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Leak Detection and Model Analysis for Nonlinear Spherical Tank Process Using Conductivity Sensor

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Abstract: Model parameters are affected by leak in process plants and this leak can be considered as disturbance in model evaluation. A non linear spherical tank of 40 liter capacity was used for this study. Process Model was generated experimentally using step response technique with online conductivity as monitoring parameter. A microcontroller using ATMEGA16 was used for the measurement of conductivity with and without leak of process liquid. The process model parameters were affected due to leak up to seventeen percent in the range of flow rates studied. *Copyright © 2008 IFSA.*

Keywords: Leak, Tracer, Model, Conductivity, Microcontroller, Spherical

1. Introduction

Leakage in pipes and process vessels can affect to varying degree the model parameters as well as product quality. Many authors [1-7] have used conductivity to develop models. Moreno et al. [8] have used conductivity to control water quality. Billmann [9] has designed a liquid flow sensor for detection of leak in pipes. Hiroki [10] has developed a unit for water leak detection in fusion reactors. Verde [11], Bausch et al. [12], and Convey [13] have also studied leak in pipelines. Nelemegam et al. [14] have used Microcontroller to evaluate conductivity. These authors have not analyzed the effect of leak on model parameters. This work quantitatively analyses the effect of leak of process fluid on model parameters.

2. Experimental Setup

Fig.1 shows the setup used in this study. A concentrated sodium chloride tracer solution and fresh water are fed to a 40 liter spherical tank through suitable rotameters. Online conductivity sensor from M/s Honeywell in the exit pipe measures the conductivity of the flowing liquid. The signal is suitably modified and interfaced with an inbuilt ADC (PA0) of a microcontroller. The microcontroller ATmega16 is a low power, high performance 8 bit microcontroller. It has 16 k Bytes of in-system Self-Programming Flash, 1K Byte internal static RAM, 512 bytes EEPROM, two 8 bit timer/counter, one 16 bit timer/counter, 8 channel 10 bit ADC, 4 PWM channels, programmable serial UART, on chip analog comparator and 32 programmable I/O lines. Two row 16 character alpha numeric LCD display is interfaced to port D of the microcontroller to display the results. A key board is interfaced with PORT C of microcontroller. An ICL232 chip is interfaced with microcontroller to transmit and receive data from PC. ICL232 IC chip is a dual RS232 transmitter/receiver interface circuit that meets all EIA RS232 specification. The input side of the chip is connected to TxD/RxD pin of microcontroller and the output side of ICL232 is connected to COM1 port of PC.

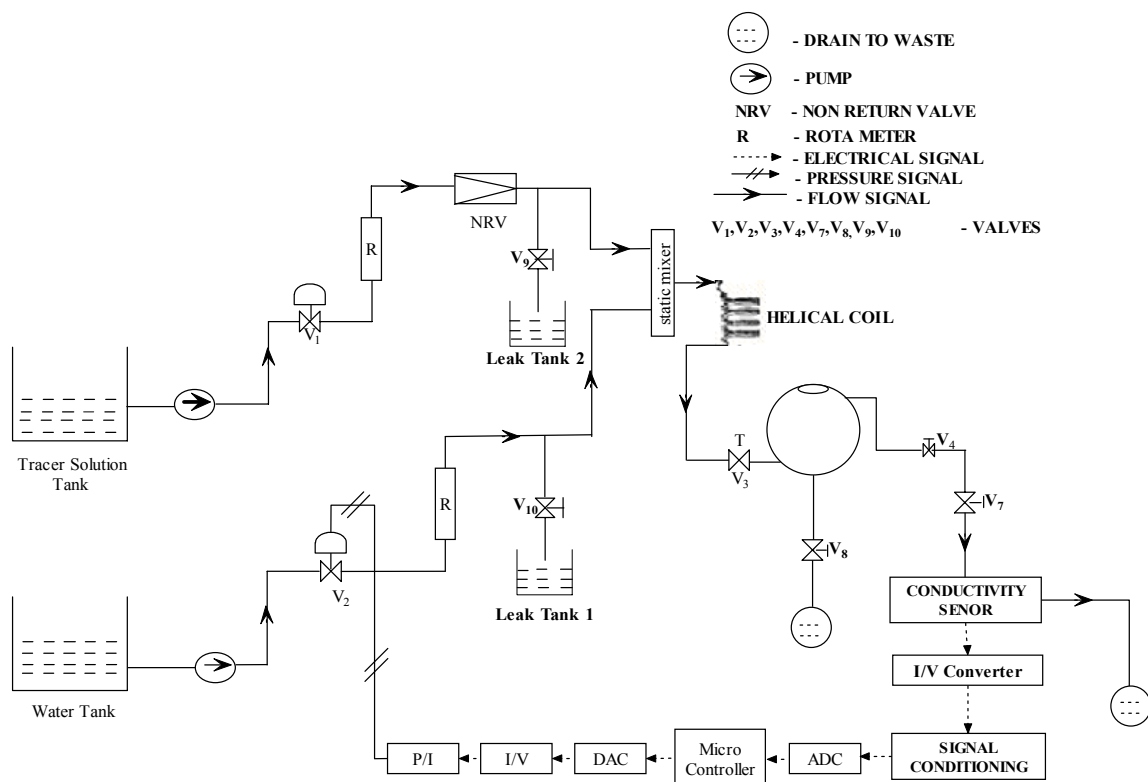


Fig. 1. Experimental setup for leak measurement.

2.1. Calibration

Conductivity sensor was calibrated with known solutions of sodium chloride. Fig.2. shows the calibration curve.

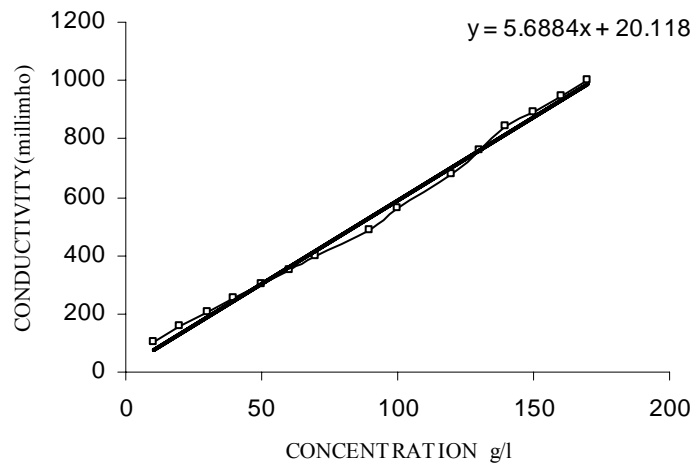


Fig. 2. Calibration curve for conductivity sensor with known concentration.

2.2. Measurement Procedure

The process flow model was established [15] by open loop analysis by varying water flow rates from 2 to 5 lpm. Tracer was injected as a step from 0 to 0.5 lpm. The outlet conductivity was recorded. A leak of different magnitude was introduced in the pipeline by manipulating valve V_{10} for pure water. The exit conductivity with leak was also measured.

2.3. Software

Software was developed in C language to initialize the LCD display, serial port, to start ADC conversion, to check end of conversion, to read data from ADC, to compute conductivity of the sample, for measurement of time, data computation for acquired data, storage of data and to send data to PC, to receive data from PC. The software is compiled by C compiler and the resulting codes are stored in the program memory of the ATmega16 microcontroller and the program was executed for measurement of conductivity with and without leak.

2.4. Model Analysis

The data in Figs. 3 to 5 was fitted to a first order plus dead time model [16] given by equation 1. where K_p is the process gain, τ_d the time delay and τ is the process time constant. The model parameters with and without leak are given in Table 2.

$$G_p(s) = \frac{K_p e^{(-\tau_d s)}}{\tau s + 1} \quad (1)$$

3. Results and Discussion

The variation of conductivity with and without leak for various flow rates of water are given in Figs. 3 to 5. Varying quantity of leak (as a fraction of main flow rate) is introduced after initial stabilization by manipulating valve V_{10} and is indicated by arrow mark in Figures 3 to 5. Table 1 records the leak induced and the corresponding error in final value of conductivity. Table 2 gives the model parameters

with and without leak. The process gain (K_p) and time constant (τ_p) are affected from 5 to 58 percent due to leak as seen from Table 2.

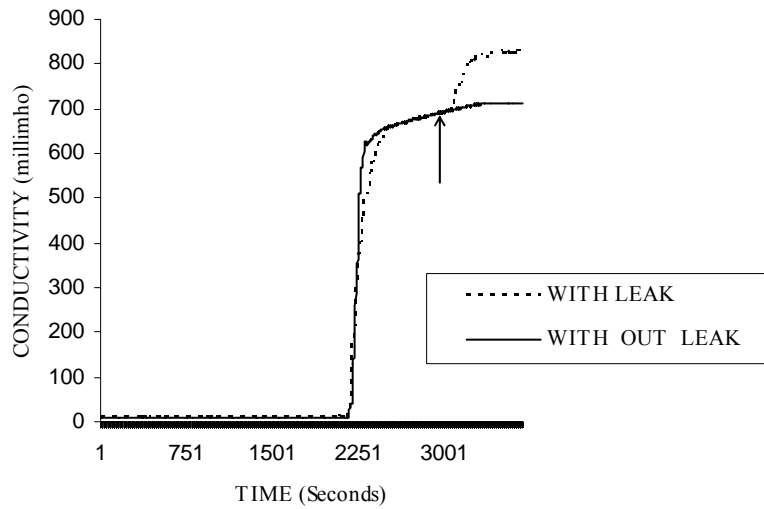


Fig. 3. Response for 50 percentage leak of water.

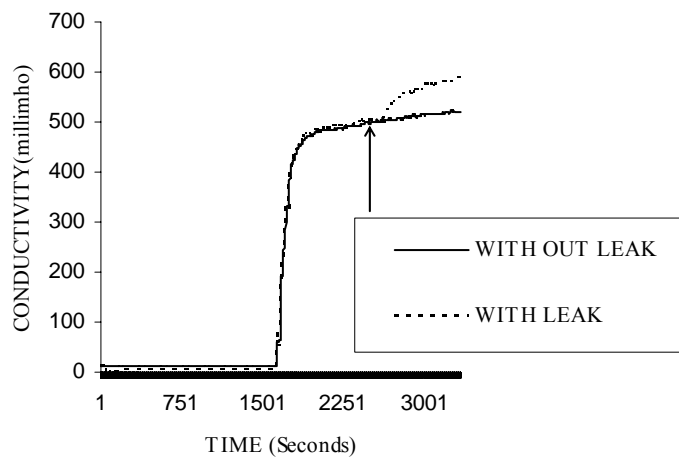


Fig. 4. Response for 66 percentage of leak of water.

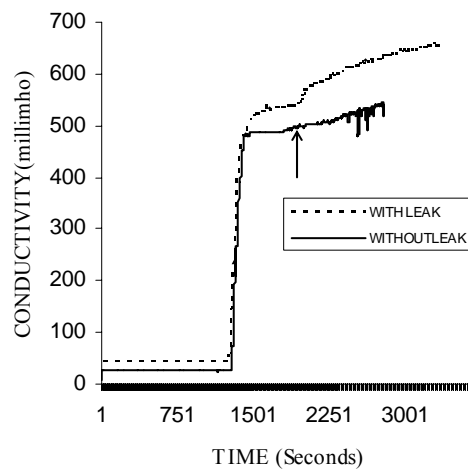


Fig. 5. Response for 75 percentage of leak of water.

Table 1. Effect of leak on final value of conductivity.

S.No	Main flow rate lit/min	Leak flow rate lit/min	Percentage leak ((Main flow-leak flow) / Main flow)) x 100	Final Conductivity Value millimho/cm		Percentage error in conductivity
				Without Leak	With Leak	
1	2	1	50	700	830	15
2	3	1	66	560	620	16
3	4	1	75	490	590	17

Table 2. Model Parameter with and without leak for various flow rates.

S.No	Leak ratio (%)	Main Flow rate(lit/min)	Model parameters							
			Without leak			With leak			% change due to leak	
			Process Gain (K _p)	Time constant Secs (τ _p)	Delay Time Secs (τ _d)	Process Gain (K _p)	Time Constant Secs (τ _p)	Delay Time Secs (τ _d)	Process Gain (K _p)	Time Constant Secs (τ _p)
1	75	4	5.46	27	1400	5.75	36	2000	5	33.3
2	66	3	6.25	36	1500	8.31	55	2525	32	52.8
3	50	2	8.38	42	2000	13.3	60	2900	58	42.8

4. Conclusion

Model parameter analysis and leak detection based on microcontroller for a non linear spherical process has been studied. Their characteristics based on delay time, time constant, process gain are compared for both processes. From Table 2 it is observed that due to leak in the process, model parameters are affected and also conductivity level varies from 15 percent to 17 percent. This shows that leak adversely affects model analysis and effective care should be taken.

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Advancing Vehicle and Body Armor Protection in an Asymmetric Environment

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Mission-critical topics include:

- Unidirectional Body Armor Systems to Defeat EFPs and IEDs
- Innovations in Survivability of Ground Vehicles
- Design and Performance Improvements for Individual Ballistic Protection

www.idga.org/us/map/ifsa

Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In addition, some special sponsored and conference issues published annually.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

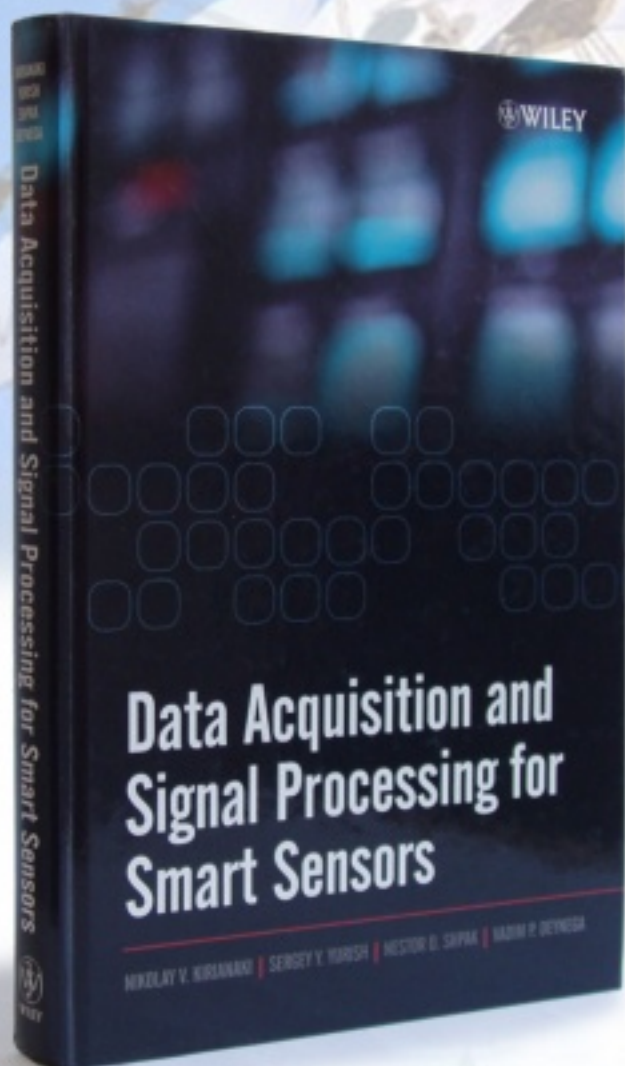
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KNOWLEDGE FOR GENERATIONS



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(from IEEE Instrumentation & Measurement Magazine review)



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