VIDEO SURVEILLANCE AND SIGNAL PROCESSING OF PIPELINE LIQUID FLOW

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Abstract – The quality and the quantity of liquid fluid flow in pipelines is a crucial issue for human beings' daily life, especially for leak detection. The control and managing of pipelines have been assuming a major importance for all kinds of fluids to be conveyed through. When the fluid is like oil, hazardous fluid and/or water for human beings' necessity, the monitoring of pipelines becomes extremely fundamental. For complex pipeline networks, even if flowmeters deliver data about fluid quantities, they cannot be used for each part of a complex and extended network because of heavy increasing costs. The research proposes the use of video surveillance in terms of video validation of a magnetic flowmeter in order to measure the amount of fluid by using only video camera located on an analog flowmeter. A specific algorithm has been developed to process liquid frames.

Keywords - Signal processing, Flowmeter, Uncertainty, environmental measurements

1. INTRODUCTION

Magnetic flow meters operate on a principle based on Faraday's law of electromagnetic induction. The meter generates an electromagnetic field in the pipeline and measures the amount of voltage created by charged particles in the water as they move through the magnetic field with the water. The faster the velocity of the water, the greater the voltage that is generated. Sensors on opposite sides of the inside of the spool measure the amount of voltage created. The voltage is amplified, measured and the velocity of the fluid is calculated. Most meters automatically convert this velocity measurement to display flow, a few meters display velocity only and the conversion to flow must be made manually. By measuring the size of an induced electromagnetic force, the flow rate can be calculated [1] [2] [3]. Electromagnetic force value in terms of voltage and volume flow can be calculated from the following expressions.

$$U = BLv \,. \tag{1}$$

$$Q = vA \,. \tag{2}$$

where *U, B, L, v, Q, A* terms represent induced voltage, magnetic field, distance between electrodes, flow velocity, volume flow, pipe cross-sectional area, respectively. An electromagnetic flowmeter description is shown in fig 1.

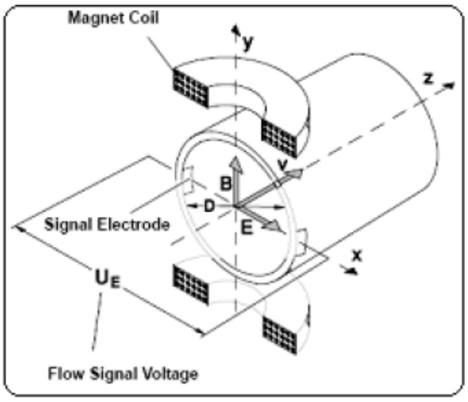

Fig.1 Experimental layout

The flowmeter consists of a conductive pipe with an insulated inner surface liner or a nonconductive pipe which is mounted in the gap of the magnet, two electrodes , and electromagnet such as a permanent magnet. The liquid must be electro-conductive. The conductive electrodes are in contact with the liquid and are oriented perpendicularly to both the direction of flow and the lines of the magnetic field. When the magnet coils are energized by a current, small magnetic field is created across the fluid [4].

As denoted in the abstract, leak detection and damage prediction are important and must be monitored. Economic, social and environmental factors make leak containment and reliability analysis of plants essential. Different factors contribute to pipeline damage: low quality or faulty materials used in production of pipelines and junctures, design errors, insufficient maintenance, high operating pressure or random damage. For water resource management in particular, leaks along pipelines and inner networks should not exceed physiologic values around 10-15% in normal operating conditions. In different western countries, in the drinkable water sector, leaks reach 30% [5] with peaks around 50% in some urban areas, such as Italy [6], and they produce an economic damage of more than 650 million dollars per year. Taking into account the fact that water availability is not inexhaustible, the environmental cost of leaks is very high. Nowadays, modern technology allows accurate measurement of flow [7], pressure and levels in water networks. Previous studies have adopted different methods for leak detection in plants. Non-invasive methods are based on the use of techniques such as terrain analysis for detecting chemical substances or acoustic emissions. Among the currently known techniques, it is possible to include those developed by different authors [8-11], who use transient analysis; this analysis requires a huge quantity of real-time data and hence, it has a high computational cost or, in some circumstances, it is difficult to adopt. Video surveillance remains a good alternative because it allows to measure the flow, hence to detect changes in water flow and eventual coarse impurities.

2. PROPOSED METHOD

For complex and interlaced networks of pipelines, it becomes very costly to use magnetic flowmeter, in particular in case of non electro-conductive fluid it is not possible to use them.

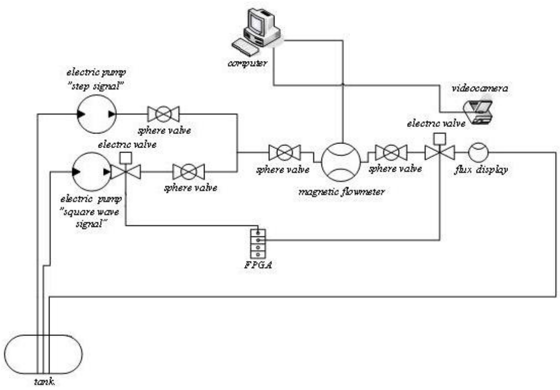

Fig.2 Experimental layout

This paper illustrates a method of video surveillance of an experimental pipeline (fig.2) by using a video camera connected to a hardware platform for processing frames [12] coming from a modified analog "house flowmeter" which is mounted on the same pipeline with an ADMAC AE-210DN flowmeter and an ADMAC AE-14 converter that are produced by Yokogawa (see fig.3 and fig.4). The main idea is to use the video surveillance as a flowmeter in order to obtain a similar accuracy as for the magmeter.

Fig. 3 Video surveillance and acquisition system

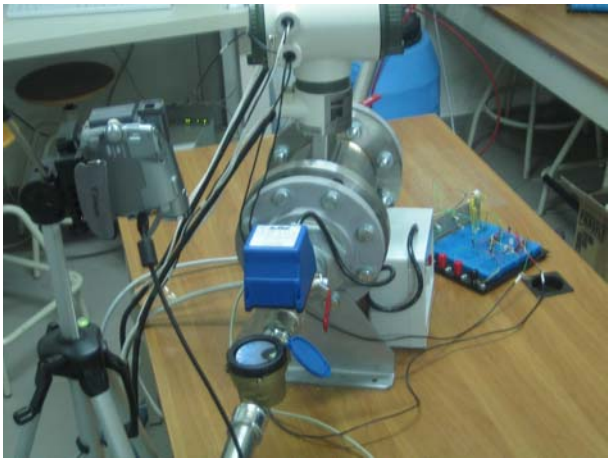

Fig. 4 Acquisition system details

The key idea is to exploit the angular distance between two points P_1 and P_2 according to the fig.5. the angular distance is calculated using the relationship of Eq.(3). Thus, the flow is given by Eq.(4).

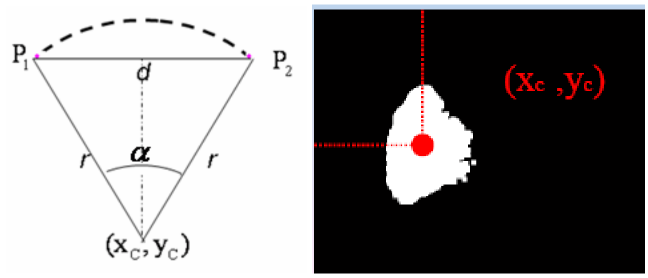

Fig. 5 Angular distance and its location in the house flowmeter

$$\alpha = 2\arcsin\left(\frac{d}{2r}\right). \tag{3}$$

$$flow = \frac{speed + 0.3}{9.18}. \tag{4}$$

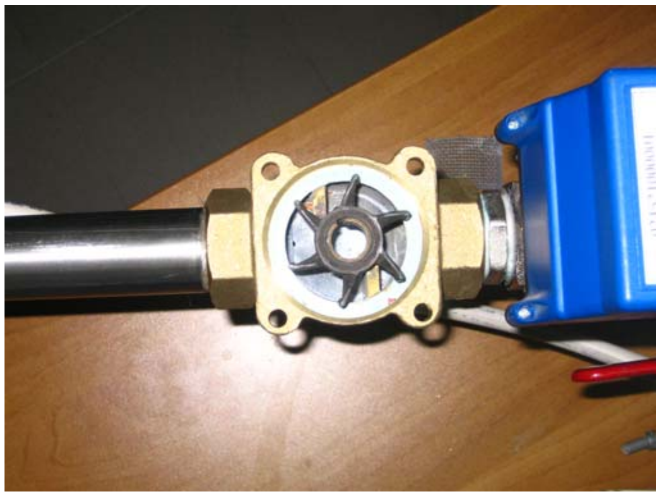

Fig. 6 Video surveillance and acquisition system

The magnetic flowmeter used for comparison in this research has the transfer function described in Eq.(4). It is a second order function.

$$G(s) = \frac{3.04 \bullet 10^{-3}}{s^2 + 0.067s + 1.94 \bullet 10^{-3}} . \qquad (4)$$

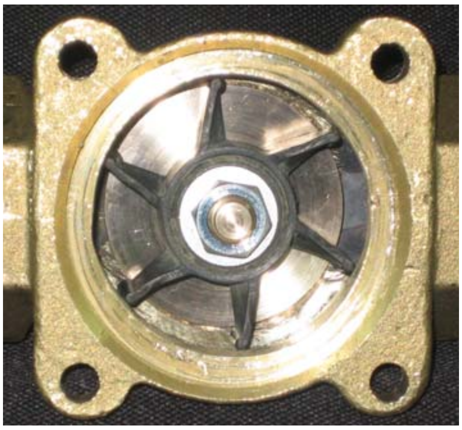

Fig.7 Modified flowmeter–step 1

Fig.8 Modified flowmeter step-2

For the purposes of the research an analog "house flowmeter" of fig. 6 has been modified according to fig.7 and fig.8 in order to exploit the rotation of tuyères. The algorithm is based on the acquisition of the distance between two points [13] belonging to two consecutive frames. Hence, the frame are amplified through an intensifier board designed for the purposes of this research. Fig. 9 depicts the frame acquired by the camera according to Eq. (3).

Fig. 9 Acquired frame

The algorithm works as follows:

- acquire *n* voltage values (amplitudes) & compute the average;
- determine the corresponding flow of the previous values;
- acquire 25 frames from the camera each 0.04 sec;
- determine the rotation speed of analog "house flowmeter";
- compute the flow;
- compute error;
- display;
- if yes stop, otherwise go the first step

3. FINAL COMMENTS

After the calibration and the searching of the equivalence between the frame of the house flowmeter and the real flow using the magnetic flowmeter, now it is possible to obtain the video surveillance. In a preliminary way, we measured the flow using the magnetic flowmeter (see fig. 10, water speed vs time). Hence, we produced the results of fig. 11. The video results is almost similar to those recovered by magnetic flowmeter. The difference consists in timing and maximum amplitude. The average values are similar. This kind of measurements could be interesting where it is necessary to perform broad (qualitative) measurements without using magnetic flowmeter. It is a low cost system.

A specific acquiring and image processing has been implemented in matlab environment, where one can see, for square wave water input, the comparison between the real flow (red plot) and the estimated one through [14] video acquisition (blue plot). The video surveillance is able to follow the rotation of the "house flowmeter". The video surveillance system is able to follow the rotation and the results can be considered encouraging [15].

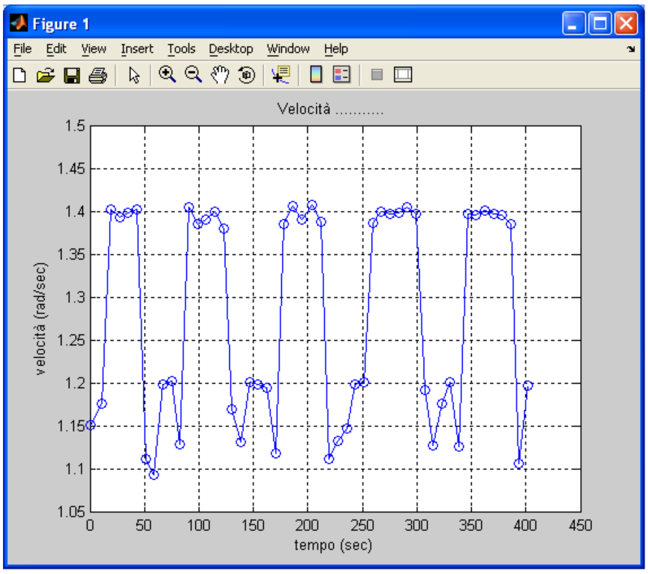

Fig. 10 Flowmeter operating data

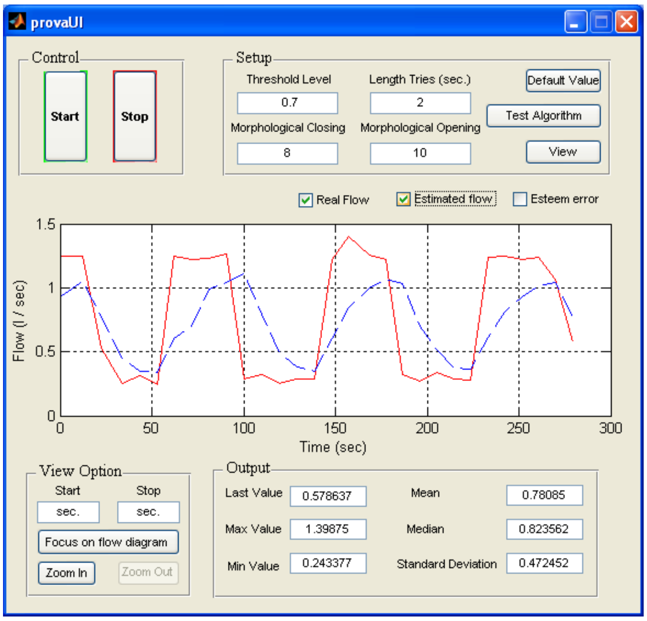

Fig. 11 Comparison between magnetic flowmeter trend (red colour) and video surveillance one (blue one)

In order to summarize the main scope of this research, it is important to emphasize the possibility of estimating the flow in pipelines by using a video surveillance.

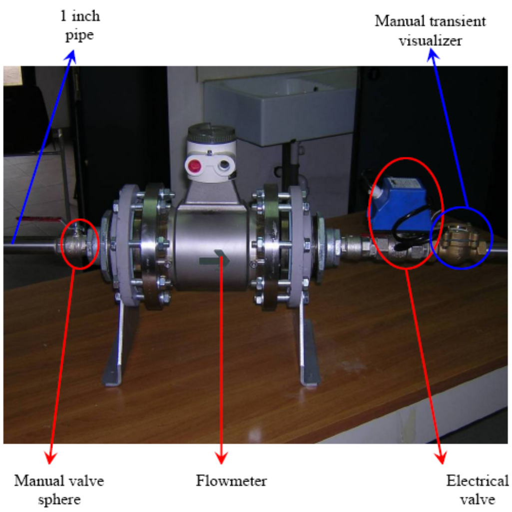

Fig. 12 Flowmeter on pipeline

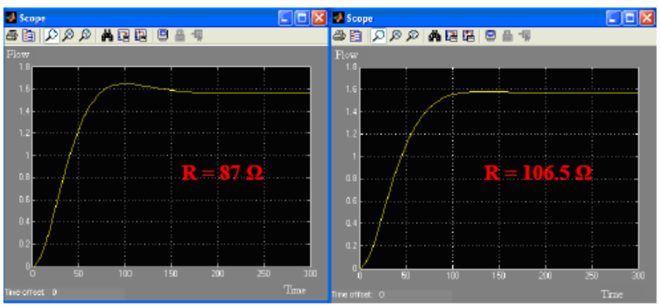

Fig. 13 Resistance changing effect

The paper has also faced the comparison between a real flowmeter as indicated in fig.12 which transfer function is described in fig. 13 and fig.14. So the these figures reflect the trend of fig. 15. This trend is also retrieved in our research according to fig.11.

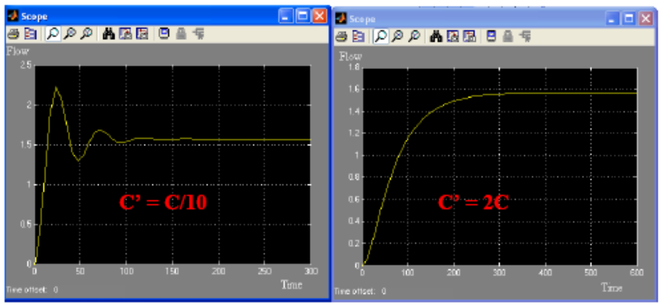

Fig. 14 Capacitance changing effect

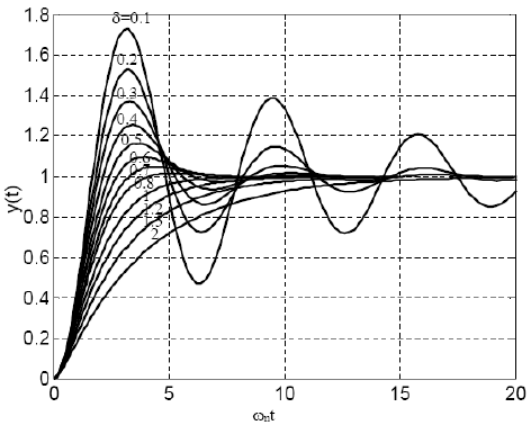

Fig. 15 Evolution of the second-order system changing dumping

The difference between the use of magnetic flowmeter and the video-meter is related to the opportunity of decreasing the cost of flow monitoring and measuring the flow aside from the physical characteristics of the fluid, namely, electro-conductivity, temperature, viscosity, etc.. By means of the video-metering, there is no contact with the fluid to be measured and with the pipeline containing the fluid.

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