Turkish Journal of Electrical Engineering & Computer Sciences
http://journals.tubitak.gov.tr/elektrik/
Research Article
Turk J Elec Eng & Comp Sci
(2022) 30: 2418 – 2432
© TÜBİTAK
doi:10.55730/1300-0632.3947

Improving the performance of industrial mixers that are used in agricultural technologies via chaotic systems and artificial intelligence techniques

Onur KALAYCI[1,*], **İhsan PEHLİVAN**[2] **Selçuk COŞKUN**[3]
[1]Department of Mechatronics Engineering, Faculty of Technology, Sakarya University of Applied Sciences, Sakarya, Turkey
[2]Department of Electric-Electronics Engineering, Faculty of Technology, Sakarya University of Applied Sciences, Sakarya, Turkey
[3]IMKB Sakarya Vocational and Technical Anatolian High School, Sakarya, Turkey

Received: 15.11.2021 • **Accepted/Published Online:** 16.09.2022 • **Final Version:** 28.09.2022

Abstract: In this study, it is aimed to show how important to apply chaotic systems and Fuzzy Logic artificial intelligence technique to increase the production performance of industrial mixers used in agriculture in terms of important criteria such as product quality, homogeneity, time, and energy saving by using. A PLC (Programmable Logic Controller) controlled mixer whose all functions can be controlled by the HMI (Human Machine Interface) operator panel is designed and manufactured for experimental studies. Water, leonardite and potassium hydroxide (KOH) mixture components are mixed in a newly designed mixer in three different ways by using traditional, chaos, and artificial intelligence techniques in order to obtain liquid humic acid which is used as plant nutrition and soil modulator in agriculture. For the chaotic mixing option, chaotic systems with different dynamic features are chosen from the literature. After converting the time series values of chaotic systems to the frequency values with the program written on the PLC device, it is provided to rotate at variable speeds according to different chaotic systems of the mixer motor connected to the frequency inverter. Fuzzy Logic is chosen for the artificial intelligence mixing option. Fuzzy Logic membership functions and rules are established in accordance with the results of the chaotic systems mixing experiments and the data obtained from experts in humic acid production. Mixing experiments are carried out by using an interface program that makes the choice of chaotic systems and motor rotation speed range. By mixing humic acid components with traditional methods, the comparison is done in terms of product quality, solute ratio, pH values and total energy consumption. When the developed mixer is provided to operate with chaos and artificial intelligence methods, it is observed that more efficient results are obtained in terms of criteria such as product quality, homogeneity, time, and energy savings compared to the traditional mixing methods.

Key words: Artificial intelligence, chaos, chaotic systems, fuzzy logic, humic acid, mixer

1. Introduction

Mixers are among the most important devices used in the food, pharmaceutical, and chemical industries. The main task of mixers is to bring about chemical and physical change. Factors affecting confusion are mixing temperature, mixing time, mixer type, and mixer motor speed. The studies have shown that most of the problems encountered during the mixing process was due to the lack of information and along with that whether the occurrence of the whole mixing operation depends on arbitrary criteria. As a result of the forementioned situation, the statement of "the mixing process was completed properly" is subjective. Thus, to enable

*Correspondence: okalayci67@gmail.com

homogeneity, it requires a higher engine speed and more time which causes more energy consumption. This study aims to compare and evaluate the performance results by doing experimental mixing studies in which fuzzy logic and chaotic systems are used together and separately to improve the performance of traditional industrial mixers in terms of crucial criteria such as product quality, homogeneity, time, and energy saving. In line with this objective, a prototype mixer was designed for experiential studies, and in this mixer, liquid humic acid which is one of the most commonly used plant nutrition and soil conditioner in agricultural production was obtained. Since the majority of mixtures consist of liquid-liquid and liquid-solid mixtures, research has focused on these two mixtures. Banhero and Bodger [1] investigated the theory of mixing of substances in solid, liquid, and gaseous states, Vauck and Müller [2] conducted studies on the degree of mixing, mixing time, mixing methods, and the standardization of mixers. Henzler [3] observed the homogeneity of continuously operating mixers in his research. Ilten [4] examined mixers, mixing methods, mixing phenomena, and mixing power calculations in his master's thesis.

Chaos, is a branch of science that is used to explain nonlinear events. In addition to displaying complex behaviors, chaos has a special internal order. Having order in addition to its complexity feature indicates that a chaos event is not a random situation [5]. Chaos can be briefly expressed as dynamical systems that are hypersensitive to initial and input conditions [6]. In 1963, the equations found by M.I.T.'s meteorologist E. N. Lorenz while simulating fluid heat-diffusion in the atmosphere are the first of the nonlinear systems that show sensitive adherence to initial conditions and chaos [7]. The sensitive dependence of chaotic systems on the initial conditions, the irregular structure in time dimension, having different and unlimited periodic oscillations, having a wide power spectrum, having a fragmented (fractal) limit set, and containing signs whose frequency and amplitude cannot be determined in a limited area are important features of chaotic systems. Due to these characteristics, the number of chaotic system studies conducted in scientific and industrial areas such as cryptology, control, image processing, communication, and artificial neural networks is increasing rapidly [8]. Chaotic systems can be analyzed in two groups as discrete-time and continuous-time chaotic systems. Discrete-time chaotic systems are generally one or two-dimensional and they can consist of one or two equations. On the other hand, continuous-time chaotic systems are at least three-dimensional and they include at least three equations [9].

It is known that quality mixing and spreading are two basic requirements to ensure homogeneity in mixtures. Sensitive dependence on initial conditions and control parameters, propagation; complexity, and randomness feature are the most important factors of chaotic systems that will provide quality mixing. Based on these properties of chaotic systems, Kalaycı et al. [10] controlled the speed of the mixer which is designed to obtain humic acid from leonardite both with chaotic systems and traditional methods and observed that the mixing with the chaotic system is more efficient in terms of criteria such as product quality, homogeneity, time and energy savings compared to the mixing with traditional methods. Kalaycı et al. [11] designed a delta robot-based chaotic mixer controlled by Arduino Uno R3 board and MATLAB, and did experimental studies during which the comparison of homogeneity and orbital distribution ratio (ODR) parameters was done at the selected mixing time by using 7 different chaotic systems for a solid-liquid mixture type. In his master thesis, Kurt [12] investigated whether chaotic mixers could be used instead of fixed and circular motion mixers in terms of less working time, less power consumption, and obtaining a higher percentage of homogeneous mixtures. Chau et al. [13] compared the results of chaotic mixing with the results of constant speed mixing using a feedback DC motor in which the rotation speed was chaotically adjusted. Ye and Chau [14] compared the results of chaotic mixing with the results of constant speed mixing using a DC motor in which the speed of rotation was adjusted chaotically by the destabilization method. The acid-base neutralization reaction was evaluated in the experiment. Murtadha et al. [15] studied the chaotic control of a liquid mixer. In this work, the water-salt mixture was mixed for 30 s. The results were evaluated by measuring the concentration. Zhang and Chen [16] rotated the mixture contained chamber with a DC motor by keeping the blades of the mixer fixed. The speed of the engine is set chaotically using the Chua circuit. A water-sugar mixture was evaluated in the experiment. Kavur et al. [17] designed a Delta Robot based on a chaotic system to mix graphene nanoplatelets in their study.

Artificial intelligence technology has been developing more and more with every day that goes by. New products have been emerging and showing up more in daily life. The decision-making power of the computer is taken by equipping automation systems with artificial intelligence technology. More recent commercial systems are emerging day by day and the functional features of the systems increase. During the liquid humic acid production process, which is obtained as a result of the experiments used in this study, also benefits from the previous experiences, studies, and the knowledge of the experts in this field. According to this, at the end of the literature research in this study, Fuzzy Logic which is one of the artificial intelligence techniques, was preferred for the chaotic system's selection to be used in the designed mixer. Fuzzy Logic is a powerful tool used to model human thinking and perception. As an extension of Boolean logic, it was designed by Lotfi Zadeh in 1965 on the basis of fuzzy sets mathematical theory as a generalized structure of the classical fuzzy set theory. Fuzzy logic provides very valuable flexibility in judgment by considering the wrong or ambiguous situations and creating some values among them, instead of separating the concept as false or true, when it comes to the grading or staging a condition or situation [18]. The steps of Fuzzy Logic design are as below; the first step is to form a membership function up to the input and output variables of the revealed solution. This step is called "fuzzification". In the second step, "fuzzification rules" are determined according to the opinions and the experience of the field experts. In this step, suitable output options are designed by following the basic fuzzification decision algorithm. This step is named "Decision". As for the third and the last step, the fuzzification outputs are converted to final outcomes which are called "defuzzification". According to the literature research on controlling chaotic systems with fuzzy logic artificial intelligence method; Harb and Al-Smadi [19] made chaotic behavior periodic and balanced by using the Mamdani Model. Lian et al. [20] suggest fuzzy tracking control for chaotic systems with unmeasurable states. Park et al. [21] created an adaptive fuzzy control (AFC) scheme based on well-known Takagi-Sugeno (T-S) fuzzy models for MIMO plants by presenting the control methodology for the uncertain chaotic dynamics of Lorenz systems. Li and Zhang [22] worked on fuzzy modeling of chaotic systems using Takagi-Sugeno (TS) models.

One of the sectors where mixers are mostly used is the production of agricultural fertilizers and plant nutrition products. In research conducted in this field, it has been observed that the products manufactured are obtained by combining more than one plant nutrient and mixing them homogeneously. Liquid humic acid originated from leonardite is one of the most used products in our country and in the world in the field of agriculture. Humic acid is a dark brown-gray-black organic substance that can easily dissolve in an alkaline medium, but it dissolves slowly in water and does not dissolve in an acidic medium. In addition to the positive contribution to the development of plants by increasing the rate of organic matter in the soil, it also reduces the rate of chemical fertilizers to be used and therefore reduces the negative effects of these chemical fertilizers on the environment. Humic acids and fulvic acids accelerate mineral uptake by increasing the root growth of the plant. Therefore, the plant has a more developed, large body, the number and the maturity of fruits increase [23]. The most important source of humic acids is the deposited layers of soft brown coals usually found in leonardite. Humic acid is not a fertilizer. But it is a very important complement to fertilizer. Humic acid helps nutrients pass from the soil to the plant [24]. Various studies have been carried out using different methods and mixing ratios to obtain humic acid. Bentli et al. [25] conducted a series of experiments in the production of humic acid from leonardite in order to determine the effects of working parameters such as alkali type and concentration, ambient temperature, reaction time, mixing speed and solids ratio, and achieved an 80%-85% humic acid yield by a mixture done with 0.5M NaOH, 60 min mixing time and 750 Rpm mixing at room temperature (23 °C). David W. Goff [26] obtained 23% humic acid yield by mixing 907 kg of leonardite and 181 kg of sodium hydroxide (NaOH) in 3482 L of water for 40 h at 40Rpm in his patent study on humic acid production methods. Özdemir [27] investigated the determination of optimum parameters in humic and fulvic acid production from lignites obtained from the regions of Bükköy of Manisa, Türkobası and Çobançesmesi of Edirne and obtained a 42.74% humic acid yield with an optimum amount of KOH and 9 h mixing time. He also analyzed the humic and fulvic acid yields obtained from each region, noting they are different due to the raw material quality.

The literature studies considered and summed up in this study, are classified into four categories as seen. The first category studies are merely about mixers, the second category studies are only about chaos and mixers, the third category studies are just about chaos and fuzzy logic, and the fourth category studies are solely about the studies related to the humic acid mixture production and methods. Likewise, when the reviewed literature studies are generally analyzed;- The studies, done to improve the mixer's performance, mainly cover the changes applied in the mechanical parts and the calculations of the design process of the mixers. - On the other hand, the chaotic system applied mixers studies are the studies that are done to improve the performance of the mixers' used in laboratories. - Besides, the studies analyzing the fuzzy logic and the chaotic system together the applications are not observed to be used in any mechanical mixers.
This study will be the first one towards improving the performance of the mixers used specifically in agriculture by using chaos, fuzzy logic, and humic acid terms simultaneously.

Features of designed prototype mixer, how to obtain speed data from differential equations of chaotic systems, how to determine chaotic systems to be used in experimental studies, designing of fuzzy systems and how to apply it to the mixer and ultimately, experimental study methods are clarified respectively in materials and methods section of this study. In results section, tables are shown in order as follows; first, table mixing results are shown by the traditional method, then mixing results are done with chaotic systems, and lastly, the results with fuzzy logic systems. In the discussion section, results obtained as a result of the mixing process with traditional, chaotic, and fuzzy logic are analyzed in terms of ph, dissolution rate, total energy consumption, and total humic + fulvic acid. In the conclusion section, by having an outcome evaluation according to the analysis done in the discussion section, its contribution to the upcoming studies is stated.

2. Materials and methods

In this study, a PLC (Programmable Logic Controller) controlled prototype mixer whose all functions, seen in Figure 1, could be controlled by the HMI (Human Machine Interface) operator panel was designed and manufactured in order to obtain liquid humic acid. Experimental studies were run in terms of increasing the performance of this mixer with chaotic systems and artificial intelligence techniques.

2.1. Features of the designed mixer

In this mixer, 0.55 kW asynchronous motor as the mixing motor and the spiral mixer as the mixer head model were used. Omron NX1P2-9024DT1 as PLC control device, Omron HMI as operator panel and Omron 0.75kw frequency inverter were used for the speed control of the mixer motor. A 2000 W PLC controlled heater was added to the system to keep the mixture at a constant temperature. In addition, a CNet 8 Port Ethernet switch was used for NX1P2-9024DT1 PLC, HMI operator panel and PC connections. NX1P2-9024DT1 PLC and 0.75 kw frequency inverter were connected to each other by Ethercat communication cable, which is the standard of Omron products. An interface software was written in the Omron Nx Designer program in order to control all functions of the designed mixer system via the HMI operator panel. The Main Screen view of the designed interface program is shown in Figure 2.

Figure 1. Designed and manufactured prototype mixer.[10]

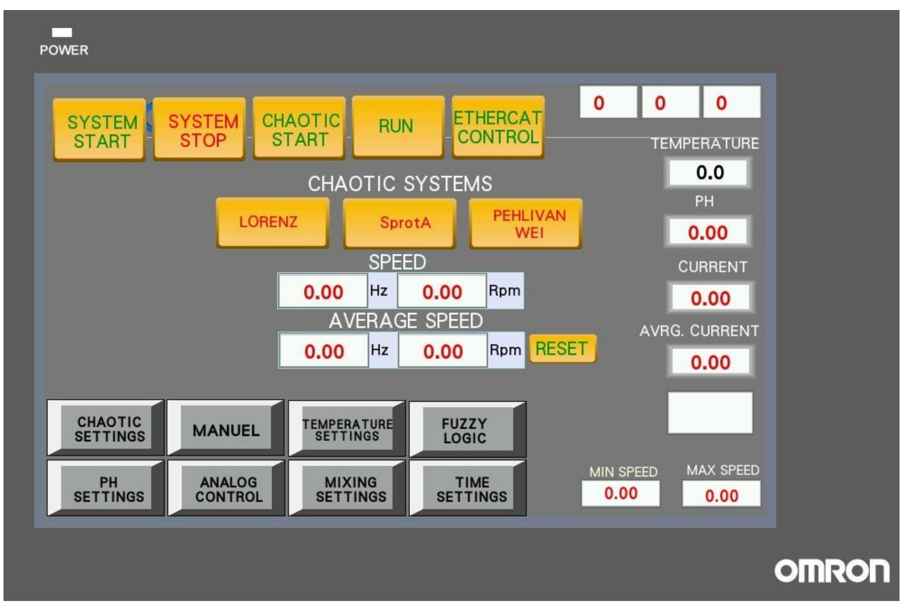

Figure 2. Main screen view of the interface program designed to control all functions belonging to the mixing system.

DFRobot SEN0161 model pH sensor was used to measure the pH value of the obtained humic acid mixture in real-time. The DFRobot SEN0161 pH sensor is Arduino compatible and it produces analog signals in the range of 0-10V. The output signal was connected to the analog entry edge of the NX1P2-9024DT1 PLC device. After measuring the pH value of the mixture manually by using a second Adwa Ad12 pH sensor with two-point calibration system, the calibration of the DFRobot SEN0161 pH sensor used in the system is made by a program written to the PLC on the operator panel.

2.2. Obtaining speed data from chaotic systems

Lu-Chen 2003, Lorenz, Sprott A, Aizawa, Guckenheimer-Holmes and Pehlivan-Wei chaotic systems were selected from the literature to be used in experimental studies.

The differential equations of the chosen Lu-Chen 2003 chaotic system are seen as in Equation (1). The initial conditions were determined as x (0) = 0, y (0) = - 0.1, z (0) = 9, and the parameters were determined as a = 5, b = 10, c = 3.4 [28].

$$x = a.x - y.zy = -b.y + x.zz = x.y - c.z \tag{1}$$

The differential equations of the chosen Lorenz chaotic system are seen as in Equation (2). The initial conditions were determined as x (0) = 0, y (0) = - 0.1, z (0) = 9 [7].

$$x = 10.(y - x)y = -x.z + 28.x - yz = x.y - \frac{8}{3}.z \tag{2}$$

The differential equations of the selected Sprott A chaotic system are seen as in Equation (3). The initial conditions were determined as x (0) = 0, y (0) = 0.5, z (0) = 0 [29].

$$x = yy = -x + y.zz = 1 - y^2 \tag{3}$$

The differential equations of the chosen Aizawa chaotic system are seen as in Equation (4). The initial conditions were determined as x(0) = 0.1 , y(0) = 0, z(0) = 0, and the parameters were determined as a = 0.95 , b = 0.7, c = 0.6, d = 3.5, e = 0.25, f = 0.1 [30].

$$x = (z - b).z - d.yy = d.x + (z - b).yz = c + a.z - \frac{z^3}{3} - (x^2 + y^2).(1 + e.z) + f.z.x^3 \tag{4}$$

The differential equations of the chosen Guckenheimer-Holmes chaotic system is seen as in Equation (5). The initial conditions were determined as x (0) = 1, y (0) = -1, z (0) = 1, and the parameters were determined as $a = 3, c = -0.4, d = 1.6, e = 0.44, f = 1, \omega = 20.25, \lambda = 0.4, u = 1.7$ [31].

$$x = \lambda.x - \omega.y + a.z.x + d.z.(x^2 + y^2)y = \lambda.y + \omega.x + a.z.yz = u - z^2 - e.(x^2 + y^2) - c.z^3 \tag{5}$$

The differential equation of the chosen Pehlivan-Wei chaotic system is seen as in Equation (6). The initial conditions were determined as x (0) = - 4, y (0) = 1 and z (0) = - 4 [32].

$$x = y - y.zy = y + y.z - 2.xz = 2 - x.y - y^2 \tag{6}$$

While selecting chaotic systems with an interface software developed in Labview program (Figure 3), initial conditions and time parameters can be changed. Through the written script codes, this program solves differential equations belonging to the selected chaotic system by using the Runge Kutta (RK45) numerical solution algorithm in MATLAB. After having copied the x, y, z chaotic time series data obtained in the excel format on the sd card, they were downloaded to the NX1P2-9024DT1 PLC.

Mixer control software was written on PLC by using the Omron Sysmac Studio program. By means of this software, X coordinate of each chaotic system chosen through an operator panel is scaled in the minimum and maximum frequency ranges. The obtained frequency values are sent to NX1P2-9024DT1 PLC controlled frequency inverter in time intervals that can be adjusted on the operator panel. In this way, the mixer motor to which the frequency inverter is connected, is able to rotate with variable chaotic speeds.

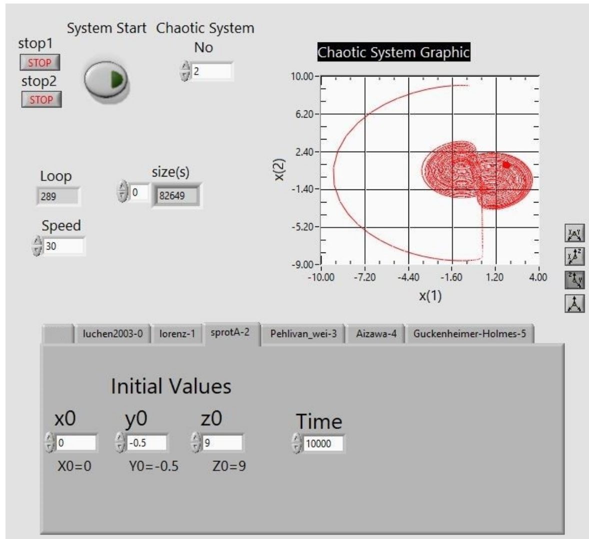

Figure 3. Interface software developed in labview for the solution of chaotic equations.

2.3. Determining the chaotic systems to be used

In order to determine the most suitable chaotic system to be used in experimental studies, a selection was made among Lu-Chen, Lorenz, SprottA, Aizawa, Guckenheimer-Holmes and Pehlivan-Wei chaotic systems, based on average mixing speeds. As a result of operating these chaotic systems in the mixer at a frequency range of minimum 8 Hz and maximum 20 Hz for 60 min, the average mixing speeds seen in Table 1 were measured. Accordingly, it was deemed appropriate to use the following in the mixer; Sprot A chaotic system at a frequency of 15.71 Hz. with 471.3 Rpm. as a ”high-speed system”, Lorenz chaotic system at a frequency of 14.88 Hz. with 446.4 Rpm. as the ”medium speed system” and Pehlivan-Wei chaotic system at a frequency of 13.78 Hz. with 413.4 Rpm. as a ”slow speed system”.

Table 1. Average mixing speed of chaotic systems.

CHAOTIC SYSTEMS	RANGE (Hz)	TIME (Min.)	AVERAGE FREQUENCY (Hz.)	AVERAGE SPEED (Rpm.)
Lu-Chen 2003	8-20	60	13.89	416.7
Lorenz	8-20	60	14.88	446.4
Sprott A	8-20	60	15.71	471.3
Aizawa	8-20	60	13.95	418.5
Gucken-Holmes	8-20	60	14.63	438.9
Pehlivan-Wei	8-20	60	13.78	413.4

2.4. Designing the fuzzy logic system and applying it to the mixer

An interface program was developed in Labview program for the fuzzy logic-controlled mixer system. A Computer and the NX1P2-9024DT1 Plc device were connected together with an Ethernet switch, and communication of the interface program with Plc device was provided via OPC (Open Platform Communications) server. In this way, the “pH” value of the mixture, the “time” in the mixture and the instantaneous “current“ values could be read in real time with the Labview program and the Fuzzy Logic controller outputs could be transmitted to the Plc device (Figure 4).

Membership Functions related to input variables and outputs were designed in accordance with the ”Fuzzy System Designer” sub-program in the Labview program, the experiment results done with chaotic systems, and the data derived from the experts. The Fuzzy Logic system input variables are the ”Ph” value of the mixture, elapsed “Time” in the mixture, and the instantaneous ”Current” value of the mixer motor. The Fuzzy Logic system output variables are the ”System” variables that decide which chaotic system (SprotA, Lorenz, Pehlivan-Wei) the system will work with and the ”Speed” variable that decides in which speed ranges the chaotic system will operate (Figure 5).

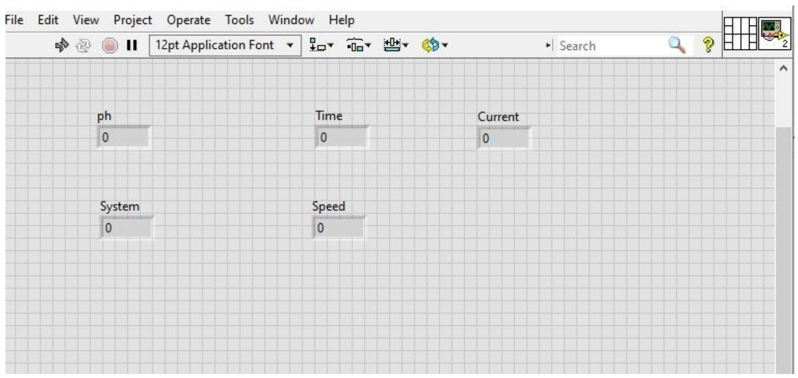

Figure 4. Interface program of fuzzy logic controlled mixer system.

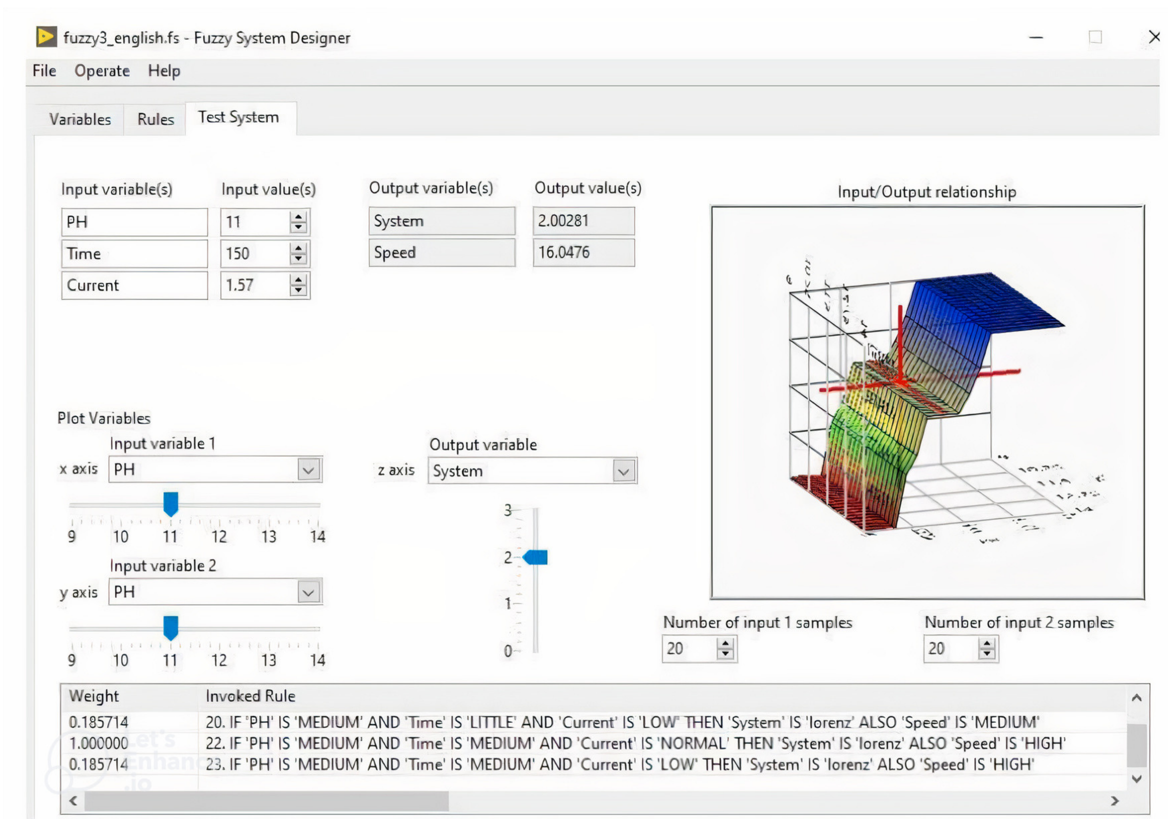

Figure 5. Input and output variables of fuzzy logic controlled mixing system.

During fuzzification phase, as seen in Figures 6a,6b, 6c, 6d, the trapezoid function is used since the number of components having full membership is more than one in the range of membership functions belonging to “ph, time, current” input variables and “speed” output variable. As seen in Figure 6e, triangle function shape is used since there is only one component having full membership in the range of membership functions belonging to “system” output variable. While preparing the membership functions, the input variable parameters and output values prepared for the membership function are taken into consideration and 36 Fuzzy Logic rules are created according to these membership functions by using Mamdani Method during the decision phase (Figure 6f).

The Fuzzy System Designer program, working with the interface program, sends the ”System” and ”Speed” data to PLC device on the OPC server in real-time by deciding which chaotic system and in which speed ranges the mixer engine will run according to the membership functions and the Fuzzy Logic rules created in compliance with these membership functions by using the Center of Area Method in the defuzzification phase.

The working flow diagram of the system is in Figure 7

2.5. Experimental study methods

In all experimental studies, according to the literature researches made for humic acid production, 10 L of water, leonardite sifted with 2mm diameter after grinding in the feed crushing machine and 200 gr potassium hydroxide (KOH) were used. Although sodium hydroxide (NaOH) was used in literature searches, it was not preferred in this study due to its harmful effects on agriculture.

The leonardite obtained from the quarries of the Uşak region was used and as a result of the analysis, it was determined that the organic matter ratio was 45.5% and the total humic and fulvic acid ratio was 34.5%.

These products were mixed in three different ways by using traditional methods, chaotic systems, and Fuzzy Logic artificial intelligence technique. The mixing time was 180 min and the mixing temperature was 50°. The minimum frequency was determined as 10 Hz and the maximum frequency was determined as 20 Hz in chaotic systems.

The pH values of the mixture were measured every 30 min during mixing. After taking the liquid humic acid obtained at the end of 3 h, the insoluble leonardite remaining at the bottom of the mixing bowl was taken into a container. Under that, insoluble leonardite was dried in the Mega-Therm M160 sterilizer device at 105° for 12 h and the amount of solvated dry leonardite was calculated. In addition, the total humic and fulvic acid ratios (HA + FA) in the humic acid obtained in experimental studies were analyzed in a special laboratory according to the California method and evaluated not only according to the dissolution rate but also the product quality.

3. Results

In this section, mixing results acquired at the end of 180-min-mixing by applying traditional methods, chaotic systems, and fuzzy logic are shown.

3.1. Mixing with the traditional method

PH values obtained as a result of 180 min of mixing at 50° constant temperature using the traditional method at 20 Hz (600 Rpm.) and 10 Hz (300 Rpm.) constant frequency were shown in Table 2. The amount of insoluble leonardite (sediment), dissolution ratio, average speed, total energy consumption, and total humic + fulvic acid values are shown in Table 3.

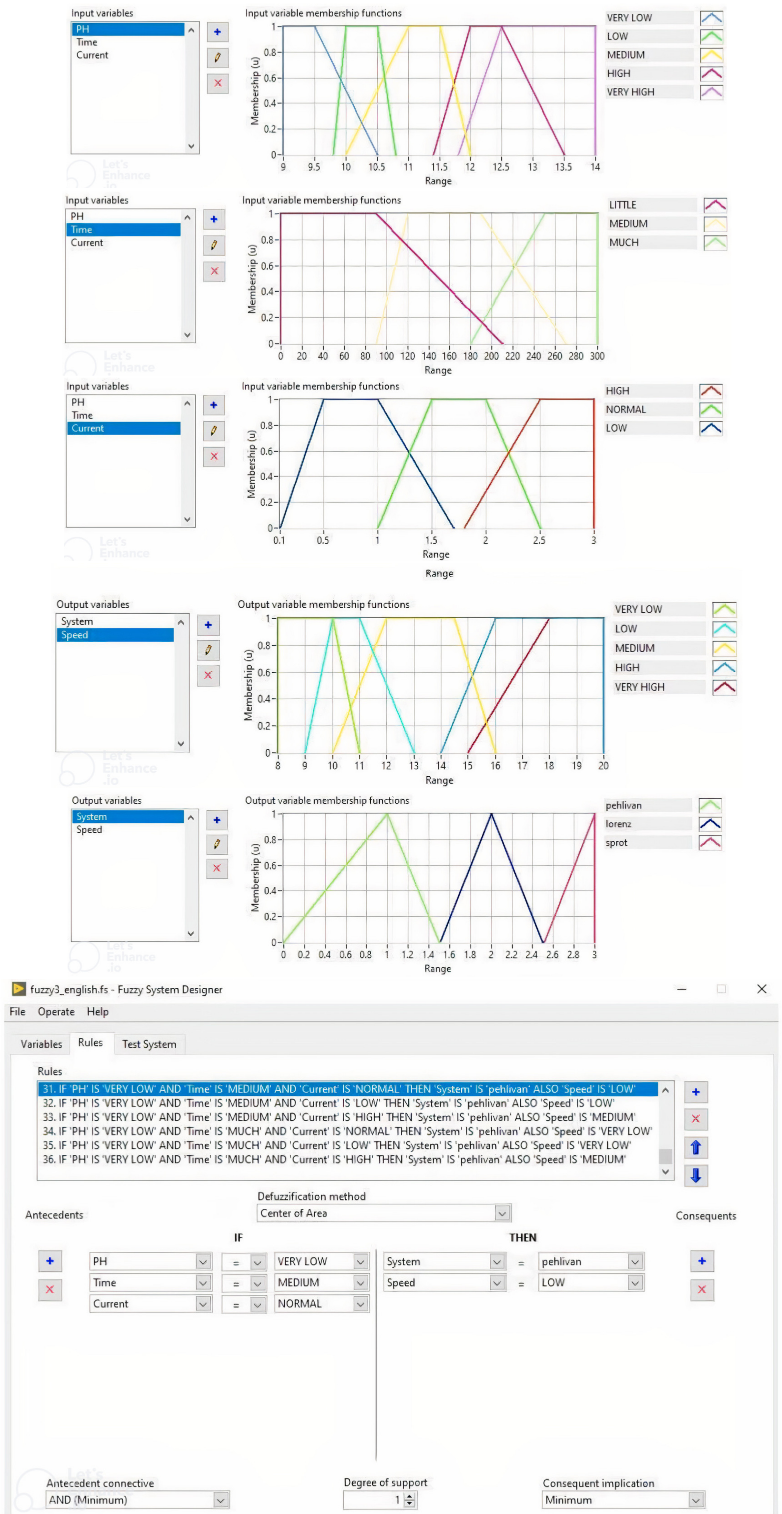

Figure 6. Membership functions for the speed and system output of the fuzzy logic controller.

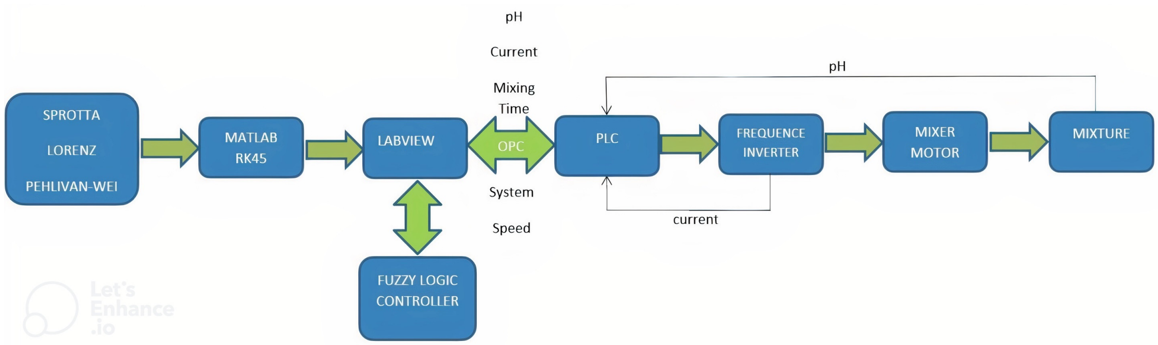

Figure 7. The flowchart of chaotic mixer based on artificial intelligence.

Table 2. pH values of mixtures.

SYSTEMS	TEMPR. °	0min. pH	30min. pH	60min. pH	90min. pH	120min. pH	150min. pH	180min. pH
10Hz. Constant (300Rpm.)	50	13.06	11.71	11.47	11.18	11	10.93	10.83
20Hz. Constant (600Rpm.)	50	12.95	11.55	11.19	10.90	10.75	10.58	10.50

Table 3. Dissociation, energy consumption and total humic-fulvic acid values of mixtures (TEMPR.: Temperature, SED.: Sediment, DISSOL.: Dissolution, AVR. FREQ.: Average Frequence, AVR. CONS.: Average Consumption, TOTAL CONS.: Total Consumption, HA+FA: Humic Acid + Fulvic Acid)

SYSTEMS	TEMPR. °	SED (kg.)	DISSOL. (%)	AVR. FREQ. (Hz.)	AVR. SPEED (Rpm.)	AVR. CURRENT (Ampere)	AVR. CONS. (KwH.)	TOTAL CONS. (KwH)	HA+FA (%)
10Hz. Constant (300Rpm.)	50	0.851	65.96	10	300	1.48	0.3256	0.9768	
20Hz. Constant (600Rpm.)	50	0.258	89.68	20	600	1.65	10.363	1.089	2.75

3.2. Mixing with chaotic systems

Ph values obtained as a result of 180-min-mixing at 50° constant temperature by using Sprott A, Lorenz, Pehlivan-Wei chaotic systems are shown in Table 4. The amount of insoluble leonardite (sediment), dissolution ratio, average speed, total energy consumption, and total humic + fulvic acid values are shown in Table 5.

3.3. Mixing with fuzzy logic system

The pH values obtained as a result of 180-min-mixing at 50° constant temperature (Fuzzy-50) and nonconstant temperature (Fuzzy-38) by using Fuzzy Logic method are shown in Table 6, the amount of insoluble leonardite (sediment), dissolution ratio, average speed, total energy consumption and total humic + fulvic acid values are given in Table 7.

Table 4. pH values of mixtures.

SYSTEMS	TEMPR. °	0min. pH	30min. pH	60min. pH	90min. pH	120min. pH	150min. pH	180min. pH
SprottA	50	12.47	11.66	11.13	11	10.85	10.65	10.50
Lorenz	50	12.37	11.50	11.12	10.90	10.78	10.55	10.40
Pehlivan-Wei	50	12.28	11.72	11.30	11.14	10.98	10.78	10.72

Table 5. Dissociation, energy consumption and total humic-fulvic acid values of mixtures (TEMPR.: Temperature, SED.: Sediment, DISSOL. : Dissolution, AVR. FREQ.:Average Frequence, AVR. CONS.: Average Consumption, TOTAL CONS.: Total Consumption, HA+FA: Humic Acid + Fulvic Acid)

SYSTEMS	TEMPR. °	SED (kg.)	DISSOL. (%)	AVR. FREQ. (Hz.)	AVR. SPEED (Rpm.)	AVR. CURRENT (Ampere)	AVR. CONS. (KwH.)	TOTAL CONS. (KwH)	HA+FA (%)
SprottA	50	0.138	94.48	15.73	471.87	1.57	0.3454	1.0362	2.61
Lorenz	50	0.334	86.64	14.85	445.58	1.55	0.341	1.023	2.43
Pehlivan-Wei	50	0.415	83.40	13.68	410.54	1.53	0.3366	1.0098	2.35

Table 6. pH values of mixtures.

SYSTEMS	TEMPR. °	0min. pH	30min. pH	60min. pH	90min. pH	120min. pH	150min. pH	180min. pH
Fuzzy-50	50	12.46	10.88	10.60	10.40	10.15	10	9.9
Fuzzy-38	38-50	12.56	10.79	10.55	10.37	10.30	10.27	10.25

Table 7. Dissociation, energy consumption and total humic-fulvic acid values of mixtures (TEMPR.: Temperature, SED.: Sediment, DISSOL.: Dissolution, AVR. FREQ.: Average Frequence, AVR. CONS.: Average Consumption, TOTAL CONS.: Total Consumption, HA+FA: Humic Acid + Fulvic Acid)

SYSTEMS	TEMPR. °	SED (kg.)	DISSOL. (%)	AVR. FREQ. (Hz.)	AVR. SPEED (Rpm.)	AVR. CURRENT (Ampere)	AVR. CONS. (KwH.)	TOTAL CONS. (KwH)	HA+FA (%)
Fuzzy-50	50	0.126	94.96	13.25	397	1.57	0.3454	1.0362	2.32
Fuzzy-38	38-50	0.134	94.64	13.93	418	1.58	0.3476	1.0428	2.35

4. Discussion

As a result of 180 min mixing, it was observed that the humic acid ph values in the mixing done with the Fuzzy-50 Fuzzy Logic artificial intelligence model reached a lower value compared to the Ph values in the mixing done with traditional methods and chaotic systems (Figure 8a). When the used potassium hydroxide (KOH) ratio or the mixing time is increased, the pH value can be lowered more. However, the form of the product will deteriorate and become useless if it is below the pH 7 value.

It was observed that the highest dissolution ratio in humic acid mixtures obtained from experimental studies was 94.96% and 50° with fuzzy logic mixing method in constant temperature (Fuzzy-50), the lowest total dissolution ratio was 65.96% in the constant speed mixing method done with the traditional method at 10 Hz. (300 Rpm.) (Figure 8b). The comparisons of dissolution ratios in the mixing done with Fuzzy-50 Fuzzy Logic artificial intelligence and other mixing types are given as in the following:

5.28% higher than the dissolution ratio in traditional mixing done with 20 Hz 600 Rpm, 29% higher than the dissolution ratio in traditional mixing done with 10 Hz 300 Rpm, 0.48% higher than the dissolution ratio in mixing done with SprottA chaotic system, 8.32% higher than the dissolution ratio in mixing done with Lorenz chaotic system, 11.56% higher than the dissolution ratio in mixing done with Pehlivan-Wei chaotic system.

It was observed in experimental studies that the maximum energy consumption calculated at the end of 180 min of mixing was in the mixing method with a constant speed of 1.089 kWh and 20 Hz (600 Rpm.), and the lowest energy consumption was in the mixing method with a constant speed of 0.9768 kWh and 10 Hz (300 Rpm.) (Figure 8c). It is observed that the total energy consumption of traditional mixing done at 20 Hz. 600

Rpm. is 4.4% higher than the total energy consumption of the mixing done with 38 fuzzy logic and 5% higher than the total energy consumption done with 50 fuzzy logic and SprottA chaotic system.

According to the analysis results of humic acid samples obtained from experimental studies, it was observed that the total humic + fulvic acid ratio in conventional mixing at a constant speed of 20 Hz (600 Rpm) was the highest value compared to other methods and the closest result to this value was the mixing done with the SprotA chaotic system (Figure 8d).

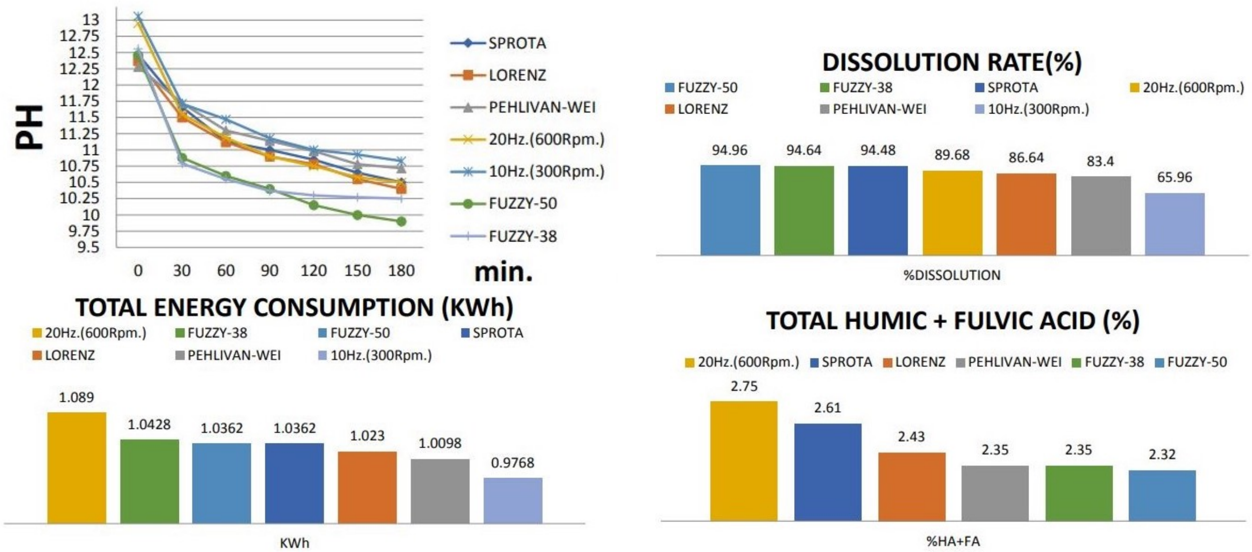

Figure 8. Analyzes of the results of experimental studies.

5. Conclusion

As a result of this study, important results have been obtained about improving the performance of mixers used in agricultural technologies with artificial intelligence techniques and chaotic systems. In mixing done with the Fuzzy Logic artificial intelligence technique and chaotic systems, more dissolution occurred compared to traditional methods while energy consumption was lower. The fact that the mixing done with fuzzy logic has the lowest ph and the highest dissolution ratio, it is observed to have the lowest Humic + Fulvic acid ratio. While this situation reveals that it is required to keep the pH value high during the separation process of humic + fulvic acid from leonardite, it also shows that the mixing speed is an efficient factor in the humic production as well. Accordingly, it is thought that the product quality can be improved to higher values if different chaotic systems are used in both humic acid production and different product processes, or if the average mixing speed is increased by changing the minimum and maximum frequency values of the chaotic systems. The experimental results and their comparison acquired at the end of this study show that the mixers used in agricultural technologies especially humic acid manufacturing can be made more productive in terms of criteria such as product quality, homogeneity, time, and energy savings by using chaotic systems and Fuzzy Logic artificial intelligence technique. Moreover, this study demonstrates that keeping the heat stable in liquid humic acid production process does not affect much as assumed. This outcome also has a positive effect on energy consumption occurring as a result of keeping the mixer's temperature stable during the mixing process.

In the future, methods developed in this study can be used in many mixers in distinctive industrial areas. The performance of the mixer can be increased by using different artificial techniques instead of fuzzy logic.

Separate mixer heads and chaotic systems can be included according to physical and chemical features of the products to be mixed. Moreover, it is expected that this peculiar method will not only contribute to the mixers but also to the machines used in the grinding, crushing, and sifting process.

Thanks

On behalf of the authors, I would like to thank Sakarya University of Applied Sciences, Scientific Research Projects Unit (BAP) for their financial support to the doctoral dissertation project numbered 2018-2-9-163.

References

[1] Banhero JT, Bodger WL. Introduction to chemical engineering. ITU publications 1979; 731-737.

[2] Vauck W, Müler H. Basic operations of chemical engineering introduction.Theodor Steinkopff 1966;2: 307-328.

[3] Henzler HJ. Eignung Von Kontinuierlich Durchströmten Mischern Zum Homogenisieren. WILEY-VCH publish 1972;1-8.

[4] İlten, N . Mixers and investigation of flow events in the mixing vessel. Master thesis, Uludag University, Institute of Science and Technology, Department of Mechanical Engineering, Bursa, Turkey, 1986.

[5] Pehlivan İ. New chaotic systems: Electronic circuit realizations, synchronization and secure communication applications. PhD thesis, Institute of Science and Technology, Sakarya University, Sakarya, Turkey,2007.

[6] Hilborn RC. An Introduction For Scientists And Engineers. Chaos and Nonlinear Dynamics, Oxford University Press, Oxford, UK, 1994.

[7] Lorenz E. Deterministic nonperiodic flow. Journal of Atmospheric Sciences 1963;20:130–141.

[8] Akgül A. Random number generator design with new chaotic systems and high security encryption of multimedia data. PhD thesis, Institute of Science and Technology, Sakarya University, Sakarya, Turkey, 2015.

[9] Coşkun S. Design and implementation of chaos sourced and adc based novel true random number generators. PhD thesis, Institute of Science and Technology, Sakarya University, Sakarya, Turkey, 2017.

[10] Kalayci O, Pehlivan I, Coşkun S. Improving the performance of mixers used in humic acid production with chaotic systems. Turkish Journal of Agriculture - Food Science and Technology 2021; 9 (3): 508-514.

[11] Kalayci O, Pehlivan I, Akgul A, Coskun S, Kurt E. A new chaotic mixer design based on the delta robot and its experimental studies. Mathematical Problems in Engineering 2021; Volume 2021, Article ID 6615856: 15.

[12] Kurt E. A new chaotic mixer design and application. Master Thesis, Sakarya University, Institute of Science and Technology, Mechatronics Engineering, Sakarya, Turkey, 2017.

[13] Chau KT, Shuang Y, Yuan G, Chen JH. Application of chaotic-motion motors to industrial mixing processes. In: IAS2004; 2004.pp.1874-1880.

[14] Ye S, Chau KT. Destabilization control of a chaotic motor for industrial mixers. In: IAS2005;2005.pp. 1724-1730.

[15] Murtadha MA, Abdurrahman M, Korman AI. Chaotic control of liquid mixer. Senior Design Project II, University of Sharjah, Department Of Electrical & Computer Engineering, Sharjah , United Arab Emirates,2008.

[16] Zhang Z, Chen G. Liquid mixing enhancement by chaotic perturbations in stirred tanks mixing. Science Direct, Chaos, Solitons and Fractals 2008; 36: 144–149.

[17] Kavur AE, Demiroğlu S, Seydibeyoğlu MÖ, Baser Ö, Güzeliş C et al. Design and implementation of chaotic System based robust delta robot for blending graphene nanoplatelets. In: 21St International Conference on Methods and Models in Automation and Robotics (MMAR);2016.

[18] Şimşir M. Fault diagnosis of hub motors with artificial intelligence techniques. PhD thesis, Institute of Science and Technology, Sakarya University, Sakarya, Turkey, 2016.

[19] Harb AM, Al-Smadi I. Chaos control using fuzzy controllers (Mamdani Model). In: Li Z., Halang W.A., Chen G. (eds) Integration of Fuzzy Logic and Chaos Theory. Studies in Fuzziness and Soft Computing 2006; 187. Springer, Berlin.

[20] Lian K, Liu P, Wu T, Lin W. Chaotic control using fuzzy model-based methods. Int. J. Bifurc. Chaos 2002; 12: 1827-1841.

[21] Park C, Lee C, Park M. Design of an adaptive fuzzy model based controller for chaotic dynamics in lorenz systems with uncertainty. Elsevier Information Sciences 2002; 147: 245–266.

[22] Li Z, Zhang X. On fuzzy logic and chaos theory. In: Wang P.P., Ruan D., Kerre E.E. (eds) Fuzzy Logic. Studies in Fuzziness and Soft Computing 2007; vol 215: Springer, Berlin.

[23] Yigit F, Dikilitas M. Effect of humic applications on the root-rot diseases caused by fusarium spp. on tomato plants. Plant Pathology Journal 2008; 7 (2): 179- 182.

[24] Engin VT, Cöcen EI. Leonardite and humic matters. Journal of Underground Resources 2012; 1 (2).

[25] Bentli İ, Demir U, Karaağaçlıoğlu İE, Çelik MS. Production of humic acid from leonardite by alkaline lich methods. In: MINEX 2015 6th Mining, Natural Resources and Technologies Fair, 14-16 May, Fuar, İzmir; 2015.

[26] Goff DW. United States Patent 19 Goff 54 Method Of Producing Humic Acid. 76 872 Bettino Ct., Houston: Tex. 77024 21 Appl. No.: 188,360 22 Filed: 1980.

[27] Özdemir A. Production of humic acid and fulvic acid from lignites. Master Thesis, Ankara University, Institute of Science, Chemical Engineering Department, Ankara, Turkey, 2016.

[28] Chen G, Lu J. Dynamical analysis. Control and Synchronization of the Generalized Lorenz Systems Family, (in Chinese) Science Press, Beijing, 2015.

[29] Sprott JC. Some simple chaotic flows. Physical Review E 1994;50 (2):647-650.

[30] Aizawa A, Coullet P, Spiegel E, Tresser C. Asymptotic chaos. Physica D 1985; 14 (3): 327-47.

[31] Guckenheimer J, Holmes PJ. Nonlinear oscillations. Dynamical Systems, and Bifurcations of Vector Fields. Newyork, USA: Springer-Verlag New York, 1983.

[32] Pehlivan I, Wei Z. Analysis, nonlinear control and circuit design of another strange chaotic system. Turkish Journal of Electrical Engineering and Computer Science 2012; 20, 1229–1239.