Design an intelligent flow measurement technique by optimized fuzzy logic controller

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ABSTRACT. From the qualitative and quantitative point of view, an accurate liquid flow measurement is an essential requirement in a process control system. But due to the non linear characteristics of the liquid flow process it is necessary to accomplish an optimization technique. In most of the flow process control system the output flow depends on a number of input parameters like sensor output, pipe diameter, experimental liquid density, conductivity & viscosity. In conventional optimization it is very time consuming to obtain the optimal flow rate from the process after continuously tuning the input parameters. Hence computational intelligent optimization technique is utilized to achieve the optimum flowrate. In present paper contact type anemometer flow sensor is used as a flowsensor placed in three different sets of pipe diameter. Among 134 datasets 117 data is used for constructing the FIS model & 17 data sets for testing purpose. Four different Fuzzy model is designed (named as a Test 1, Test 2, Test 3 & Test 4) by considering the number of inputs & nature of the membership function. The accuracy of these models lying between 86%-92%. It can be observed that among all the four types of Test FIS, four input trapezoidal FIS (Test 2 FIS) is better than the other three Test FIS in terms of the accuracy, RMSE error, variance & stability.

RÉSUMÉ. Du point de vue qualitatif et quantitatif, une mesure précise du débit de liquide est une exigence essentielle dans un système de contrôle de processus. Mais en raison des caractéristiques non linéaires du processus d'écoulement de liquide, il est nécessaire de réaliser une technique d'optimisation. Dans la plupart des systèmes de contrôle de processus de flux, le débit de sortie dépend d'un certain nombre de paramètres d'entrée tels que la sortie du capteur, le diamètre du tuyau, la densité du liquide expérimental, la conductivité et la viscosité. En optimisation conventionnelle, l'obtention du débit optimal du processus prend beaucoup de temps après le réglage continu des paramètres d'entrée. Par conséquent, une technique d'optimisation intelligente informatique est utilisée pour obtenir le débit optimal. Dans le présent article, un capteur de débit à anémomètre à contact est utilisé en tant que capteur de débit placé dans trois ensembles différents de diamètre de tuyau. Sur 134 jeux de *données, 117 données sont utilisées pour construire le modèle FIS et 17 jeux de données pour le but de l'essai. Quatre modèles Flou différents sont conçus (nommés Test 1, Test 2, Test 3 et Test 4) en considérant le nombre d'entrées et la nature de la fonction d'adhésion. La précision de ces modèles se situe entre 86% et 92%. On peut constater que parmi les quatre types de test FIS, le FIS trapézoïdal à quatre entrées (test 2 FIS) est supérieur aux trois autres tests FIS en termes de précision, erreur RMSE, variance et stabilité.*

KEYWORDS: *flow sensor, modelling, fuzzy logic controller, membership function.*

MOTS-CLÉS: *capteur de débit, La modélisation, Contrôleur logique flou, fonction d'adhésion.*

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1. Introduction

In most of the process control system, to achieve the optimum goal or output there is a need to calculate the inputs to drive a process outputs & for these purpose researcher needs to make a mathematical relation between input–output. To optimize the performance of a multivariable process control through the classical method, it is inflexible and time-consuming. Dutta Kumar (2016a) described the different conventional PID tunning for the analysis of transfer function of process control system. Hence the alternative approach is adopted where computational optimization of the process is designed through the input–output relationship using different computational intelligence techniques. The model is designed on based of physical phenomenon or the previously recorded input–output data for a given system. Once the model is developed computational optimization can be applied to determine the inputs to the process those will satisfy a certain given criterion. Normally, in a liquid flow control process flow rate depends on several important factors like sensor output, pipe diameter, liquid conductivity, liquid viscosity, liquid density etc. In this present investigation, author develops a mathematical model between above mentioned variables using different membership fuzzy logic model so that it can describe the liquid flow control process in efficient manner.

Liquid flow rate measurement is one of the high precision operations in most of the process control industries, but most of the cases it suffers from the setback of various effects, like the effect of energy associated with a flowing fluid through a pipe line, Doppler effect and effect of speed of the fluid suction pump etc. which are important causes for rejection of a sensor in process industry. The liquid flow rate passing through the pipeline is measured by the various types of flow sensor like positive displacement type sensor like mass flow rate sensor such as corolis, vane type sensor & anemometer proposed by Bera *et al.* (2007; 2001; 2012), Ahmed *et al.* (2006), where mass flowrate is relied upon the product of volume flowrate & liquid density. To overcome all these problems an Anemometer type mass flow rate measurement sensor has been described in Bera *et al.* (2007; 2001) where flow rate of the fluid is the function of temperature sensitive resistance which is converted into heat energy hence transducer output of the anemometer flow sensor is non linear with flowrate. Therefore, researcher needs to minimize the non linearity characteristics of transducer output & liquid flowrate. The present investigation proposed a hybrid evolutionary algorithm along with neural network model where the desired flow rate is obtained by optimizing transducer output, pipe diameter & liquid density considering also.

K.S Fu *et al*. first invented the Intelligent control system by means of beyond the adaptive & learning control process. The main logic behind the intelligent control is that the designer needs not to be designed the system which ought to be rigidly modelled because intelligent control system stimulates the given input and evaluates the output which is approximately close to the experimental result. There are a number of intelligent control system are available in process control industry which includes: Fuzzy logic controller by Takagi Sugeno (1985), Artificial neural network by Kalogirou & Nahak *et al.*, Genetic Algorithm by Michalewicz etc.

Lammerink (1995) proposed a simple intelligent gas mixture flow sensor for measuring the two different parameter gas flow rate & percentage of helium content of a helium-nitrogen gas mixture using artificial neural network model. The optimized algorithm approximates the calibration data of flow velocity of the flowing gas in a pipe after knowing the flow sensor voltage and fluid temperature. An intelligent flow measurement technique is proposed by Santosh (2012) to optimized by the ANN to make the ultrasonic sensor output more linear with flow rate as well as process will be more adaptive with respect to the process parameters like pipe diameter, liquid density & liquid temperature.

Fuzzy logic is capable to control the non linear system which would be difficult to model in mathematically. Thats why fuzzy logic widely open up the door for the process control system. In recent years it is applicable for solving the real world problems like tubidity measurement (Dutta, 2015b), image processing, motion control, robotics, pattern recognization, database management system, medical appliances, industrial engineering etc. Dutta Kumar (2016c) also describe how Fuzzy PID produce the better result than conventional open loop controller on a speed control od DC motor. Dutta *et al.* (2016b) described the different open loop PID control technique on liquid flow process model.

The main objectives of the present work are to design an intelligent flow measurement technique by fuzzy logic controller which is adaptive to variation in pipe diameter, liquid density & liquid temperature & make a linear relationship between input &output parameter. The proposed technique is subjected to the experimental data for validation. The paper is organised as follows: after introduction in Section 1, a brief description flow sensor & theoretical model is given in Section 2 & Section 3. Problem statement & the relationship between sensor output v/s flowrate with respect to the different process parameters & proposed fuzzy model is discussed in Section 4. Section 5 deals with the result and the paper is ended with conclusion and future scope of work in Section 6.

2. Flow sensor

Due to wide range of fluid speed (up to 600 lpm for the present experiment) by means of convection method, long time research tool & provides high resolution and less interference of noise on output, in this research we used semiconductor based

Anemometer flow sensor instead of the other type of flowsensor. Present paper sensor designed by placing four transistor in diametrical plane of a PVC pipe at right angles to each other to form a bridge circuit. Base & emitter terminal of each transistor are shorted to form P terminal while collector terminal consider as N terminal so that transistor can be considered as conventional PN junction diode (Dutta, 2015a). After forming a wheatstone bridge circuit one pair of transistor operates in a forward biased mode while the opposite arm transistor operates in a reverse bias. Due to the cooling technique the change in resistance for the forward biased transistor & reverse biased transistor will be different. The resulting bridge output voltage is sum of the positive & negative half cycle output voltage which are again linearly depends on the change in forward biased resistance. As the change in resistance is linearly propotional to the flow rate .Hence sensor output produces a linear voltage corresponding to the flowrate.

Figure 1. Semiconductor based Anemometer

3. Experimental setup

Table 1. Experimental setup

Machine/tools	Specification/Description
process control setup Flow & Level measurement and Control	Model no. WFT -20-I
Anemometer Flow sensor	Designed by the SL 100 transistor
PVC pipe	Diameter with 20mm,25mm & 30mm
Digital Multimeter	3 ½
Rota meter	Taking the reading of the Flow rate ranging 0-600 lpm

The experimental work is carried out with the Flow & level measurement & control set up (Model no. WFT -20-I) shown in fig.1 & Table 1 describe the setup model along with other components of the experiments.

Figure 2. Experimental set up for liquid flow rate measurement

In the present investigation, the liquid velocities measured were in the range of 0lpm-600lpm. Anemometer based flow sensor voltages were calibrated against different liquid flow velocities. In this experimental set up water is pumped up in poly vinyl chloride (PVC) pipe from reservoir tank. A DC motor is connected in reservoir to drive the system. The rate of change of the water flow is measured in Rota meter indicator. Non linear electrical signal is achieved across the non contact type liquid flow sensor connected at the end of the PVC pipe. Change in water flow affects the output of the sensor signal. Water from the sensor is fall into the cylindrical tank which is again connected to the main water reservoir through a pipe so that cyclic process is formed. From the above experimental setup we get sensor output voltage with respect to the variation of the water flow rate under the different combination of pipe diameter & water parameters. Experiments are carried out at different flow rates, sensor output, pipe diameter & liquid density. The output variable is considered as liquid flow rate predicted by the optimization technique defined by the function of input parameter sensor output, pipe diameter & liquid density. The experimental conditions are shown in Table 2.

For this work, total 134 sample data have been observed which consist of four independent variables sensor output voltage, pipe diameter, liquid (water) conductivity & viscosity. Among these 134 datasets 17 number of datasets are used for the testing purpose shown in table 3. In this section characteristics of anemometer flow meter are simulated to understand the difficulties associated with the available measurement technique. For this purpose, simulation is carried out with three different pipe diameters these are 20mm, 25mm & 30mm, three different liquid densities 993kg/m^3, 995kg/m^3 & 996kg/m^3. Three different liquid viscosity 898.2,797 &725.45 Pa.S. Three different conductivity 606,615 & 622w/m.k are considered. Various values of input flow considering a particular pipe diameter, liquid density, viscosity & thermal conductivity. MATLAB2015a environment is used for simulation and the following characteristics are found.

Table 2. Ranges of the process parameters

Process Conditions (Input parameters)	Range of the parameters
Sensor output voltage	210 mv to 285 mv
Pipe diameter(mm)	20mm, 25mm & 30mm
Water conductivity (W/m.k)	606,615 & 622(W/m.k)
Water Viscosity	725.4,779.7 &898.2 µpas.sec
Water Density	993.9,995.6&996.9kg/m3

Figure 3 to figure 6 show the variation of sensor voltages with the change in flow rate considering different values of liquid conductivity, liquid density, diameter and liquid viscosity. It has been observed from the above graphs that the output from the converter circuit has a nonlinear relation. Datasheet of anemometer suggests that 10% to 60% of full scale input range is used in practice for measurement. The conventional calibration techniques are found to have drawbacks 1) it is time consuming process and 2) whenever any one of the system parameter (pipe diameter, liquid density, liquid conductivity and viscosity) is changed then further recalibration is needed so it restrict full scale of input range &3) its use is restricted only to a portion of full scale of input.

To overcome these limitations, an intelligence system is in cooperation with the anemometer to produce the linear output over the full scale of the input and make the system more adaptive in nature during the variation in pipe diameter, liquid density, thermal conductivity & viscosity. Here optimized fuzzy logic controller is used as an intelligence system along with thermal flow sensor. The designed optimized fuzzy logic model having the following properties: 1) Adaptive to variation in diameter of the pipe 2) adaptive to variation in liquid density 3) Adaptive to variations in liquid conductivity 4) adaptive to variation in viscosity & 5) Outputs follows a linear relation with the input flow rate. The output voltage also varies with the change in pipe diameter, liquid density, viscosity & thermal conductivity.

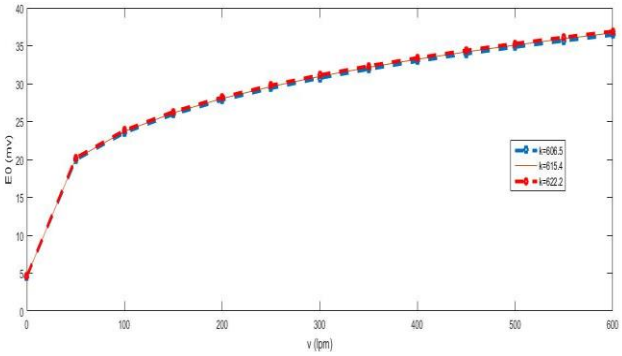

Figure 3. Sensor output v/s flow rate with respect to different conductivity

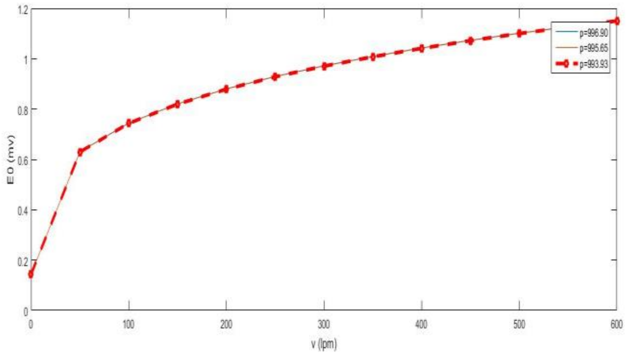

Figure 4. Sensor output v/s flow rate with respect to different liquid density

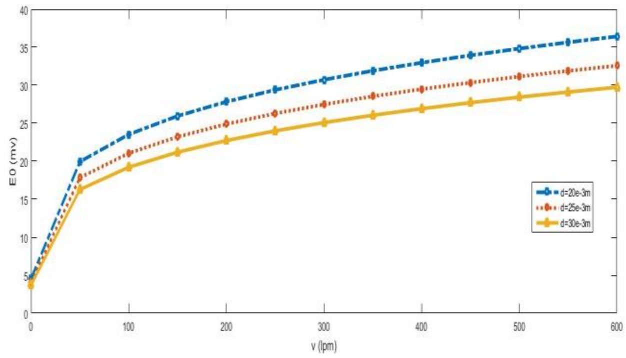

Figure 5. Sensor output v/s flow rate with respect to different diameter

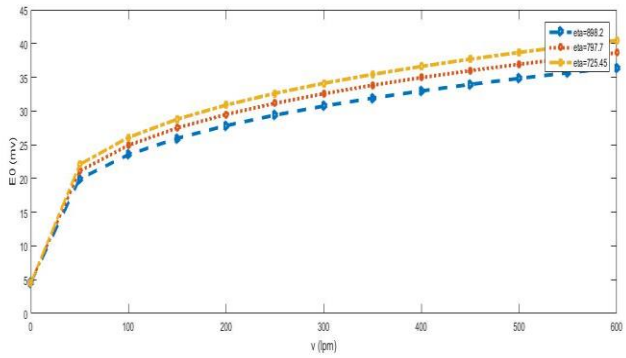

Figure 6. Sensor output v/s flow rate with respect to different viscosity

3.1. Dataset used

Table 3. Input data for Fuzzy logic models design

Voltage at the input of the FLC	0lpm	50lpm	100lpm	---------	550lpm	600lpm
D=20mm, =898.2, k=606.5	204	207	208	---------	225	227
D=25mm, =898.2, k=606.5	214	216	218	----------	245	247
D=30mm, =898.2, k=606.5	224	226	228	---------	255	256
D=20mm, =797.7, k=616.6	214	215	216	---------	231	232
D=25mm, =797.7, k=616.6	218	222	224	---------	249	252
D=30mm, =797.7, k=616.6	238	242	246	---------	274	277
D=20mm, =725.4, k=622.2	215	218	220	---------	238	241
------------------------------------	232	235	237	---------	258	261
D=30mm, =725.4, k=622.2	241	247	248	---------	276	282

Table 4. Experimental datasets for testing purpose in liquid flow control process

Sensor output	Diameter	Conductivity	Viscosity	Flow rate
0.218	0.024	0.606	0.8982	0.0008
0.221	0.025	0.616	0.7797	0.0008
0.225	0.025	0.616	0.8982	0.0016
0.232	0.025	0.597	0.7797	0.0016
0.234	0.02	0.615	0.982	0.0024
0.237	0.027	0.622	0.7797	0.0024
0.238	0.03	0.6065	0.7254	0.0024
0.239	0.025	0.616	0.8982	0.0032
0.241	0.027	0.622	0.7797	0.0032
0.245	0.024	0.6065	0.7254	0.0032
0.247	0.024	0.616	0.8982	0.004
0.247	0.025	0.622	0.7797	0.004
0.25	0.025	0.6065	0.7254	0.0048
0.256	0.025	0.616	0.8982	0.0048
0.254	0.024	0.622	0.7797	0.0056

0.259	0.03	0.606	0.7254	0.0064
0.265	0.027	0.622	0.7797	0.0072

4. The proposed optimized FLC

4.1. Implementation

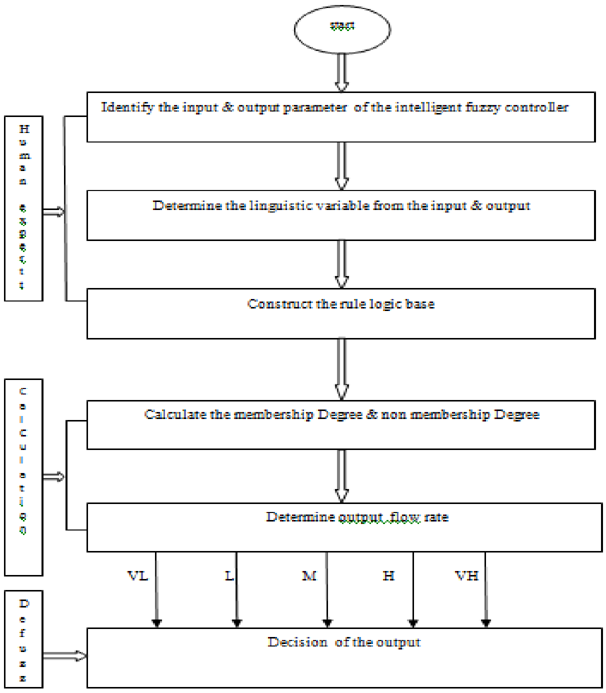

Figure 7. The flowchart for the process control

Membership function of FLC is somewhat trial and error type exercise. The set of MFs, the empirical relation between inputs and outputs is represented with the satisfactory level of accuracy. Figure 8 demonstrates a full number of input & output variables taken during liquid flow diagnosis. The input attributes of FLC are sensor output voltage, Diameter, conductvity, viscosity and liquid density and output attributes is flow rates. Every input & as well as output consists of three to five either triangular or trapezoidal membership functions according to the range of the function. Mamdani system is adopted in this research for describing the expertise knowledge in more intuitive similar to a human like operator. A total quantity of constructed fuzzy rules is 405 rules that classify each parameter according to the explanation. This number of rules is calculated using

$$N=p_1\times p_2\times p_3.............\times p_N \tag{1}$$

Where N represents total number of possible rules and p_N respresents the total number of linguistic parameters for the input fuzzy sets of N.

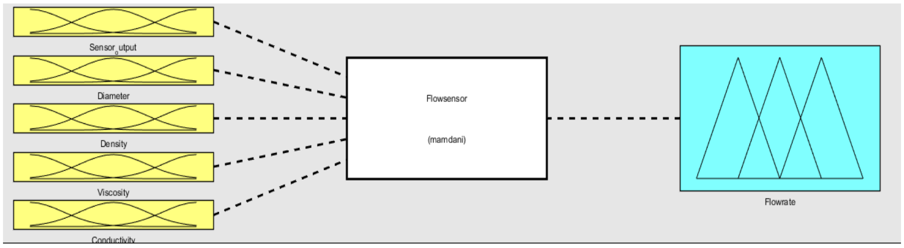

Figure 8. The FIS system for liquid flow control (input and output) for Test 3

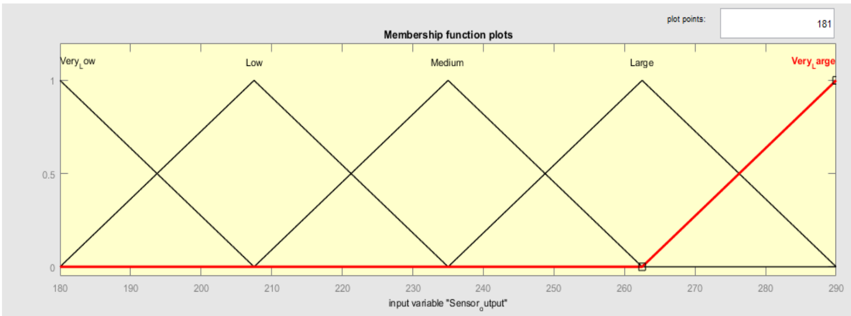

Figure 9. membership function of sensor output voltage for Test 3 FIS

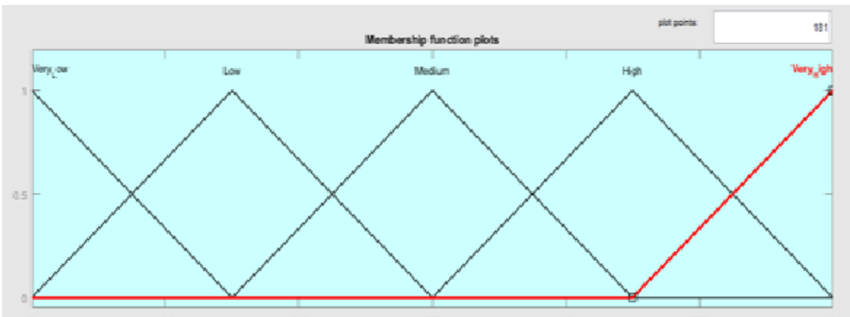

Figure 10. Membership function of flow rate for Test 3 FIS

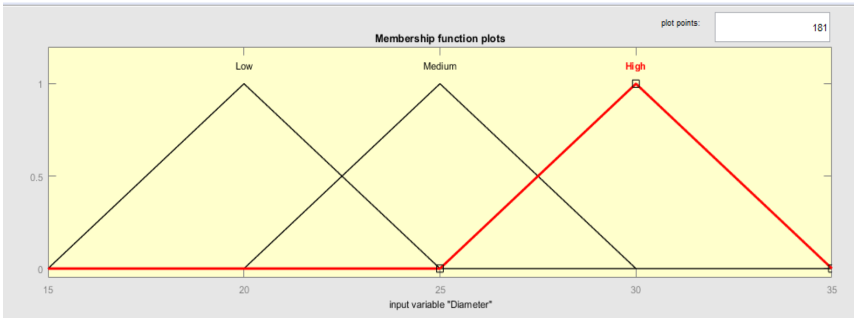

Figure 11. membership function of Diameter for Test 3 FIS

Here we present a sample of generated rules in FUZZY:

(i) RULE 34: IF sensor output IS very low AND viscosity IS low AND density IS low AND conductivity IS low AND diameter IS small THEN flow rate IS medium;

(ii) RULE 45: IF sensor output IS very low AND viscosity IS medium AND density IS low AND conductivity IS low AND diameter IS small THEN flow rate IS medium;

(iii) RULE 59: IF sensor output IS very low AND viscosity IS low AND density IS medium AND conductivity IS low AND diameter IS small THEN flow rate IS medium;

(iv) RULE 72: IF sensor output IS very low AND viscosity IS low AND density IS low AND conductivity IS medium AND diameter IS small THEN flow rate IS medium.

(v) RULE 248: IF sensor output IS medium AND viscosity IS low AND density IS low AND conductivity IS low AND diameter IS small THEN flow rate IS large.

(vi) RULE 261: IF sensor output IS medium AND viscosity IS medium AND density IS low AND conductivity IS low AND diameter IS small THEN flow rate IS large;

(vii) RULE 272: IF sensor output IS medium AND viscosity IS medium AND density IS low AND conductivity IS medium AND diameter IS small THEN flow rate IS large;

(viii) RULE 288: IF sensor output IS medium AND viscosity IS medium AND density IS medium AND conductivity IS low AND diameter IS small THEN flow rate IS large;

(ix) RULE 329: IF sensor output IS medium AND viscosity IS medium AND density IS low AND conductivity IS low AND diameter IS medium THEN flow rate IS medium;

(x) RULE 342: IF sensor output IS medium AND viscosity IS low AND density IS low AND conductivity IS low AND diameter IS medium THEN flow rate IS medium;

(xi) RULE 351: IF sensor output IS medium AND viscosity IS low AND density IS medium AND conductivity IS low AND diameter IS medium THEN flow rate IS medium;

(xii) RULE 362: IF sensor output IS medium AND viscosity IS low AND density IS low AND conductivity IS medium AND diameter IS medium THEN flow rate IS medium;

(xiii) RULE 388: IF sensor output IS high AND viscosity IS low AND density IS low AND conductivity IS low AND diameter IS low THEN flow rate IS very high;

(xiv) RULE 392: IF sensor output IS high AND viscosity IS medium AND density IS low AND conductivity IS low AND diameter IS low THEN flow rate IS very high;

(xv) RULE 395: IF sensor output IS high AND viscosity IS low AND density IS medium AND conductivity IS low AND diameter IS low THEN flow rate IS very high;

(xvi) RULE 396: IF sensor output IS high AND viscosity IS low AND density IS low AND conductivity IS medium AND diameter IS low THEN flow rate IS very high;

(xvii) RULE 398: IF sensor output IS high AND viscosity IS low AND density IS low AND conductivity IS low AND diameter IS medium THEN flow rate IS very high;

(xviii)RULE 401: IF sensor output IS high AND viscosity IS medium AND density IS low AND conductivity IS low AND diameter IS low THEN flow rate IS very high;

Table 5. Membership function of sensor voltage

Input parameter	Collection	Fuzzy sets
Sensor output	185-227 (Trapezoidal)	Very low
	195.5-248((Trapezoidal)	Low
	220-265(Trapezoidal)	Medium
	240-285(Trapezoidal)	High
	255-300(Trapezoidal)	Very high

Table 6. Membership function of pipe diameter

Input parameter	Collection	Fuzzy sets
Diameter	15-25(Triangular)	Low
	20-30(Triangular)	Medium
	25-35(Triangular)	High

Table 7. Membership function of flow rate

Input parameter	Collection	Fuzzy sets
Flow rate	-50-150 (Trapezoidal)	Very low
	50-300 (Trapezoidal)	Low
	165-435(Trapezoidal)	Medium
	315-550(Trapezoidal)	High
	465-735(Trapezoidal)	Very high

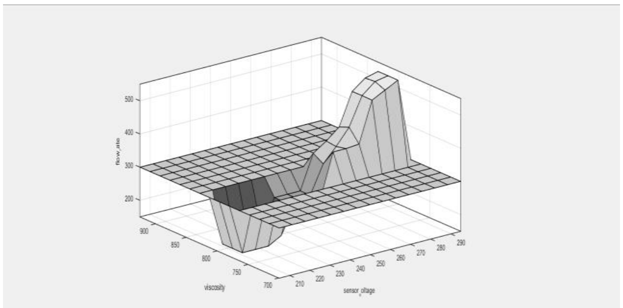

Figure 12. 3D plot of voltage, viscosity & flow rate for Test 1 FIS

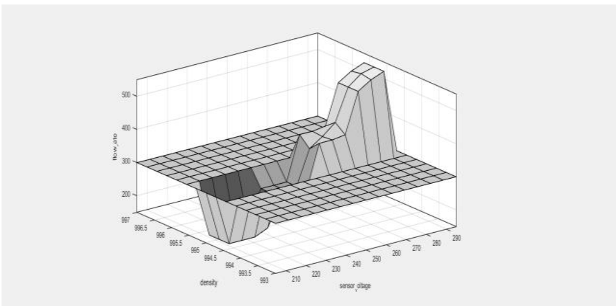

Figure 13. 3D plot of voltage, density & flow rate for Test 1 FIS

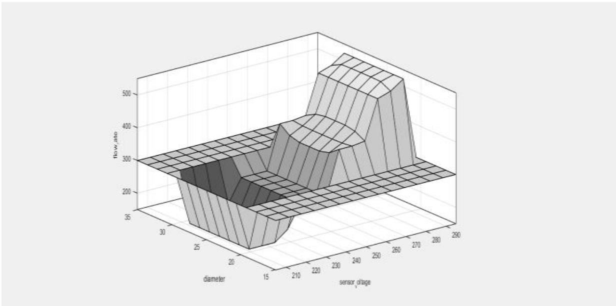

Figure 14. 3D plot of voltage, diameter & flow rate for Test 1 FIS

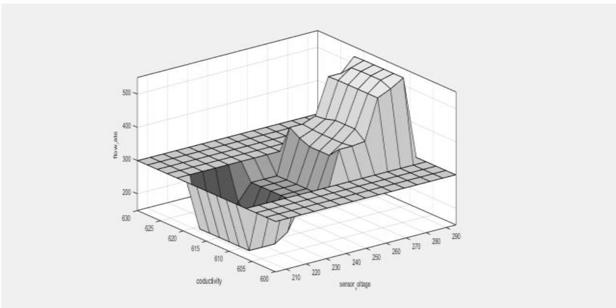

Figure 15. 3D plot of voltage, conductivity& flow rate for Test 1 FIS

5. Result & discussion

The overall performance of the optimized logic controller classified into four different categories are considered as a Test1, Test 2, Test 3 & Test 4. Each of the Test Fuzzy logic controller having own meaning which is described in below.

Test 1: There will be five inputs of the fuzzy inference system among which diameter consist of a triangular membership & rest of the inputs (liquid density, conductivity, viscosity & sensor output voltage) & output Flowrate having the trapezoidal membership function.

Test 2: There will be Four inputs of the fuzzy inference system (pipe diameter, conductivity, viscosity & sensor output voltag) & output Flowrate all having the trapezoidal membership function. Liquid density, this input discard as because from figure 8 it is seen that for the three different sets of liquid density the graphical plot between sensor output voltage & flowrate is same.

Test 3: In this fuzzy system five inputs (pipe diameter, liquid density, conductivity, viscosity & sensor output voltage) & output Flowrate all having the triangular membership function.

Test 4: In this fuzzy system five inputs (pipe diameter, liquid density, conductivity, viscosity & sensor output voltage) & output Flowrate all having the trapezoidal membership function.

To verify its performance of the proposed 4 different selection of FIS, the algorithm is tested on different parameters estimation for modelling of liquid flow control process. Here, the algorithm is tested against fuzzy logic controller based modelled as described in figure 7 where 117 number of datasets are used to train the data & construct the model in FIS. After the model is designed 17 number of datasets are tested against the model. We perform the fout different types of test against the test datasets & perform comparison among them & give statistical analysis of the evaluated results.

5.1. Accuracy test

Accuracy test determine by the observation of liquid flow rate prediction under the different experimental condition of sensor output voltage, pipe diameter, liquid conductivity & liquid viscosity with respect to the experimental flow rate. In accuracy test there are two indexes namely individual absolute error (IAE) & relative error (RE) [eqn. 2 & 3] are adopted to indicate the error values between the experimental & calculated liquid flow rate.

$$IAE = |Fmeasured - Fcalculated| \tag{2}$$

$$RE = \frac{\text{Fmeasured} - \text{Fcalculated}}{\text{Fmeasured}} \tag{3}$$

Moreover, Total Absolute Error (TAE) can be defined as:

$$TAE = \sum_{i=1}^{n} IAE_i \tag{4}$$

Where n is the number of measurements in the experimental dataset, $Fmeasured$ is the experimental value of liquid flow rate and $Fcalculated$ is the estimated value of liquid flow rate for a pipe diameter and sensor output voltage. However, to calculate or estimate the values of liquid flow rate of liquid flow control process at different experimental conditions. Table 7 describes a comparative study based on total absolute error. It is clear that Test 1 fuzzy inference controller has the best performances in term of total absolute error than the other three test while Test 3 has the worst total absolute error.

From figure 16 it is seen that in Test 2 as the no of instances increases the relative error is decreases than the other 3 tests while Test 3 having the comparatively high relative error, so for present process control optimization Test 3 is more suitable. However 17 shows of the experimental data and estimated liquid flow rate of liquid flow control process for fout different Test model of FIS in liquid flow process control.

Test 2 provides the more predicted optimization value with respect to the experimental datasets.

Table 8. Comparative study based on total absolute error

Method	Total absolute error
Test 1	7.052941176
Test 2	7.224117647
Test 3	12.51764706
Test 4	9.152941176

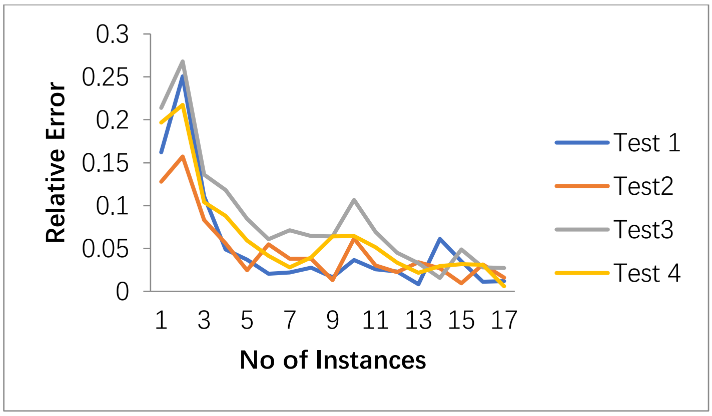

Figure 16. Relative errors for different test in a liquid flow control process

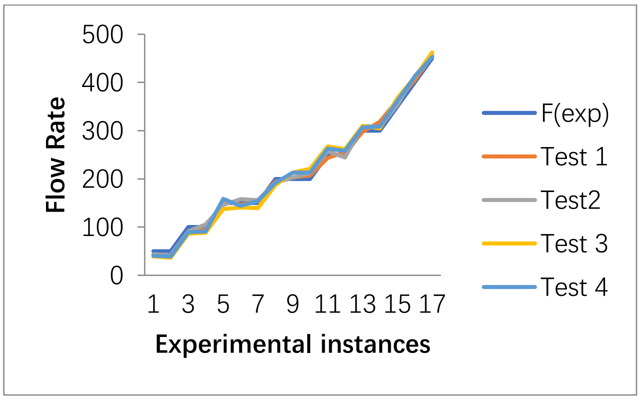

Figure 17. Comparisons of the characteristics of the experimental data and estimated liquid flow rate using different FIS Test based model

5.2. Accuracy & RMSE:

Another important performance measuring criteria is Accuracy & RMSE. After the FIS optimization we statistically manipulate the these two important criterion. Least RMSE & maximum accuracy is the best choice for optimization technique. From the table 8 it is seen that Test 2 FIS have the maximum Accuracy & least RMSE while Test 3 FIS have the worst accuracy maximum RMSE.

Table 9. Comparative study based on RMSE error & Accuracy

Methods	RMSE	Accuracy
Test 1	8.161843794	91.83815621
Test 2	7.712564615	92.28743538
test 3	13.00904663	86.99095337
Test4	9.607765854	90.39223415

6. Conclusion

Modelling of liquid flow control in process industry is an interesting task for the researcher. Optimized FLC is used in a process control in an environment, especially in flow control when we recurrently deal with inaccurate information (information which is occasionally vague, inadequate, or incorrect). In this regard, decision support system and artificial intelligence using FIS techniques can help us to handle this complexity in a successful, and proficient way.

In present liquid flow process control system flowrate is depends upon a multiple number of the control parameters like sensor output, pipe diameter, water viscosity, conductivity & density. Primarily FIS is construct by using 117 number of train datasets which consists of different sets of pipe diameter, water conductivity, viscosity, density & sensor output. After construct the FIS 17 number of datasets are used for test & validation purpose. In present work we construct 4 different Test FIS for performing the optimization of output flowrate. This Test FIS construct by the number of inputs & the nature of the membership function .Test FIS is construct in such a manner so that estimated liquid flow rate fit best with the experimental results. Finally it is observed that 4 inputs FIS (Test 2) where all are in trapezoidal membership provides better accuracy than the rest of three Test FIS.

The simulation is performed for each of the Test FIS & the statistical analysis of the results is also given in previous section. All the results indicate that the overall performance of the proposed Test 2 FIS (4 inputs Trapezoidal) outperformed the others Test FIS foremost of the cases for the modelling of liquid flow process control. Instead of these one of the disadvantages of the Test 2 FIS is total absolute error is high than the Test 1 FIS. However all the Test FIS can useful to predict the liquid flowrate with quite satisfactory.

More detailed & accurate modelling of the liquid flow control process can be designed by increseing the membership function is the one of the future aspects. Moreover further tunnings of other evolutionar algorithm, hybrid intelligent control & metaheuristic optimization technique are necessary to achieve the more efficiency, accuracy & stability.

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