Engineering Growth Connection

TWO TANK INTERACTING SYSTEM (PC-115)

Foreword

Welcome to the fast growing family of K.C. product owners. We appreciate your interest in us and thank you for buying our product.

You have chosen the finest quality product in the market which is produced using latest techniques and has underwent strict quality control tests. It is a product that we are proud to build and you are proud to own it.

Our products are easy to understand and operate. They are excellent for students who are trying to gain practical knowledge through experiments.

However your comfort and safety are important to us, so we want you have an understanding of proper procedure to use the equipment. For the purpose, we urge you to read and follow the step-by-step operating instructions and safety precautions in this manual. It will ensure that your favourite product delivers reliable, superior performance year after year.

This manual includes information for all options available on this model. Therefore, you may find some information that does not apply to your equipment.

All information, specifications and illustrations in this manual are those in effect at the time of printing. We reserve the right to change specifications or design at any time without notice.

Customer satisfaction is our primary concern. Feel Free to contact us for any assistance. So what are you waiting for, roll up your sleeves and let us get down to work!

K.C. Engineers Pvt. Ltd.

Important Information About This Manual

Reminder for Safety

Modification on Equipment:

This equipment should not be modified. Modification could affect its performance, safety or disturbance. In addition damage or performance problems resulting from modification may not be covered under warranties.

Precautions and Maintenance:

This is used to indicate the presence of a hazard that could cause minor or moderate personal injury or damage to your equipment. To avoid or reduce the risk, the procedures must be followed carefully.

Contents

TWO TANK INTERACTING LIQUID-LEVEL SYSTEM

1. OBJECTIVE:

To study the dynamic response of liquid level in two tank interacting system.

2. AIM:

2.1 To calculate the valve resistance of both the tank.

2.2 To calculate the time constant of both the tank.

2.3 To calculate the step response of two tank interacting system to a step change in input flow and compare it with the theoretical response.

3. INTRODUCTION:

The principle distinction to be made in multi-capacity processes is in how the capacities are joined. If they are coupled, they interact with one another, in which case the contribution of each is altered by the interaction. In interacting system the levels in both tanks interact because any change in the down stream level will affect the upstream level.

The following general rules are applied to the principle of interaction;

1. The degree of interaction is proportional to the ratio of the smaller to the larger capacity (not time constant). Where this ratio is low (<0.1), the capacities may assumed not to interact

2. Interaction always works towards increasing the larger time constant and decreasing the smaller one.

3. Specifically with regard to the behavior of the system with equal time constant and of equal capacity, the effect is a combination of one large and the rest small time constants.

4. THEORY:

A dynamic system is the one in which there is some varying amount of accumulation of conserved quantities with time. Consider a liquid level system shown below in which two tanks are arranged in series such that the response of first tank depends on the conditions in the second tank. Such a system is said to be an interacting system and is a lumped parameter system.

The arrangement is such that the flow through the resistance R_1 depends on both h_1 and h_2. Such a system is known as interacting system. Selecting a macroscopic system consisting of the entire tank, the total transient material balance for:

1. Tank (1):

$$\frac{d(A_1 h_1 \rho)}{dt} = q\rho - q_1\rho$$

$$\frac{dh_1}{dt} = \frac{q}{A_1} - \frac{q_1}{A_1}$$

Assuming the flow - head relationship for resistance R_1 is linear.

$$q_1 = \frac{h_1 - h_2}{R_1}$$

$$\frac{dh_1}{dt} = \frac{q}{A_1} - \frac{h_1 - h_2}{A_1 R_1} \qquad \text{…………..} (1)$$

$$Q = f(t)$$

2. Tank (2):

$$\frac{d(A_2 h_2 \rho)}{dt} = q_1\rho - q_2\rho$$

$$\frac{dh_2}{dt} = \frac{q_1}{A_2} - \frac{q_2}{A_2} \qquad \text{…………..} (2)$$

Assuming the flow - head relationship for resistance R_2 is linear.

$$q_2 = \frac{h_2}{R_2}$$

$$\frac{dh_2}{dt} = \frac{q_1}{A_2} - \frac{h_2}{A_2 R_2}$$

In terms of deviation variables

$$Q = q - q_s$$

$$Q_1 = q_1 - q_{1s}$$

$$Q_2 = q_2 - q_{2s}$$

$$H_1 = h_1 - h_{1s}$$

$$H_2 = h_2 - h_{2s}$$

$$\frac{dH_1}{dt} = \frac{Q - Q_1}{A_1} \qquad \text{............ (3)}$$

$$\frac{dH_2}{dt} = \frac{Q_1 - Q_2}{A_2} \qquad \text{............ (4)}$$

In terms of deviation variables, Q_1 and Q_2 can be expressed as:

$$Q_1 = \frac{H_1 - H_2}{R_1} \qquad \text{............ (5)}$$

$$Q_2 = \frac{H_2}{R_2} \qquad \text{............ (6)}$$

Taking the laplace transforms and solving the above equations we get:

$$\frac{H_2(S)}{Q(S)} = \frac{R_2}{\tau_1\tau_2 S^2 + (\tau_1 + \tau_2 + A_1 R_2)S + 1} \qquad \text{..............(7)}$$

For $\tau_1 = \tau_2$

On taking inverse laplace transform, we obtain theoretical response of the system as:

$$H_2(t) = MR_2\left[1 + 0.17e^{-t/0.38\tau_1} - 1.17e^{-t/2.62\tau_1}\right] \qquad \text{...............(8)}$$

Equation (8) represents the theoretical response of an interacting two tank liquid level system to a step change of magnitude (M) in the feed rate to tank (2).

5. DESCRIPTION:

Apparatus is self-contained re-circulating unit. It consist a sump tank, two tanks and an over head tank. Sump tank and over head tank are connected by pump. Level indicators are provided with scale at Tank1 and Tank2. Rotameter is provided to measure the flow rate of water. Valves are provided for the process and drainage.

6. Utilities Required:

6.1 Electricity supply: Single phase, 220 V AC, 50 Hz, 5-15 Amp combined socket with earth connection.

6.2 Water supply (Initial fill).

6.3 Floor drain required.

6.4 Floor area required: 1 m x 1 m.

7. Experimental Procedure:

7.1 Starting Procedure:

7.1.1 Close all the valvesV_1-V_6.

7.1.2 Fill the sump tank with water.

7.1.3 Switch ON the power supply and the pump.

7.1.4 Wait till the over flow from over head tank.

7.1.5 Now open the flow control valveV_1 and adjust the flow rate (10-20 LPH).

7.1.6 Partially open the valve V_2-V_3, and wait till a constant height is achieved by Tank1 and Tank2.

7.1.7 Note down the inlet flow rate and height of Tank1 and Tank2, which is the initial heights.

7.1.8 Now increase the inlet flow rate 10-20 LPH (step change) by valve V_1.

7.1.9 Simultaneously start the stopwatch and record the heights of liquid level in the Tank1 and Tank2 with time, till next constant height is reached.

7.1.10 Note down the final constant heights and flow rate.

7.1.11 Repeat the same experiment for different step change.

7.2 Closing Procedure:

7.2.1 If the experiment is over switch OFF the pump and power supply.

7.2.2 Open the valve V_2 and drain valves V_3-V_6.

8. OBSERVATION & CALCULATIONS:

8.1 DATA:

Inner diameter of tank D_1	= 0.108 m
Outer diameter of the down comer D_2	= 0.022 m

OBSERVATIONS :

Q_i = ______ LPH

Q_f = ______ LPH

h_{1i} = ______ cm

h_{2i} = ______ cm

8.2 OBSERVATION TABLE:

S.No	t (sec)	h_1 (cm)	h_2 (cm)

8.3 CALCULATIONS:

$$M = \frac{Q_f - Q_i}{1000 \times 3600} \quad (m^3/sec)$$

h_{1f} = ___________ (cm) [final value of h_1]

$$H_1 = \frac{h_{1f} - h_{1i}}{100} \quad (m)$$

h_{2f} = ___________ (cm) [final value of h_2]

$$H_2 = \frac{h_{2f} - h_{2i}}{100} \quad (m)$$

$$R_1 = \frac{H_1 - H_2}{M} \quad (sec/m^2)$$

$$R_2 = \frac{H_2}{M} \quad (sec/m^2)$$

$$A_1 = \frac{\pi}{4}(D_1^2 - D_2^2)\ (\text{m}^2)$$

$$A_2 = \frac{\pi}{4}(D_1^2 - D_2^2)\ (\text{m}^2)$$

$$\tau_1 = A_1 \times R_1\ (\text{sec})$$

$$\tau_2 = A_2 \times R_2\ (\text{sec})$$

$$\left[\frac{H_2}{MR_2}\right]_{\text{exp}} = \frac{h_2 - h_{2i}}{MR_2 \times 100}$$

For $\tau_1 = \tau_2$

$$\left[\frac{H_2}{MR_2}\right]_{the} = 1 + 0.17e^{\frac{-t}{0.38\tau_1}} - 1.17e^{\frac{-t}{2.62\tau_1}}$$

CALCULATION TABLE :

S. No.	t (sec)	$\left[\frac{H_2}{MR_2}\right]_{\text{exp}}$	$\left[\frac{H_2}{MR_2}\right]_{the}$

Plot a graph of $\left[\frac{H_2}{MR_2}\right]_{\text{exp}}$ vs t and $\left[\frac{H_2}{MR_2}\right]_{the}$ vs t.

9. NOMENCLATURE:

Nom	Column Headings	Units	Type
A_1	Cross-sectional area of Tank(1)	m^2	Calculated
A_2	Cross-sectional area of Tank(2)	m^2	Calculated
D_1	Inner diameter of Tank(1) & (2)	m	Given
D_2	Outer diameter of the down comer for Tank(1) & (2)	m	Given
H_1	Height difference of water in the Tank(1)	m	Calculated
H_2	Height difference of water in the Tank(2)	m	Calculated

$\left[\frac{H_2}{MR_2}\right]_{exp}$	Experimental response	*	Calculated
$\left[\frac{H_2}{MR_2}\right]_{the}$	Theoretical response	*	Calculated
h_1	Height of water in the Tank(1)	cm	Measured
h_{1f}	Maximum value of height of water in the Tank(1) h_1	cm	Calculated
h_{1i}	Initial height of water in the Tank(1)	cm	Measured
h_2	Height of water in the Tank(2)	cm	Measured
h_{2f}	Maximum value of height of water in the Tank(2) h_2	cm	Calculated
h_{2i}	Initial height of water in the Tank(2)	cm	Measured
M	Magnitude of step change	m^3/sec	Calculated
Q_f	Final inflow to the Tank(1)	LPH	Measured
Q_i	Initial inflow to the Tank(1)	LPH	Measured
R_1	Valve resistance of the Tank(1)	sec/m^2	Calculated
R_2	Valve resistance of the Tank(2)	sec/m^2	Calculated
t	Time	sec	Measured
τ_1	Time constant for Tank(1)	sec	Calculated
τ_2	Time constant for Tank(2)	sec	Calculated

* Symbols are unit less

10. PRECAUTION & MAINTENANCE INSTRUCTIONS:

10.1 Do not run the apparatus if power supply is less than 200 volts & more than 220 volts.

10.2 Always keep apparatus free from dust.

10.3 To prevent clogging of moving parts, run pump at least once in a fortnight.

10.4 Always use clean water.

10.5 If apparatus will not in use more than one month, drain the apparatus completely.

11. TROUBLESHOOTING:

11.1 If pump gets jam, open the back cover of pump and rotate the shaft manually

12. REFERENCES:

12.1 Coughanowr, Donald R. (1991). *Process Systems Analysis and Control.* 2nd Ed. ND: Mc Graw-hill International. pp 83-86.

13. Block Diagram: