelho, 1983).

3. Material and Method

According to the manufacturer's manual, the observed reading uncertainty for the studied instrument, Fig.2, for measurements in m/s, is of 0,03m/s. However, in order to confirm the manufacturer's data, the calibration of the instrument was done. Initially, the velocity was measured in all of the probe's frontal area, so as to verify the differences in velocities on points located in different positions. With this objective, the probe was inserted in a 30cm wide and 50 cm high acrylic canal, and the velocities measured using the LDA were used, in order to co-relate with the ones measured by the probe. The initial measurements were taken using the LDA, in the region closer to the inferior wall, taking gaps of 10mm in the x and z directions, until all the probe's area was covered. The measurements were taken upstream the probe, where its interference did not yet occur. (Andrade, 2002). The measurements positions can be observed in Fig.3.


(a) (b)
Figure 2 - a) Probe's handle with propeller; b)mini-computer display
Source: User's Manual-Global Water, 2002

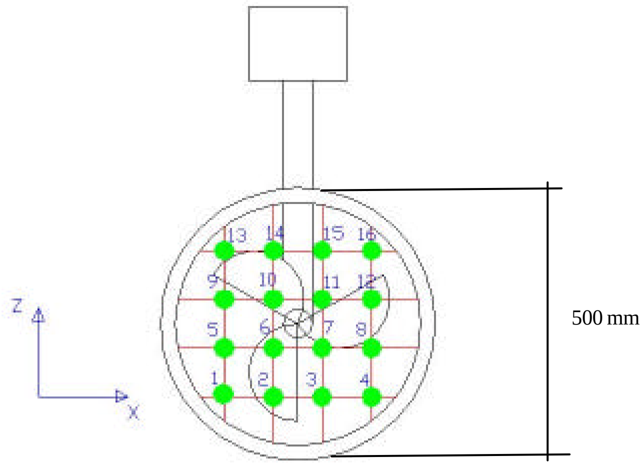

Figure 3- Velocity Measurement points in the studied probe's frontal area
Source: Viana,2005

After the measurements using the LDA, in the 16 control points, in the probe's frontal area, the average value of these velocities were compared to the average velocity observed in the probe's display. The differences found between the velocity observed in the LDA and the flow probe, in different points, can be verified in table.1

From this table, it could be observed that the values obtained in different points using the LDA, showed a maximum variation of 0,02m/s. With this information, the velocity values, in different points of the probe´s area, were considered invariable. For the calibration of the instrument, the probe was placed in the center of a test tube, and then, the velocity was measured for different flows. The flow control was made by an electromagnetic probe. For velocity control, the LDA's measure volume was placed in the center part of the test tube. The assembly for the probe's calibration can be seen in Fig.4, and Fig.5 shows a detail of the LDA passing through the test tube during the measurements.

Table 1 – Comparison between the average velocity values, measured in different points using the LDA, and the velocity values measured using the Probe

Point	**$V_{aver\,LDA}$ (m/s)**	**$V_{aver\,probe}$ (m/s)**
1	0,90	0,97
2	0,90	0,97
3	0,91	0,97
4	0,90	0,97
5	0,92	0,97
6	0,91	0,97
7	0,91	0,97
8	0,90	0,97
9	0,92	0,97
10	0,91	0,97
11	0,90	0,97
12	0,91	0,97
13	0,90	0,97
14	0,90	0,97
15	0,90	0,97
16	0,90	0,97

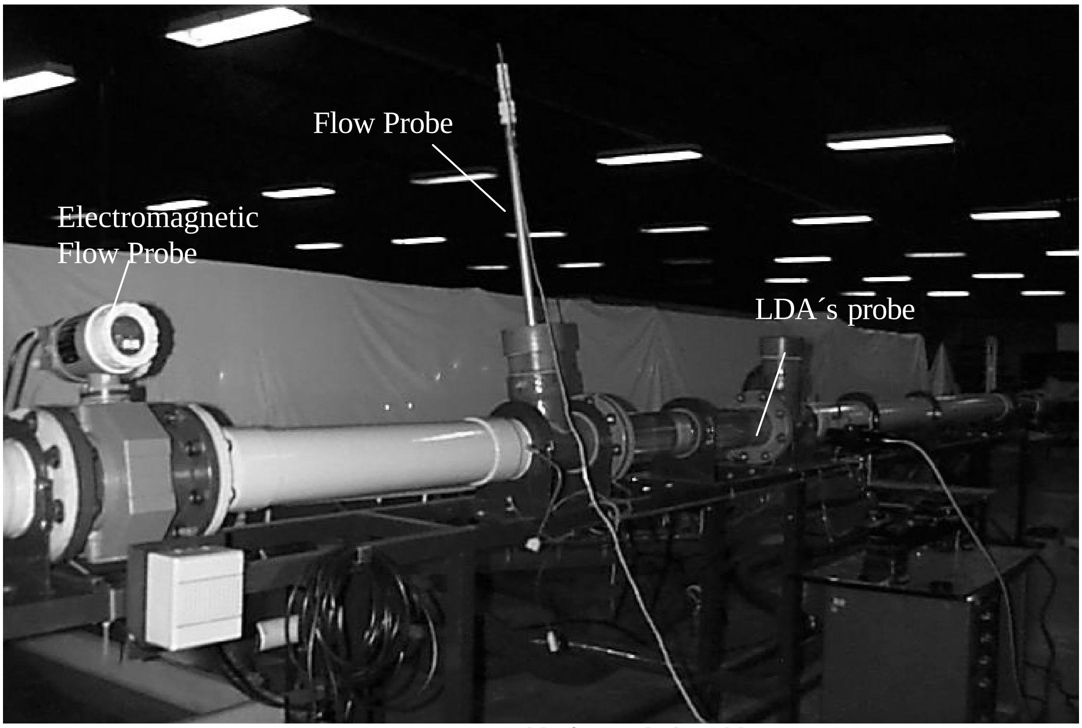

Figure 4) System Assembly for Probe´s Calibration
Source: Viana, 2005

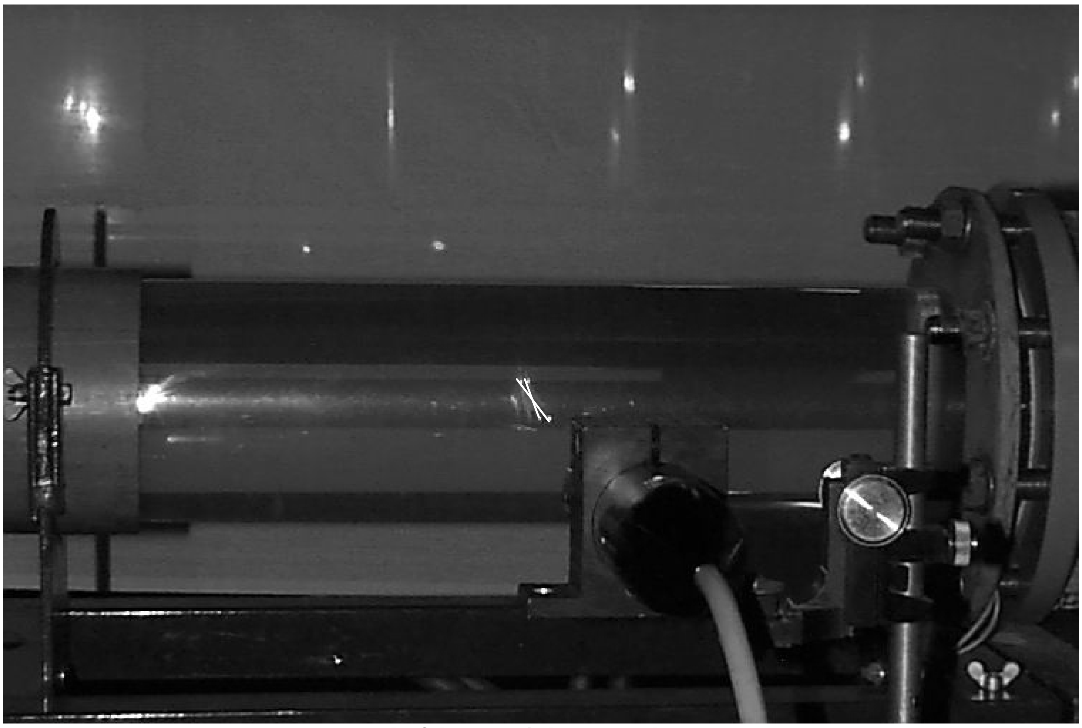
Figure 5) Detail of the LDA´s beams making measurements
Source: Viana, 2005

4.Results

After the calibration of the instrument, and the inspection of its hysteresis, table 2 was constructed, where we can find the system conditions of calibration. The chart containing the calibration curve and the calibration equation, was constructed using the "Statistica" program.

Table 2- System´s Operational Conditions in the Probe´s Calibration

		Crescent				Decrescent			
$Freq_{pump1}$ (Hz)	$Freq_{pump2}$ (Hz)	Q (m^3/s)	V_{LDA} (m/s)	$V_{probemed}$ (m/s)	$V_{probemax}$ (m/s)	Q(m^3/s)	V_{LDA} (m/s)	$V_{probemed}$ (m/s)	$V_{probemax}$ (m/s)
20	0	0,0094	0,721597	0,792	0,8	0,0091	0,684658	0,85	0,86
25	0	0,0115	0,87244	1,05	1,1	0,0115	0,845946	1,05	1,05
30	0	0,0138	1,03384	1,184	1,2	0,014	1,00862	1,188	1,24
35	0	0,0164	1,14118	1,378	1,39	0,0162	1,15524	1,381	1,44
40	0	0,0187	1,31404	1,59	1,6	0,0183	1,31062	1,584	1,63
45	0	0,0206	1,47309	1,777	1,79	0,0205	1,45542	1,78	1,80
50	0	0,0229	1,63875	1,973	1,98	0,0228	1,60014	1,976	2,00
55	0	0,025	1,77061	2,162	2,18	0,025	1,75321	2,164	2,18
60	0	0,0271	1,91632	2,355	2,38	0,027	1,88287	2,35	2,36
35	38	0,0276	2,00737	2,417	2,48	0,0276	1,98256	2,473	2,42
40	38	0,0296	2,13807	2,579	2,64	0,0296	2,08852	2,574	2,60
40	40	0,0303	2,14727	2,631	2,69	0,0301	2,14282	2,629	2,65
45	40	0,0319	2,28337	2,785	2,81	0,0321	2,25342	2,785	2,82

Adjusting the model using multiple linear regression, where the variables are the velocity measured using the LDA (V_{LDA}) and the Flow Probe (V_{probe}). The following equation was found:

$$V_{LDA} = \left(V_{Probe} \times 0{,}794908 + 0{,}065014\right) \quad (2)$$

For this equation, conditioning parameters were found; R, R^2 which corresponds to the equation adjustment, beta which is the the coeficient of the equation and B which is the constant component. They can be verified in Table3.

Table3) Conditioning Parameters of the equation which co-relates the LDA velocity and the Probe velocity

R= ,99930487 R²= ,99861021 Adjusted R²= ,99848387						
F(1,11)=7903,9 p<,00000 Std.Error of estimate: ,02034						
	BETA	St. Err. of BETA	B	St. Err. of B	t(11)	p-level
Intercpt			0,065014	0,017883	3,635622	0,003918
Probe	0,999305	0,01124	0,794908	0,008941	88,9038	4,55E-17

Using the co-relation of the measured velocities, by the Flow Probe and the LDA, the calibration curve can be determined, and therefore the uncertainty due to the intereference of the instrument in the flow can be found. Figure 6 shows the calibration curve of the Flow Probe.

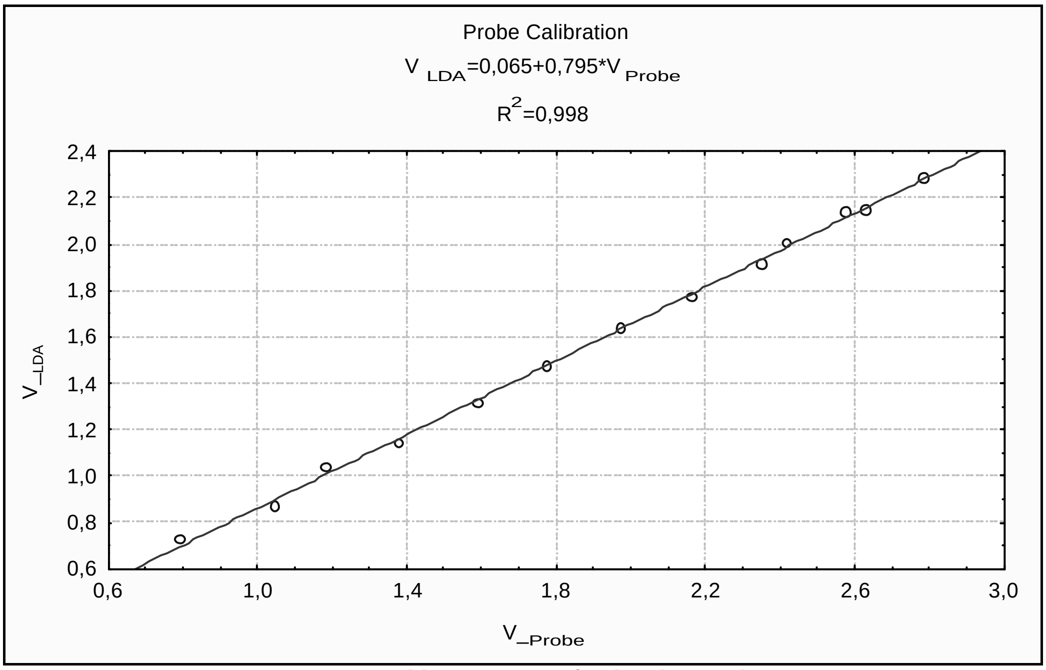

Figure 6- Calibration Curve for the Flow Probe
Source: Viana, 2005

5. Conclusion

As observed in the presented tests, the invasive measurement system, such as the Flow Probe, promotes an interference in the flow, and therefore, a large uncertainty in the velocity reading is caused, together with a distortion of the hydraulic behavior of the system to be analysed. However, it could be observed that, the utilization of non-invasive instruments, such as the LDA, minimizes these uncertainties, promoting the correction of the readings observed by the invasive equipment , through the calibration curve constructed.

6. Reference

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