FUZZY SUPPORT MODEL FOR LONG PIPELINES BY USING DB2 APPROACH

Djordje Dihovicni[1], Miroslav Medenica[1]

[1] Technical College, Bulevar Zorana Djindjica 152a, Belgrade, Republic of Serbia

Abstract:
Transient in long pneumatic lines is analyzed from time delay and construction view of point. After presented mathematical model of pneumatic system, there are shown stability issues, and it is calculated length of the pneumatic pipeline for which the system is stable. The paper's main contribution is the application of decision and fuzzy logic in determination the stability of long pipeline from construction perspective by using DB2 database approach, and proposal of possible applications of knowledge database and fuzzy logic in making diagnostics conclusions about the states of the safe operation and reliability of the system.

ARTICLE HISTORY
Received: 28.04.2017.
Accepted: 31.05.2017.
Available: 30.06.2017.

KEYWORDS
Fuzzy logic, decision model, knowledge database , stability, long pipelines, mathematical model, diagnostic, reliability.

1. INTRODUCTION

There has been ongoing theoretical and empirical research in solving problem of transients in long pneumatic lines. Many theories have been developed on the subject concerned with sound transmission, and distortion of sound waves in lines, and as well have come number of mathematical models and analytical procedures for predicting the dynamic characteristics of long transmission lines [1]. The first of these assumed harmonic time dependence at the outset, and output frequency response for the small signals [2-3]. Another line of research has derived general transfer functions to be used in transient as well as frequency-response analyses.

Considering real pneumatic systems, it is crucial to describe them with time delay, nonlinearities, with attempt of not creating only academic model, by the reference [3]. Despite of these problems, development of fast algorithms and using the numerical methods for solving partial different equations, as well as enhanced simulation and animation techniques become the necessity [4].

Pneumatic cylinder systems significantly depend of behaviour of pneumatic pipes [4], thus it is very important to analyze the characteristics of the pipes connected to a cylinder. Mathematical model of this system is described by partial different equations [5], and it is well known fact that it is distributed parameter system. These systems appear in various areas of engineering, and one of the special types is distributed with distributed control [6]. The crucial two problems emphasize a finite time for a pressure signal to traverse the length of the line, and the occurring of standing waves caused that a pressure pulse at one end of the line does not result the pressure at the other end to begin to rise instantly.

The second phenomena is focused on the moment when frequency passes the natural frequency. Signal transient in long pneumatic lines is analyzed from time delay and parameter distribution view of point. The pressure or flow changing phenomena in pneumatic control systems is very complex, and has a significant effect on the stability, response and construction issues of the system and its components.

Up to now, the published papers have not been shown complete analyze of this phenomena and as well have not presented the adequate control system as shown in the reference [5]. The chosen system should be stable in required period of time, and this important task is obtained by using practical stability theory for distributed parameter systems

CONTACT: Djordje Dihovicni, ddihovicni@gmail.com

[5].

The fuzzy logic theory is ideal for situations that involve criteria, fuzzy sets and relations [6]. Various support models might be applied and compared with available alternatives, in order of reaching the solution. Some methods have used distance measures, t-norms, adequacy coefficients, ordered weighted averaging and other relative measures. Taking into account all factors that are necessary for obtaining quality of the process of transitions in long pneumatic pipelines, in this paper it is applied fuzzy support model. By using fuzzy logic methodology it is created a solid base for determination the optimum model of long transmission lines, from construction, time delay [13], parameter distribution and stability point of view.

The aim of this paper is:

a) Application of decision and fuzzy logic in determination the stability of long pipelines from construction view;

b) Proposal of possible applications of knowledge database and fuzzy logic in making diagnostics conclusions about the states of the safe operation and reliability of the system.

2. PROCESS DESCRIPTION

The problem of monitoring a pneumatic signal in long pipelines is given by experiment, shown in [6]. A construction issue of transmission pipelines is observed from stability perspective.

By increasing the length of the transmission pipeline, it is increasing dumping ratio ζ, but decreasing β. In case that length is increasing between 45 and 60 m , critical damping ratio is occurring, and then it is used approximation of the first order.

Test results has shown, that approximations of the first order are good and they take into account transport time delay.

In Fig. 1, it is shown a schematic representation of the pneumatic transmission lines.

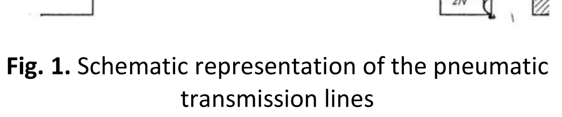

Fig. 1. Schematic representation of the pneumatic transmission lines

The Fig. 2 presents separated part of the fluid, which length is *dy* and thickness *dr*, as described in [7].

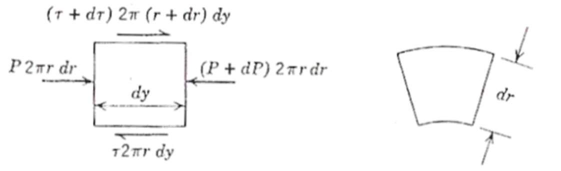

Fig. 2. Separated part of the fluid

By considering the acceleration of an element of fluid and the density change of the fluid as it moves along the line, it may be delivered the equation relating velocity, pressure and density, which is shown in details in [7], in the following form:

$$\sum F_y = -2\pi \cdot r \cdot dr \cdot dP + 2\pi \cdot dy \cdot d(r\tau) = 2\pi \cdot r \cdot dr \cdot dy \cdot \frac{P}{gRT}\frac{\partial v}{\partial t} \quad (1)$$

where *P* is differential given by equation:

$$dP = \frac{\partial P}{\partial y} \cdot dy \quad (2)$$

and taking into account that following relation holds:

$$d(r \cdot \tau) = \frac{\partial}{\partial r}\left(r \cdot \eta \cdot \frac{\partial v}{\partial r}\right) \cdot dr \quad (3)$$

finally it is obtained:

$$\frac{\partial P}{\partial y} = \frac{\eta}{r} \cdot \frac{\partial}{\partial r}\left(r\frac{\partial v}{\partial r}\right) - \frac{P}{g \cdot R \cdot T}\frac{\partial v}{\partial t} \quad (4)$$

In case of the assumption of fully developed laminar flow, equation 4 may be reduced in the form:

$$\frac{\partial P}{\partial y} = -\frac{32 \cdot \eta}{D^2} \cdot v - \frac{P}{g \cdot R \cdot T} \cdot \frac{\partial v}{\partial t} \quad (5)$$

The polytrophic equation which includes transfer of the heat inside the fluids is given in the reference [7]:

$$\frac{\partial P}{\partial t} = -n \cdot P \cdot \frac{\partial v}{\partial y} \quad (6)$$

with the initial conditions:

$$P = P_1 \text{ (when } y\text{=0)} \quad (7)$$

$$\frac{dP_2}{dt} = \frac{n \cdot P_2 \cdot A}{\overline{V_2}} \cdot v_2 \quad (8)$$

where $\overline{V_2} = (1 + k_p / k) \cdot V_2$.

The equations which are presented down below are taken from the reference [7].

Assuming an experimental time dependence of the form:

$$v = v(y) \cdot e^{st} \quad (9)$$

and that:

$$P = p(y) \cdot e^{st} + P_0 \tag{10}$$

the equations (4) and (6) are reduced to:

$$v = -\frac{dp / d\varsigma}{(n \cdot P_0 / \beta \cdot L) \cdot (E_2 + s / \beta)} \tag{11}$$

$$\frac{d^2 P}{d\varsigma^2} = \left(E_2 + \frac{s}{\beta} \right) \cdot \frac{s}{\beta} \cdot p \tag{12}$$

where $\xi = y / L$, and β is given with the following equation:

$$\beta = \frac{(n \cdot g \cdot R \cdot T)^{\frac{1}{2}}}{L} \tag{13}$$

where E_2 is given with:

$$E_2 = 32x10^2 \cdot \eta \cdot \left(\frac{g \cdot R \cdot T}{n} \right)^{\frac{1}{2}} \cdot \frac{L}{(10d)^2 P_0} = \\ = C_4 \cdot \left(\frac{T}{T_0} \right)^{\frac{1}{2}} \cdot \frac{L}{(10d)^2 P_0} \tag{14}$$

where *d*- is inner diameter, P_0 is initial pressure in the pipeline, *s*- is complex variable, η is dynamic coefficient of viscosity of the gas on the temperature *T*, C_4 is constant, and *L* the length of the pneumatic pipeline.

The general solution of the equation 12 is given in the form of:

$$p = B_1 \cdot e^{\alpha \cdot \eta} + B_2 \cdot e^{-\alpha \cdot \eta} \tag{15}$$

where B_1 and B_2 are the integration constants and:

$$\alpha = \left[\left(E_2 + \frac{s}{\beta} \right) \cdot \frac{s}{\beta} \right]^{\frac{1}{2}} \tag{16}$$

Let $p=p_1$ when $\xi=0$, and let $p=p_2$ when $\xi=1.0$, then it is possible to get required constants in the form of:

$$B_1 = \frac{p_2 - e^{-\alpha} \cdot p_1}{e^{\alpha} - e^{-\alpha}} \tag{17}$$

$$B_2 = -\frac{p_2 - e^{\alpha} \cdot p_1}{e^{\alpha} - e^{-\alpha}} \tag{18}$$

and velocity for $\xi=1$ is shown with:

$$v_2 = \frac{L \cdot s}{n \cdot P_0 \cdot \alpha} \cdot \left(B_2 \cdot e^{-\alpha} - B_1 \cdot e^{\alpha} \right) \tag{19}$$

$$v_2 = \frac{L \cdot s}{n \cdot P_0} \cdot \left(\frac{2 \cdot p_1 - (e^{\alpha} + e^{-\alpha}) \cdot p_2}{\alpha \cdot (e^{\alpha} - e^{-\alpha})} \right) \tag{20}$$

Supstituing the equations 20 and 18, into equation 12, it is obtained the equation which connects pressures p_2 and p_1. By solving the equation with p_2 it yields:

$$p_2 = \frac{p_1}{\cosh \alpha + (\bar{V} / A \cdot L) \cdot \alpha \cdot \sinh \alpha} \tag{21}$$

These results could be obtained in mathematical perspective, by using adequate approximations, given with:

$$\cosh \alpha = e^{s/\beta} \cdot \left(1 + \frac{1}{2} E_2 \cdot \frac{s}{\beta} \right) \tag{22}$$

$$\alpha \cdot \sinh \alpha = e^{s/\beta} \cdot \left(E_2 \cdot \frac{s}{\beta} \right) \tag{23}$$

$$\frac{1}{\alpha} \cdot \sinh \alpha = e^{s/\beta} \cdot \left(1 + \frac{1}{6} E_2 \cdot \frac{s}{\beta} \right) \tag{24}$$

Substituting the equations (22-24) into equation (21) gives differential equation of behaving in complex domain :

$$\frac{p_2}{p_1} = \frac{e^{-s/\beta}}{1 + \left(\frac{1}{2} + \frac{\bar{V}}{AL} \right) E_2 \cdot \frac{s}{\beta}} \tag{25}$$

as well as equation in complex domain upon mass flow:

$$\frac{\dot{m}_{12}}{p_1 \cdot A} = \left(A + \frac{\bar{V}}{L} \right) \cdot \left(\frac{g}{n \cdot R \cdot T} \right)^{\frac{1}{2}} \cdot \frac{1 + \frac{1}{6} \left[\frac{1 + 3 \cdot (\bar{V} / AL)}{1 + (\bar{V} / AL)} \right] E_2 \cdot \frac{s}{\beta}}{1 + \left(\frac{1}{2} + \frac{\bar{V}}{AL} \right) E_2 \cdot \frac{s}{\beta}} \tag{26}$$

where transport delay is presented as:

$$\tau = \frac{1}{\beta} = \frac{L}{\sqrt{n \cdot g \cdot R \cdot T}} \tag{27}$$

Transport time delay is given as ratio of length of pneumatic pipe *L*, and speed of the sound, which is equal to $\sqrt{n \cdot g \cdot R \cdot T}$.

Time constant of the first order is given as:

$$T_L = \left(\frac{1}{2} + \frac{\bar{V}}{AL} \right) \cdot \frac{E_2}{\beta} \tag{28}$$

If we present length of the pneumatic pipe from the equation (27), it yields:

$$L = \tau \cdot \sqrt{n \cdot g \cdot R \cdot T} \tag{29}$$

From the equation 27, for time constant T_L, as well as from the equations 28, it is obtained transfer function of the system in the following form:

$$W(s)=\frac{e^{-\frac{L}{\sqrt{n\cdot g\cdot R\cdot T}}\cdot s}}{1+\left(\left(\frac{1}{2}+\frac{\bar{V}}{AL}\right)\cdot\frac{E_2}{\sqrt{n\cdot g\cdot R\cdot T}}\cdot L\right)\cdot s} \quad (30)$$

If we use Pade approximation of the second order, it is obtained:

$$e^{-\tau\cdot s}=\frac{1-\frac{\tau\cdot s}{2}+\frac{(\tau\cdot s)^2}{12}}{1+\frac{\tau\cdot s}{2}+\frac{(\tau\cdot s)^2}{12}} \quad (31)$$

then it yields:

$$W(s)=\frac{1-\frac{\frac{L}{\sqrt{n\cdot g\cdot R\cdot T}}\cdot s}{2}+\frac{\left(\frac{L}{\sqrt{n\cdot g\cdot R\cdot T}}\cdot s\right)^2}{12}}{\left(1+\frac{\frac{L}{\sqrt{n\cdot g\cdot R\cdot T}}\cdot s}{2}+\frac{\left(\frac{L}{\sqrt{n\cdot g\cdot R\cdot T}}\cdot s\right)^2}{12}\right)\cdot\left(1+\left(\left(\frac{1}{2}+\frac{\bar{V}}{AL}\right)\cdot\frac{E_2}{\sqrt{n\cdot g\cdot R\cdot T}}\cdot L\right)\cdot s\right)} \quad (32)$$

By using data from our experiment such as:

E_2=4.33, *A=227.70 cm^2, T=300* K, it is obtained behaviour equation:

$$\begin{aligned}&\left(0.012\cdot L^3+0.576\cdot L^2\right)\cdot s^3+\left(0.96\cdot L^2+45.72\cdot L\right)\cdot s^2+\\&\left(31.08\cdot L+1171.16\right)\cdot s+144\\&=0.006\cdot L^2\cdot s^2-0.079\cdot L\cdot s+12\end{aligned} \quad (33)$$

where:

$$\begin{aligned}a_3&=\left(0.012\cdot L^3+0.576\cdot L^2\right);\\a_2&=\left(0.96\cdot L^2+45.72\cdot L\right);\\a_1&=\left(31.08\cdot L+1171.16\right);\\a_0&=144\end{aligned} \quad (14)$$

It is obtained that length of the transmission pipeline must be longer than 60.5 m for fulfilment stability issues, which approved implemented approximations.

Firstly it is required from technical systems certain quality of dynamic behaviour, which manifests through the indicators of the step or frequent responses [8].

The main influence on appearance of transfer process has the poles of system transfer function which are the closest to imaginary axe of a complex plane. These poles are called the dominant poles, and for systems of higher order in case when the real part is six times higher than the imaginary part, the influence on dynamic performance can be neglected in accordance with the reference .

Dynamic characteristics of the system shown through certain indicators in time domain are investigated on step responses of transmission signal [9] in long pneumatic pipelines, from time-delay and distributed parameter perspective.

3. DECISION SUPPORT MODEL

Knowledge Base is a specialized and unique to a particular system which contains the expert knowledge of experts in the relevant fields of knowledge, which is entered through a system of acquiring knowledge and that does not change over time [10].

In order to achieve better performance in the knowledge base is collected and other types of knowledge. Working memory contains the current data that are variable on the problem that should be solved [11]. The closing mechanism on the basis of variable data and fixed knowledge in the knowledge base solves the problem [12]. The user of the expert system communicates with the user via the interface.

Very common problems in the literature are decision making issues [13]. The decision process could be carried out by using ideals that are compared with the available alternatives. One of the measures might be by using distance measures, or using t-norms and related techniques. In case of adequacy coefficients technique, the Luckasiewics t-norm is used in the comparison process, in a such of manner, that if the result of the available alternative is higher than the ideal, the result is neutralized and if it is equal or lower it is calculated as in the Hamming distance [14].

Taking into account that the certain values in decision making aren't always correct, and that there are always vague processes and it is difficult to estimate decision making processes with an exact numerical value, Dubois and Prade have defined the fuzzy numbers $\overline{N}$ as a fuzzy set which membership function is $\mu_{\overline{N}}(y): R\rightarrow[0,1]$, where *R* is set of coefficients of satisfaction in a range between 0 and 1, and $\overline{N}(a,b,c)$is a fuzzy set that can conform to different set of a, b, c characteristics [14].

For system realization an object oriented programming approach has been used, and the program has been developed using the C# language. Each module has a supportive library, [15], and the logical structure is based on the classes, which are described down below for illustrating purpose.

Main classes are:

- **Analyses** group which has a primary task of collecting necessary facts about system,
- **Cyber security group** is used for checking cyber threats,
- **Practical stability** group which determines if the system is stable or not. If the system is unstable in view of practical stability, then it is automatically rejected,
- **Fuzzy controller** group which gives information about stability,
- **Diagnosis group** describes all possible causalities for not required results, or potential causalities for not optimal costs,
- **Performance group** is used for the optimal performance.
- **Cost group** is used for the optimal cost effect.
- **Decision making** algorithm for optimal performance and cost consists of two phases:
- **Phase 1** is used for input Analyses class, Practical stability class and diagnosis class.
- **Phase 2** is used for output Performance and Cost group.

The knowledge application is connected to an IBM DB2 Server, where is created a database. The application stores some of its data in traditional database columns [16], and some of it in native XML columns.

The DB2 database consists of following tables: analyses, practical stability, diagnosis, perfo-rmance, cost. The tables also have meta columns and foreign keys, so it is easy to pull data from several tables.

The id column in each table is used as the unique identifier for the data in that table. The data column has a type of XML data and holds the main data in XML format.

The key question of the problem of creating an appropriate decision support model, is in determining how good is a combination of requirements for the function of stability of the long pneumatic system, [17]. The first step determines the extent in which the stability is necessary for the performance of the process system.

The second step is focused on analyzing the coefficient of satisfaction expressing the extent in which the technology satisfies the requirements. The way in which technologies meet integration requirements is a fuzzy variable, given the adequate description that can be used to quantify the veracity of the hypothesis.

In practice it is very often the case that the conclusions adopted on diagnostic systems in process safety are wrong, and therefore incorrectly evaluated the working potentials of the system. In order to avoid it, it is mandatory to involve experienced and highly skilled diagnostician in certain situations. However, it can happen that the engagement of experienced and highly trained diagnostician in certain situations is not adequate solution, so the decision models have a crucial role in making diagnostic conclusions about the states of the system in process safety.

The next step is based on monitoring of all possible situations and impacts to process systems in purpose of achieving the optimal performance. The last issue involves cost effect.

These five aspects constitute theoretical basis of the model and they are presented with adequate coefficients C_1, C_2, C_3, C_4 and C_5. Coefficient C represents product of the coefficients from C_1 to C_5.

In this paper it is proposed following semantics for the set of five terms to point different styles of decisions on the strategic management process.

A) VG = Very Good= (0.8, 0.9, 1.0)
B) G= Good=(0.6, 0.7, 0.8)
C) M=Medium=(0.4, 0.5, 06)
D) B=Bad=(0.2, 03, 0.4)
E) VB=Very Bad=(0.0, 0.1, 0.2)

The attacks on critical infrastructure can have devastating consequences and are considered to be high value targets for cyber terrorists, so it is necessary to use modern ID responsive to intruders which include log-off an offender or modify firewall setting to block network traffic.

4. APPLYING OF FUZZY LOGIC

Fuzzy logic uses the theory of fuzzy sets and provides an analytical modelling algorithm, for the statements whose truth-value can be part of a continuous transition from exact to false [18].

When it comes to the theory of classical sets, some element or belong or not belong to a particular set, elements of the set are ultimate distinctive, and elements belonging to a fuzzy set is characterized by the number of interval [0,1]. The membership function maps the each element of the universal set to the fuzzy set. Fuzzy logic maintains formal methodology for showing, manipulating, and implementing of human knowledge about how to make decisions [18].

It is well known fact, that many long pipe engineering problems rather than crisp information involve imprecise and ambiguous information. The new trends try to incorporate fuzzy sets to tackle imprecise and ambiguous information of real problems [18]. Therefore there is a need to extend the structured query language (SQL) [19] to formulate a global query on a fuzzy multi databases under relational data model.

The Membership Function Editor is the tool that lets, display and edits all of the membership functions associated with all of the input and output variables for the entire fuzzy inference system. The Membership Function Editor shares some features with the FIS Editor, as shown in the below figure. In fact, all of the five basic graphic user interface (GUI) tools, have similar menu options, status lines, and Help and Close buttons.

The knowledge application is connected to an IBM DB2 Server, where is created a database [18]. The application stores some of its data in traditional database columns, and some of it in native XML columns. By using a programming language Matlab it is designed fuzzy controller. As input signals into fuzzy controller it is used several factors such as: age, temperature, and length of the pipeline. The output signal from fuzzy controller is the number from an interval [0,1], which describes the stability of the long pipeline and required intervention. As the proposed number closer to the 1, then it is more chance of instability of such object.

The input signals in the fuzzy controller are converted into appropriate phase forms, they are modified so that they can be properly interpreted and compared with the rules in the rule base. This makes it possible the membership functions that map the degree of truth of a statement. Membership functions are continuous measure of security if the variable is classified as the linguistic value.

These input signals are transferred into adequate fuzzy forms, by using membership functions which are mapping the degree of truth of some allegations.

When it is concerned the age of the pipeline, it is used continuous function, as presented in Fig. 3.

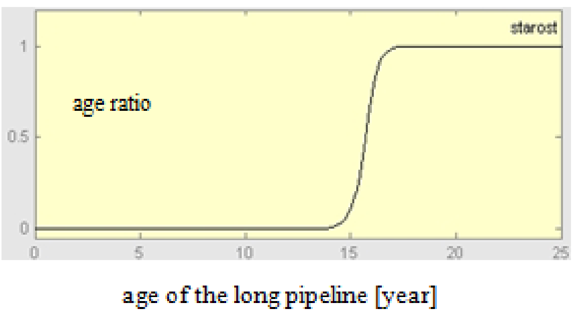

Fig. 3. Continual function that determinates the age

Another input signal which has used in this scientific paper, is the temperature in the long pipeline, and is shown in the figure down below with trapezoid function (Fig. 4).

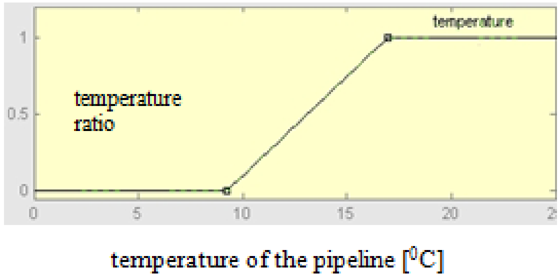

Fig. 4. Trapezoid function that determinates the temperature of the long pipeline

Fuzzy controller is presented in Fig. 5.

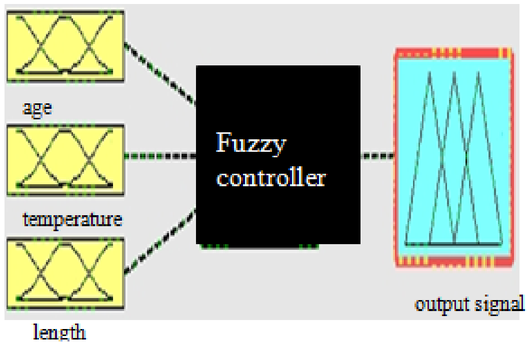

Fig. 5. Fuzzy controller

When it comes to the length of the long pipeline three functions that overlap each other are introduced, and they determine the degree of stability of a long pipeline. The functions presented length of the pipeline from construction point of view, as they are shown in Fig. 6.

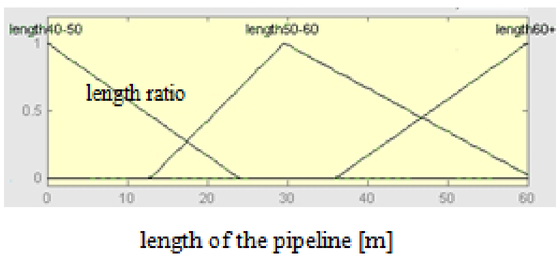

Fig. 6. Three overlapped functions that determinates the length of the long pipeline

Taking into account the output signal there are 5 membership functions, as given in Fig. 7:

A) stable;

B) border case;

C) instable required small intervention;

D) instable required medium intervention;

E) instable required serious intervention.

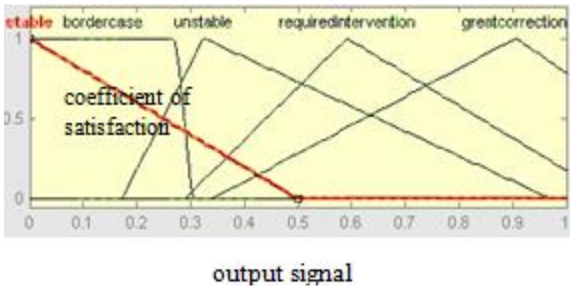

Fig. 7. Output signal with 5 membership functions

The rule base contains the knowledge of how best to control the system in the form of a set of logical rules. The task of fuzzy controller is the applying of fuzzy logic that maps its input into an output signal.

The key mechanism for that, is the list of if-then statements which we call rules. All rules are executed in parallel, and their order is not important, and this kind of list rules are called rule base. The rules are relating to the linguistic variables and their properties. If the terms have been already defined, all the terms and all the characteristics that define those terms may be accessed by designing a system that interprets those rules. Functional fuzzy logic must contain more than one stage of linguistic rules.

The rule that is used to obtain a diagnostic conclusion about the stability of the long pipeline would be: If the temperature is higher than 18 [^{0}C], if the length of the pipeline is longer than 60.5 m and if the long pipeline is not too old it is stable.

Combining these rules is obtained a compact mathematical representation of the entire knowledge base. Depending on the type of application that is used aggregation is reduced to one of the logical operations such as conjunction and disjunction.

5. CONCLUSIONS

It is obvious that phenomena of transient of the pressure and the flow in pneumatic control systems, especially with long pneumatic lines have character of time delay and parameter distribution, and that further analyze should be implemented. This paper describes the simulation of pneumatic system with long pipelines, observing the problem from time delay perspective and filling construction issues. Mathematical models of these systems are described by partial different equations, but apart from distributed phenomena we can't neglect system time delay.

From the condition of Raut criteria, that all elements of the first column of Raut schema must be positive, it is obtained that the length of the pneumatic pipeline must be longer than 60.5 m, and that approves the validity of the approximations which are applied for observing the problem from the time delay view of point.

Our knowledge database is created in DB2, and it involved all possible reasons for non adequate performance. Key modules for obtaining best performance, safety and the low cost are a good base for the program support in C# programming language and the UML representation.

The application of fuzzy logic in determination the stability of long pneumatic lines, avoids the need for engaging highly trained and experienced diagnosticians who are not always there when there is a need to solve a problem, and whose service is quite expensive.

The proposed fuzzy based model can be applied for discovering stability issues for long pneumatic pipelines from construction view of point, taking into account temperature, age and the other factors. Using these methods it is possible to continuously monitor multiple diagnostic parameters, so that necessary appropriate measures can be taken in order to assure the stability of the system represented by long pneumatic pipeline.

REFERENCES

[1] Dj. Dihovicni, N. Nedic, Stability of Distributed Parameter Systems on Finite Space Interval, 32-nd Yupiter Conference, Zlatibor 2006, pp.317-320.

[2] Dj. Dihovicni, M. Medenica, Fundamental Matrix Approach in Solving Practical Stability for Distributed Parameter Systems, Computationall Intelligence in Business and Economics, Proceedings of the MS'10 International Conference, 15–17 July 2010, Barcelona, Spain, Vol.3, pp.703-711.

[3] A. Hmamed, Further results on the delay independent asymptotic stability of linear systems, Int J. System. Sci., 22(6), 1991: pp.1127-1132.

[4] Dj. Dihovicni, Pole Assignment for Glass Capilary Tube Drawing Process by using Matlab and Maple Language, Applied Engineering Letters, 1(3), 2016: pp.67-71.

[5] Z.L. Nenadic, D.L. Debeljkovic, S.A. Milinkovic, On practical stability of time delay systems, Proceedings of the 1997 American Control Conference, Vol.5, No.4-6, America, 1997, pp.3225-3236.

[6] Dj. Dihovicni, M. Medenica, Mathematical Modelling and Simulation of Pneumatic Systems**,** Advances in Computer Science and Engineering, Chapter 9, 2011: pp.161-186. DOI: 10.5772/15313

[7] Dj. Dihovicni, Contructing knowledge database in stability of pneumatic pipelines**,** Technical diagnostics, 14(1), 2015: pp.7-14.

[8] E. Tissir, A. Hmamed, Sufficient stability conditions of interval time delay systems, Adv Modelling Anal., C45, 1996: pp.1-16.

[9] R.E. Jaeger A.D. Pearson, J.C. Wiliams, H.M. Presby, Fiber Drawing and Control in Optical Fiber Telecommunications, Academic Press. New York, 1980, pp.263-298.

[10] A. Kaufmann, J. Gilaluja, Introduction to the theory of fuzzy subsets in business management, International Conference on Intelligent Technologies in Human related Sciences Leon, Spain, Vol.2, 1996: pp.217-223.

[11] Z. Adamovic, N. Jevtic B. Ilic, Application method of artificial intelligence in reaching conclusions of the situation diagnostic machine in process industry, Technical Diagnostics, 3(1), 2012: pp.33-40.

[12] J. Bergmans, S. Gutnikov, V. Krasnoproshin, S. Popok, H. Vissia, Computer-Base Support to Decision-Making in Orthopaedics, International Conference on Intelligent Technologies in Human related Sciences Leon, Spain, Vol.2, 1996: pp.217-223.

[13] F. Herrera, E. Herrera-Viedma, E. Lopez, Computer-Base Support to Decision-Making in Orthopaedics, International Conference on Intelligent Technologies in Human related Sciences, Leon, Spain, Vol.2, 1996: pp.205-213.

[14] J. Merigo, A. Gil-Lafuente, Decision making techniques in a unified model between the weighted average and the Owa operator, Computational Intelligence in Business and Economics, 2010: pp.181-188.

[15] H. Monga, S. Baghla, Approach to security in wireless sensors networks, Applied Engineering Letters, 1(3), 2016: pp.80-84.

[16] D. Perez, J. Batista, Decision Support Model for Information Systems Integration in Supply Chains: a Fuzzy Approach, Computational Intelligence in Business and Economics, 2010: pp.281-288.

[17] Raman, S. Baghla, H. Monga, Method & Implementation of Data Flow, Applied Engineering Letters, 1(4), 2016: pp.105-110.

[18] A. Sharma, A. GoswamI, D. Gupta, Fts-Sql: A query Language for Fuzzy Multidatabases, Proceedings of the World Congress on Engineering - WCE 2009, Vol.1, London U.K, 2009: pp.69-74.

[19] J. Walker, Cyber security concerns for emergency management, Emergency Management, Chapter 3, 2012: pp.39-60. DOI: 10.5772/34104