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Artificial neural fuzzy system and monitoring the process via IoT for optimization synthesis of nano-size polymeric chains

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Abstract. Synthesis of acrylate-based dispersion resins involves many parameters including temperature, ingredients concentrations, and rate of adding ingredients. Proper controlling of these parameters results in a uniform nano-size chain of polymer on one side and elimination of hazardous residual monomer on the other side. In this study, we aim to screen the process parameters via Internet of Things (IoT) to ensure that, first, the nano-size polymeric chains are in an acceptable range to acquire high adhesion property and second, the remaining hazardous substance concentration is under the minimum value for safety of public and personnel health. In this regard, a set of experiments is conducted to observe the influences of the process parameters on the size and dispersity of polymer chain and residual monomer concentration. The obtained dataset is further used to train an Adaptive Neural network Fuzzy Inference System (ANFIS) to achieve a model that predicts these two output parameters based on the input parameters. Finally, the ANFIS will return values to the automation system for further decisions on parameter adjustment or halting the process to preserve the health of the personnel and final product consumers as well.
Keywords: hazardous material; healthcare; internet of things (IoT); optimization; process monitoring

1. Introduction

Internet of Things (IoT) is the monitoring and processing data acquired from sensors through infrastructure of internet (Ashton 2009, Lu and Neng 2010, Xu *et al*. 2014). It has found applications in healthcare systems (Yin *et al*. 2016), agriculture (Dlodlo and Kalezhi 2015, Tzounis *et al*. 2017), mining (Qiuping *et al*. 2011) and chemical processing (Ley *et al*. 2015, Vijayakumar and Ramya 2015, Kim *et al*. 2017, Prabhu *et al*. 2019). The ongoing application of IoT makes it the future of internet. The application of IoT is very diverse from a domain as big as entire world to domain as small as single process and synthesis line in a factory. This method composed of two sections; one is the collecting data from the sensors and data acquisition devices and second is the processing and analyzing data to make proper decisions. Analyzing and processing data is performed using several methods including artificial neural network (ANN), machine learning (ML) and other analyzing and prediction methods (Aggarwal and Kumar 2019).

Ley *et al*. (2015) discussed potential application of Internet of Chemical Things (IoCT) in the future of chemical experiments and claimed that chemistry will change to adopt IoCT. Further, it is discussed that IoCT would fill the vacancies in measuring process and experiment parameters which might be missed in human measuring. Prabhu *et al*. (2019) discussed the use of IoT for chemical reactions and how it improves reliability and transparency of the experimental data through simultaneous data sharing with all scientists. They further employed a designed IoT model to inspect Ph-oscillating reaction and milk spoilage. Wen *et al*. (2020) reviewed recent development in wearable chemical sensors and systems helping health condition monitoring. They suggested that chemical sensors would eventually become self-power multifunctional systems which will work with the aid of IoT. Prabhu *et al*. (2020) in their paper comprehensively described use of micro-controllers and single-board computers to improve experimental design and screening experiments conditions. In this regard, they provide details of design and implementation of seven experimental routines with the help of microcontrollers and single-board computers as a part of IoT. Li *et al*. (2019) designed a wearable wrist-watch shaped sensor to measure a type of hazardous gas in the air which cause asthma attacks. They suggested that use of such devices could help the patient and also public health with continues monitoring hazardous gas through chemical sensor, smart phones and the internet.

Collecting and reporting data is one of the parts of IoT systems. One another part is the analyzing and decision making process. Using machine learning and artificial neural networks is the most effective and simplest way to comprehend the results of a dataset and sending instant feedbacks. In most cases, if-than logics works for industrial applications. However, with the aid of neural networks it become possible to choose between many options in an accurate and reliable way granted that the networks are appropriately trained (Yegnanarayana 2009). Nascimento *et*

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al. (2000) utilized neural network to acquire process parameters in chemical engineering problem to cope with nonlinear behavior of correlations between inputs and outputs. They used NN to calculate regions in which an output parameter fall into a desired range. It was observed that using these method several options of input configuration is obtained instead one possible option in solving nonlinear equations. Prediction of chemical reactivity was performed using supervised neural network in the research study by Coley *et al*. (2019). They used a massive dataset collected from patents to train their designed network to predict the organic reactions from their solvent, reagents and reactants. The model was able to predict reactivity with over 85% accuracy. They concluded that this artificial intelligence method could assist chemists in design of processes. Narayana *et al*. (2022) utilized ANN to predict and optimize heavy metal removal in adsorption processes. They used several experiments to train a neural network to observe the best condition for high rate removal. Moreover, the NN method is compared to design of experiment (DoE) method which showed the better performance and accuracy of neural network optimization. Neural network were also utilized in many other application from nanocomposites (Do *et al*. 2020) to mechanics of materials (Elangovan *et al*. 2010, Hussain *et al*. 2019, Safaei *et al*. 2019, Ankamwar and Sur 2020, Matouk *et al*. 2020, Alsultan 2021, Garg *et al*. 2021, Habibi *et al*. 2021a, Heirati *et al*. 2021, Orak and Sajedi 2021, Yanzhen *et al*. 2021).

Healthcare systems are very sensitive and delicate in which they must have high reliability in screening and reporting conditions. Using NN and IoT, it become possible to make vital decisions in emergency and normal conditions. Methods other than NN in engineering calculations take considerably greater time and efforts to reach a conclusion (Al-Furjan *et al*. 2021a, b, c, d, e, f, Dai *et al*. 2021a, Ghabussi *et al*. 2021, He *et al*. 2021, Huang *et al*. 2021, Huo *et al*. 2021, Moayedi *et al*. 2021, Shao *et al*. 2021, Shariati *et al*. 2021, Zhang *et al*. 2021a, Chen *et al*. 2022). Some methods uses semi-numerical solutions to solve equations and make a decision (Hou *et al*. 2021, Huang *et al*. 2021a, Jiao *et al*. 2021, Liu *et al*. 2021a, Ma *et al*. 2021, Moradi *et al*. 2021, Xu *et al*. 2021, Zhao *et al*. 2021, Yu *et al*. 2022). Other methods uses fully numerical procedure to solve a problem (Fazaeli *et al*. 2016, Ghazanfari *et al*. 2016, Habibi *et al*. 2016, 2017, 2018a, b, 2019a, b, c, d, Massoumi *et al*. 2018, Safarpour *et al*. 2018, Amelirad and Assempour 2019, Ebrahimi *et al*. 2019a, b, 2019, Esmailpoor Hajilak *et al*. 2019, Hashemi *et al*. 2019, Moayedi *et al*. 2019, Mohammadgholiha *et al*. 2019, Mohammadi *et al*. 2019, Pourjabari *et al*. 2019, Safarpour *et al*. 2019a, b, Shokrgozar *et al*. 2019, Amelirad and Assempour 2021). In any condition these methods are not able to respond quickly and to consider all input factors (Al-Furjan *et al*. 2021a, b, c, d, Dai *et al*. 2021a, Guo *et al*. 2021, Habibi *et al*. 2021g, h, i, j, Liu *et al*. 2021a, b, Najaafi *et al*. 2021, Safarpour *et al*. 2021, Zhang *et al*. 2021a, b). Chung and Jung (2020) employed deep learning method based on convolutional neural network (CNN) to analyze data and suggest healthcare recommendation. The study demonstrated 13% enhancement in prediction in comparison to other methods. Jiang *et al*. (2017) categorized applications of artificial intelligence (AI) methods in healthcare system. They divided the healthcare data into structures and unstructured in which different types of AI are employed. They also reviewed application of AI in three different levels of diagnosis, treatment and prognosis of disease. Raghupati and (2017) used neural network to find correlation between chronic disease and behavioral habits. With the aid of AI, it was concluded that fruit and vegetable consumption and physical exercises were against chronic conditions while alcohol and smoke had negative influence. Alam *et al*. (2019) designed an internet of medical things (IoMT) system to recognize emotions through non-invasive sensors to be further used in mining of affective state. Adamović *et al*. (2018) used ANN method to predict rate of chemical and healthcare waste production in European Union.

In this study, we aim to screen the process parameters via Internet of Things (IoT) to ensure that, first, the nano-size polymeric chains are in an acceptable range to acquire high adhesion property and second, the remaining hazardous substance concentration is under the minimum value for safety of public and personnel health. In this regard, a set of experiments is conducted to observe the influences of the process parameters on the size and dispersity of polymer chain and residual monomer concentration. The obtained dataset is further used to train an Adaptive Neural network Fuzzy Inference System (ANFIS) to achieve a model that predicts these two output parameters based on the input parameters. Finally, the ANFIS will return values to the automation system for further decisions on parameter adjustment or halting the process to preserve the health of the personnel and final product consumers as well.

2. Internet of things (IoT) system

In order to acquire data a system of sensors is designed using a standard Arduino electrical board. The system gathered data from multiple sensors in the process line including Mass Controllers (MCs), DLS and residual monomer analyzers and Temperature Indicator and Transferring (TIT) sensor. The configuration of the system is illustrated in Fig. 1. All the data measured and sensed by these 5 sensors are transferred to an electronic board in a regular pattern each second. The data further transferred to a computational server where analyzing of data is performed and decision on controlling process is made. The decision making in the computational center is based on supervised trained AI network which was prepared and trained to optimize the process using the best prior experienced conditions. There also designed the ability to add more dataset as input and retrain the model as desired or when the decisions of the system are not reliable or not true in some conditions. In such circumstances, the operator is warned and the process of training will be started based on new added datasets.

The difference between this system and traditional systems is employing AI in the process to making decisions without interference of human. Traditional controlling systems obey some specified rules previously written as if-

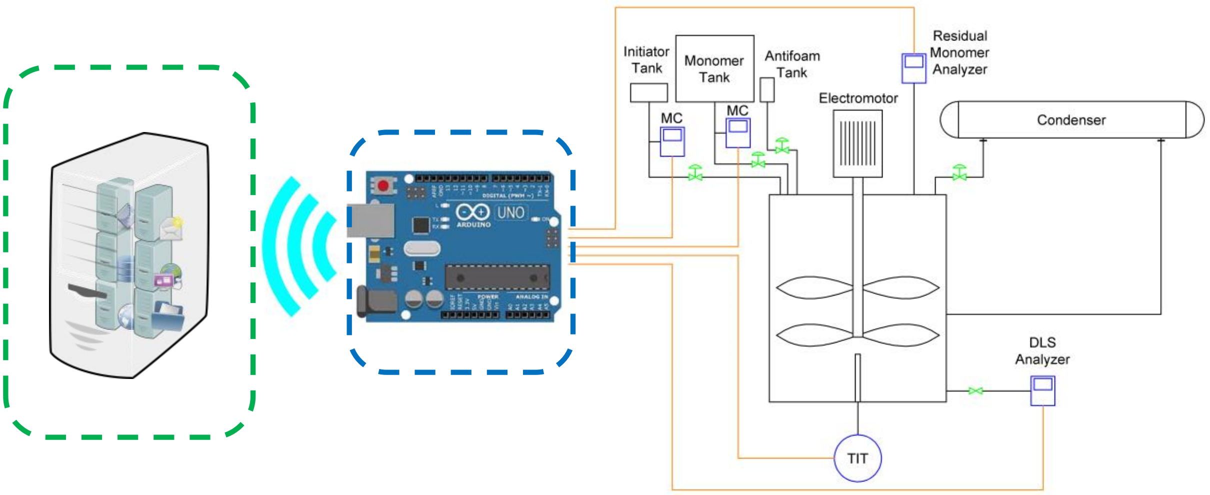

Fig. 1 IoT system to observe, collect and decision making in the acrylate-based dispersion resins synthesis

Table 1 Data acquired from process sensors

Run	Temperature [°C]	Rate of adding monomer [gr/sec]	Rate of adding initiator [mg/sec]	Poly Dispersity	Residual monomer [%]
1	61.2	34.7	366	0.96	0.107
2	60.3	35	362	0.32	0.109
3	60.4	32.1	335	0.98	0.100
4	**59.8**	**52.3**	**535**	**0.46**	**0.156**
5	59.5	21.9	233	0.62	0.072
6	64.8	41.5	426	0.51	0.119
7	65.1	36.4	375	0.85	0.099
8	65.2	35.7	370	0.64	0.096
9	65.9	33.8	350	0.34	0.094
10	**65**	**62.9**	**648**	**0.68**	**0.175**
11	**70.2**	**28.4**	**297**	**0.6**	**0.070**
12	68.9	27.6	294	0.59	0.075
13	69.7	29.3	306	0.36	0.081
14	69.4	32	338	0.3	0.085
15	71.2	31.5	325	0.74	0.078
16	76.8	44.6	460	0.8	0.105
17	75.6	40.8	428	0.39	0.102
18	75.2	43.2	452	0.59	0.099
19	75.2	39.7	416	0.38	0.095
20	75.4	46.1	475	0.94	0.110
21	81.8	36.4	384	0.98	0.079
22	81	36	378	0.94	0.082
23	**81.6**	**35.2**	**364**	**0.58**	**0.079**
24	81.6	33.9	349	0.42	0.081
25	80.6	31.5	332	0.89	0.074
26	85.4	38.5	396	0.37	0.084
27	85.6	37.9	399	0.43	0.079
28	86.4	36.8	387	0.72	0.078
29	87	36.5	381	0.78	0.082
30	**87**	**35.4**	**367**	**0.66**	**0.072**

Table 1 Continued

Run	Temperature [°C]	Rate of adding monomer [gr/sec]	Rate of adding initiator [mg/sec]	Poly Dispersity	Residual monomer [%]
31	90.6	32.4	344	0.44	0.064
32	90.8	36	374	0.6	0.069
33	91	39.4	405	0.74	0.082
34	91	41.2	430	0.74	0.087
35	91.2	35.1	366	0.99	0.069

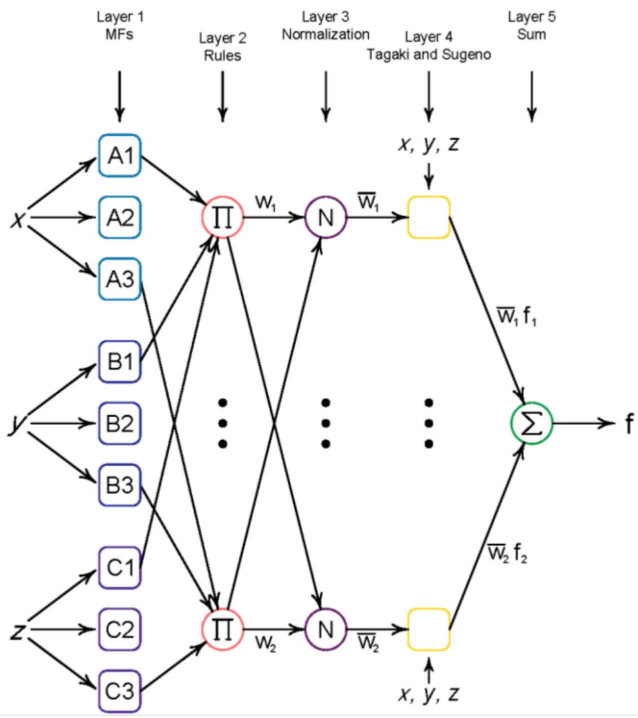

Fig. 2 Schematic of ANFIS layers for three inputs and one outputs

than rules. However, the AI system can be trained to makes better decisions on many parameters without limitations. The training process although have vital impact on the performance of the system.

3. Data acquisition

Some of the sample data gathered by designed IoT system is presented in the Table 1. The values of poly dispersity should be close to unity to have proper adhesion properties. However, the values above 0.2 is acceptable in the final product. In addition, the amount of residual monomer, because of its toxicity and danger to health safety must be kept under 0.1%wt. Otherwise, some other processes have to be performed to reduce the amount of the monomer. In any condition, the product with residual monomer higher than 0.1%wt would not release to the market. The amount of initiator is kept to around 1% of the monomer. Moreover, experiments demonstrated that in temperature between 60 to 90°C acceptable quality is obtained.

The data given in Table 1 are roughly divided into seven temperature values: 60, 65, 70, 75, 80, 85 and 90°C. All other data were simultaneously acquired by the IoT system. At first glance. It is observed that in lower rate of adding monomer and higher temperatures the hazardous residual monomer fall into safe range (<0.1%). However, for higher adding rate and lower temperature the condition is cautionary. There cannot be observed a clear correlation between poly dispersity and input parameters. Thus, we decide to design a neuro-fuzzy system to illustrate a richer correlation between parameters and design a model to predict and control the process in a more sophisticated and intelligence method.

4. Neural-fuzzy model

The ANFIS model is introduced in this section for calculating effects temperature and rate of adding monomer and initiator on the poly dispersity and residual monomer. In this regard, temperature and rate of adding monomer and initiator are regarded as input data and poly dispersity and residual monomer are the outputs. The neural network used in this this study is schematically presented in 0. As seen, this network has three inputs X, Y and Z and one output f. Membership functions in Layer 1 indicated by A_i, B_i and C_i ($i = 1, 2, 3$) converts input data to their membership values:

$$\mu_{A_i}(X), \mu_{B_i}(Y), \mu_{C_i}(Z) \tag{1}$$

In 0, the correlation between MFs and fuzzy rules are shown. Since each of the three inputs has three MFs function there are $3 \times 3 = 9$ rules in this network. However, rules can be modified based on the logic between them. These rules are applied in the Layer 2 (rules) to obtain the overall *firing strength* of each node in this layer:

$$w_i = \mu_{A_i}(X) \times \mu_{B_i}(Y) \times \mu_{C_i}(Z) \tag{2}$$

In Layer 3, all the firing strengths are normalized to adequately apply their effect portion on the final results. The normalization is performed according to following relation:

$$\overline{w}_j = \frac{w_j}{\sum_k w_k} \tag{3}$$

for $j = 1\ to\ number\ of\ Rules.$

In Layer 4, influence of the actual values of the input data is calculated on the output for each rule. In this layer,

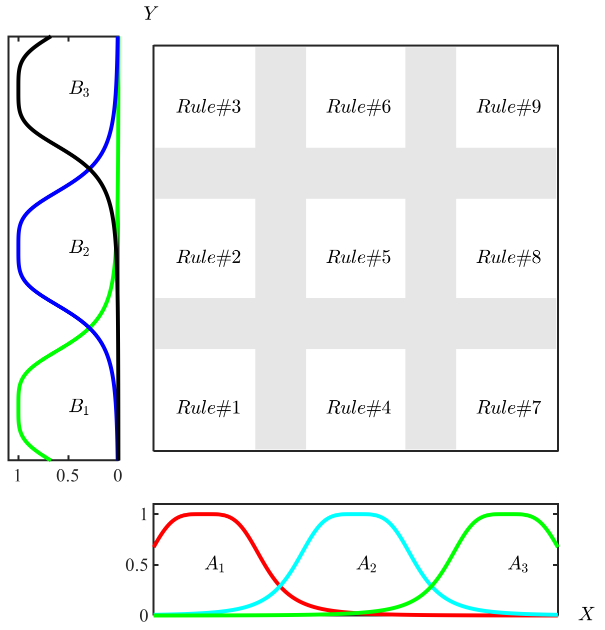

Fig. 3 Fuzzy subspaces for ANFIS with three inputs and nine rules

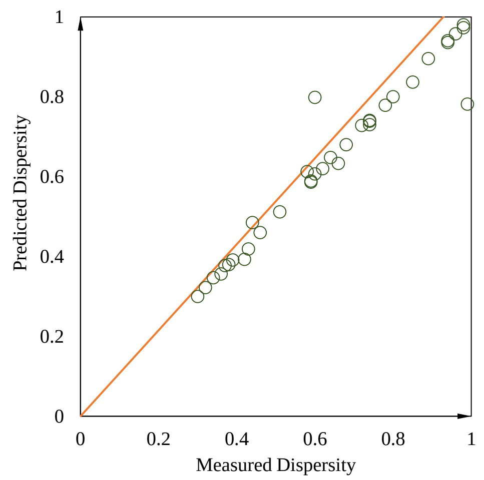

Fig. 4 Dependency of poly dispersity on the process parameters temperature and rate of adding monomer

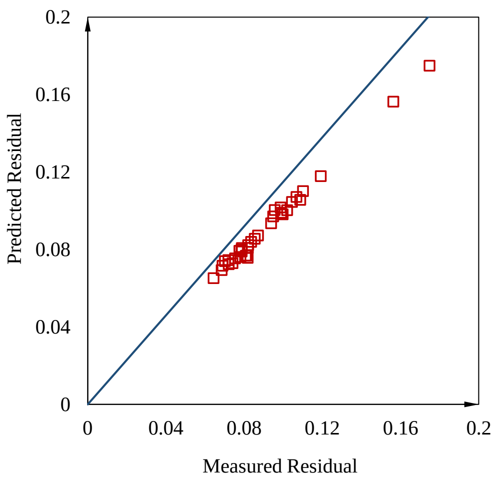

Fig. 5 Dependency of monomer residual on the process parameters temperature and rate of adding monomer

every single input data directly affect the output regardless of other provided input. This method was presented by Takagi and Sugeno's rule Takagi and Sugeno (1985), Jang (1993). The effects is considered to have be linear:

$$f_j = p_j X + q_j Y + r_j \tag{4}$$

Effects of all the input data on the output is a weighted combination of all data:

$$f = \sum_{k=1}^{NR} \overline{w}_k f_k \tag{5}$$

where NR represents number of all rules. The role of neural network is to adjust the weight values and coefficients of linear functions in Layer 4 to minimize the error of the network. Thus, an iterative method is used to obtain a model with acceptable error. Afterward, the network considered to be trained and will be ready to be tested and calculate output for new data.

5. Results and discussion

The input data in the ANFIS network described above is the temperature, rate of adding monomer and rate of adding initiator of the process. The outputs are poly dispersity and residual monomer for each a separate ANFIS model is designed. The dataset is prepared based on the acquired values from IoT. Triangle membership functions are considered for fuzzification of the input data with the following general relation:

$$f(x; a, b, c) = \max\left(min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right) \tag{6}$$

The parameters a, b and c are determined assigned by ANFIS app in Matlab.

From 35 set of data samples. 30 sets are used to train the network and 5 remaining are testing data to ensure about reliability of the network. After iteration, the overall error is 2.3% and 1.4% for poly dispersity and residual monomer, respectively, as demonstrated in Fig. 4 and Fig. 5. As seen, the train network predicts results with high accuracy.

The trained network surface for the thickness reduction is shown in Fig. 6. As seen in Fig. 6(a), there is a clear correlation between monomer residual and input parameters temperature and rate of adding monomer. With increase in temperature the hazardous residual monomer decreases. On the other hand, lower adding rate of monomer also reduces the residual. Therefore, these two parameters can be considered as controlling parameters in the process with a well-shaped behavior as illustrated with the aid of surface function. The decision making of the artificial design network is based on this surface for different conditions. However, this surface cannot be the main surface for decision making.

There is another output parameter, poly dispersity, which affects the control of process. As seen in Fig. 6(b), these two input parameters also alter the poly dispersity. Although, there is seen a fluctuated behavior of this output, some ranges of acceptable input values of temperature and rate of adding monomer can be determined. Clearly, high

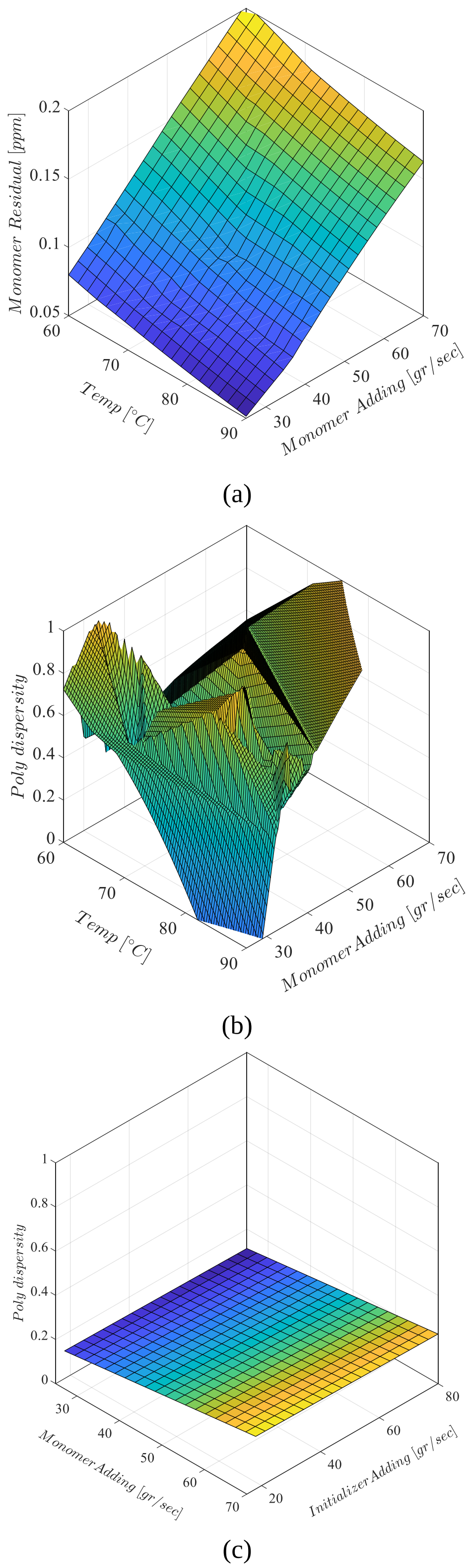

Fig. 6 Dependency of (a) monomer residual and (b) poly dispersity on the process parameters temperature and rate of adding monomer. The effect of the initializer concentration on the monomer residual is shown in (c)

temperature values along with low adding rate results in low and unacceptable values of poly dispersity, i.e., lower than 0.2.

Using these two surfaces, the intelligence system decides how to change temperature and adding rate to keep two important outputs in desirable ranges. These, decision making is not available in traditional control of the process where if-than commands control the process in most controlling systems. Therefore, a valuable result of using IoT system is the capability of using AI methods in controlling chemical process to ensure having a high quality and safe products with online checking and controlling beside instant proper decision making. One question here is that the obtained AI model is reliable? We have clear answer to this question. Based on the reliability of the input data we could train reliable AI models. With inaccurate data or neglecting influencing factor we may train AI systems with low reliability. However, experiences in other fields similar to self-driving cars make us confident that these methods have to be utilized in the chemistry and process controls. There also some other methods which are in some parts analytical and in some section are numerical to reach solve similar problems (Adamian *et al*. 2020, Al-Furjan *et al*. 2020a, b, c, d, e, f, g, h, i, j, k, Alipour *et al*. 2020, Bai *et al*. 2020, Cheshmeh *et al*. 2020, Ebrahimi *et al*. 2020, Ghabussi *et al*. 2020, Ghazanfari *et al*. 2020, Habibi *et al*. 2020, Jermsittiparsert *et al*. 2020, Li *et al*. 2020a, b, Liu *et al*. 2020a, b, Lori *et al*. 2020, Moayedi *et al*. 2020a, b, Oyarhossein *et al*. 2020, Safarpour *et al*. 2020, Shariati *et al*. 2020a, b, c, Shi *et al*. 2020, Shokrgozar *et al*. 2020, Wang *et al*. 2020, Zare *et al*. 2020, Zhou *et al*. 2020). However, the computational costs in these methods are very high (Al-Furjan *et al*. 2020a, b, c, d, e, f, g, h, i, j, k, l, m).

6. Conclusions

Synthesis of acrylate-based dispersion resins involves many parameters including temperature, ingredients concentrations, and rate of adding ingredients. Proper controlling of these parameters results in a uniform nano-size chain of polymer on one side and elimination of hazardous residual monomer on the other side. In this study, we designed an Internet of Things (IoT) system to acquire online measurement data of both input and output parameters to ensure that, first, the nano-size polymeric chains were in an acceptable range to acquire high adhesion property and second, the remaining hazardous substance concentration is under the minimum value for safety of public and personnel health. The obtained dataset is further used to train an adaptive neural network fuzzy inference system (ANFIS) to achieve a model that predicts these two output parameters based on the input parameters. The main results of the study can be encapsulated in the followings:

- IoT system can provide more online data to investigate all-time condition of the process. The data can be saved on servers.
- The gathered data can be analyzed using ANFIS system to make proper instant decisions. This analysis cannot be conducted in the traditional if-than controlling systems
- The models with high accuracy is utilized and can be adopted with more data available
- Higher temperature and lower rate of adding monomer

results in better product in terms of health safety of the product.

• The decision making in AI model is performed considering several parameters of both input and output data.

References

Abouelregal, A.E., Mohammad-Sedighi, H., Faghidian, S.A. and Adamian, A., Hosseini Safari, K., Sheikholeslami, M., Habibi, M., Al-Furjan, M.S.H. and Chen, G. (2020), "Critical temperature and frequency characteristics of gpls-reinforced composite doubly curved panel", *Appl. Sci.*, **10**(9), 3251. https://doi.org/10.3390/app10093251.

Adamović, V.M., Antanasijević, D.Z., Ristić, M.Đ., Perić-Grujić, A.A. and Pocajt, V.V. (2018), "An optimized artificial neural network model for the prediction of rate of hazardous chemical and healthcare waste generation at the national level", *J. Mater. Cycle. Waste Manage.*, **20**(3), 1736-1750. https://doi.org/10.1007/s10163-018-0741-6.

Aggarwal, S. and Kumar, A. (2019). "A smart irrigation system to automate irrigation process using IoT and artificial neural network", *Proceddings of the 2019 2nd International Conference on Signal Processing and Communication (ICSPC)*, Coimbatore, India, March.

Al-Furjan, M., Habibi, M., won Jung, D., Sadeghi, S., Safarpour, H., Tounsi, A. and Chen, G. (2020a), "A computational framework for propagated waves in a sandwich doubly curved nanocomposite panel", *Eng. Comput.*, 1-18. https://doi.org/10.1007/s00366-020-01130-8.

Al-Furjan, M.S.H., Alzahrani, B., Shan, L., Habibi, M. and Jung, D.W. (2020b), "Nonlinear forced vibrations of nanocomposite-reinforced viscoelastic thick annular system under hygrothermal environment", *Mech. Based Des. Struct.*, 1-27. https://doi.org/10.1080/15397734.2020.1824795.

Al-Furjan, M.S.H., Bolandi, S.Y., Shan, L., Habibi, M. and Jung, D.W. (2020c), "On the vibrations of a high-speed rotating multi-hybrid nanocomposite reinforced cantilevered microdisk", *Mech. Based Des. Struct.*, 1-29. https://doi.org/10.1080/15397734.2020.1828098.

Al-Furjan, M.S.H., Habibi, M. and Safarpour, H. (2020d), "Vibration control of a smart shell reinforced by graphene nanoplatelets", *Int. J. Appl. Mech.*, **12**(6), 2050066. https://doi.org/10.1142/S1758825120500660.

Al-Furjan, M.S.H., Mohammadgholiha, M., Alarifi, I.M., Habibi, M. and Safarpour, H. (2020e), "On the phase velocity simulation of the multi curved viscoelastic system via an exact solution framework", *Eng. Comput.*, 1-17. https://doi.org/10.1007/s00366-020-01152-2.

Al-Furjan, M.S.H., Oyarhossein, M.A., Habibi, M., Safarpour, H. and Jung, D.W. (2020f), "Frequency and critical angular velocity characteristics of rotary laminated cantilever microdisk via two-dimensional analysis", *Thin Wall. Struct.*, **157**, 107111. https://doi.org/10.1016/j.tws.2020.107111.

Al-Furjan, M.S.H., Oyarhossein, M.A., Habibi, M., Safarpour, H. and Jung, D.W. (2020g), "Wave propagation simulation in an electrically open shell reinforced with multi-phase nano-composites", *Eng. Comput.*, 1-17. https://doi.org/10.1007/s00366-020-01167-9.

Al-Furjan, M.S.H., Safarpour, H., Habibi, M., Safarpour, M. and Tounsi, A. (2020h), "A comprehensive computational approach for nonlinear thermal instability of the electrically FG-GPLRC disk based on GDQ method", *Eng. Comput.*, 1-18. https://doi.org/10.1007/s00366-020-01088-7.

Al-Furjan, M., Fereidouni, M., Sedghiyan, D., Habibi, M. and won Jung, D. (2021a), "Three-dimensional frequency response of the CNT-Carbon-Fiber reinforced laminated circular/annular plates under initially stresses", *Compos. Struct.*, **257**, 113146. https://doi.org/10.1016/j.compstruct.2020.113146.

Al-Furjan, M., Samimi-Sohrforozani, E., Habibi, M., won Jung, D. and Safarpour, H. (2021b), "Vibrational characteristics of a higher-order laminated composite viscoelastic annular microplate via modified couple stress theory", *Compos. Struct.*, **257**, 113152. https://doi.org/10.1016/j.compstruct.2020.113152.

Al-Furjan, M.S.H., Bolandi, S.Y., Habibi, M., Ebrahimi, F., Chen, G. and Safarpour, H. (2021c), "Enhancing vibration performance of a spinning smart nanocomposite reinforced microstructure conveying fluid flow", *Eng. Comput.*, 1-16. https://doi.org/10.1007/s00366-020-01255-w.

Al-Furjan, M.S.H., Dehini, R., Khorami, M., Habibi, M. and won Jung, D. (2021d), "On the dynamics of the ultra-fast rotating cantilever orthotropic piezoelectric nanodisk based on nonlocal strain gradient theory", *Compos. Struct.*, **255**, 112990. https://doi.org/10.1016/j.compstruct.2020.112990.

Al-Furjan, M.S.H., Dehini, R., Paknahad, M., Habibi, M. and Safarpour, H. (2021e), "On the nonlinear dynamics of the multi-scale hybrid nanocomposite-reinforced annular plate under hygro-thermal environment", *Arch. Civil Mech. Eng.*, **21**(1), 4. https://doi.org/10.1007/s43452-020-00151-w.

Al-Furjan, M.S.H., Fereidouni, M., Habibi, M., Abd Ali, R., Ni, J. and Safarpour, M. (2020f), "Influence of in-plane loading on the vibrations of the fully symmetric mechanical systems via dynamic simulation and generalized differential quadrature framework", *Eng. Comput.*, 1-23. https://doi.org/10.1007/s00366-020-01177-7.

Al-Furjan, M.S.H., Habibi, M., Chen, G., Safarpour, H., Safarpour, M. and Tounsi, A. (2020g), "Chaotic oscillation of a multi-scale hybrid nano-composites reinforced disk under harmonic excitation via GDQM", *Compos. Struct.*, **252**, 112737. https://doi.org/10.1016/j.compstruct.2020.112737.

Al-Furjan, M.S.H., Habibi, M., Ebrahimi, F., Mohammadi, K. and Safarpour, H. (2020h), "Wave dispersion characteristics of high-speed-rotating laminated nanocomposite cylindrical shells based on four continuum mechanics theories", *Wave. Random Complex.*, 1-27. https://doi.org/10.1080/17455030.2020.1831099.

Al-Furjan, M.S.H., Habibi, M., Ghabussi, A., Safarpour, H., Safarpour, M. and Tounsi, A. (2021i), "Non-polynomial framework for stress and strain response of the FG-GPLRC disk using three-dimensional refined higher-order theory", *Eng. Struct.*, **228**, 111496. https://doi.org/10.1016/j.engstruct.2020.111496.

Al-Furjan, M.S.H., Habibi, M., Jung, D.W., Chen, G., Safarpour, M. and Safarpour, H. (2021j), "Chaotic responses and nonlinear dynamics of the graphene nanoplatelets reinforced doubly-curved panel", *Eur. J. Mech. A Solid*, **85**, 104091. https://doi.org/10.1016/j.euromechsol.2020.104091.

Al-Furjan, M.S.H., hatami, A., Habibi, M., Shan, L. and Tounsi, A. (2021k), "On the vibrations of the imperfect sandwich higher-order disk with a lactic core using generalize differential quadrature method", *Compos. Struct.*, **257**, 113150. https://doi.org/10.1016/j.compstruct.2020.113150.

Al-Furjan, M.S.H., Moghadam, S.A., Dehini, R., Shan, L., Habibi, M. and Safarpour, H. (2021l), "Vibration control of a smart shell reinforced by graphene nanoplatelets under external load: Semi-numerical and finite element modeling", *Thin Wall. Struct.*, **159**, 107242. https://doi.org/10.1016/j.tws.2020.107242.

Al-Furjan, M.S.H., Oyarhossein, M.A., Habibi, M., Safarpour, H., Won Jung, D. and Tounsi, A. (2021m), "On the wave propagation of the multi-scale hybrid nanocomposite doubly curved viscoelastic panel", *Compos. Struct.*, **255**, 112947. https://doi.org/10.1016/j.compstruct.2020.112947.

Alam, M.G.R., Abedin, S.F., Moon, S.I., Talukder, A. and Hong, C.S. (2019), "Healthcare IoT-based affective state mining using a deep convolutional neural network", *IEEE Access*, **7**, 75189-75202. https://doi.org/10.1109/ACCESS.2019.2919995.

Alipour, M., Torabi, M.A., Sareban, M., Lashini, H., Sadeghi, E., Fazaeli, A., Habibi, M. and Hashemi, R. (2020), "Finite element and experimental method for analyzing the effects of martensite morphologies on the formability of DP steels", *Mech. Based Des. Struct.*, **48**(5), 525-541. https://doi.org/10.1080/15397734.2019.1633343.

Alsultan, A.S. (2021), "Assessment of microstructure and surface effects on vibrational characteristics of public transportation", *Adv. Nano Res.*, **11**(1), 101-113. https://doi.org/10.12989/anr.2021.11.1.101.

Amelirad, O. and Assempour, A. (2019), "Experimental and crystal plasticity evaluation of grain size effect on formability of austenitic stainless steel sheets", *J. Manuf. Proc.*, **47**, 310-323. https://doi.org/10.1016/j.jmapro.2019.09.035.

Amelirad, O. and Assempour, A. (2021), "Coupled continuum damage mechanics and crystal plasticity model and its application in damage evolution in polycrystalline aggregates", *Eng. Comput.*, 1-15. https://doi.org/10.1007/s00366-021-01346-2.

Ankamwar, B. and Sur, U.K. (2020), "Copper micro/nano-structures as effective SERS active substrates for pathogen detection", *Adv. Nano Res.*, **9**(2), 113-122. https://doi.org/10.12989/anr.2020.9.2.113.

Ashton, K. (2009), "That 'internet of things' thing", *RFID J.*, **22**(7), 97-114. http://www.rfidjournal.com/articles/view?4986

Bai, Y., Alzahrani, B., Baharom, S. and Habibi, M. (2020), "Semi-numerical simulation for vibrational responses of the viscoelastic imperfect annular system with honeycomb core under residual pressure", *Eng. Comput.*, 1-26. https://doi.org/10.1007/s00366-020-01191-9.

Chen, F., Chen, J., Duan, R., Habibi, M. and Khadimallah, M.A. (2022), "Investigation on dynamic stability and aeroelastic characteristics of composite curved pipes with any yawed angle", *Compos. Struct.*, **284**, 115195. https://doi.org/10.1016/j.compstruct.2022.115195.

Cheshmeh, E., Karbon, M., Eyvazian, A., Jung, D.W., Habibi, M. and Safarpour, M. (2020), "Buckling and vibration analysis of FG-CNTRC plate subjected to thermo-mechanical load based on higher order shear deformation theory", *Mech. Based Des. Struct.*, 1-24. https://doi.org/10.1080/15397734.2020.1744005.

Chung, K. and Jung, H. (2020), "Knowledge-based dynamic cluster model for healthcare management using a convolutional neural network", *Inform. Technol. Manage.*, **21**(1), 41-50. https://doi.org/10.1007/s10799-019-00304-1.

Coley, C.W., Jin, W., Rogers, L., Jamison, T.F., Jaakkola, T.S., Green, W.H., Barzilay, R. and Jensen, K.F. (2019), "A graph-convolutional neural network model for the prediction of chemical reactivity", *Chem. Sci.*, **10**(2), 370-377. https://doi.org/10.1039/C8SC04228D.

Dai, Z., Jiang, Z., Zhang, L. and Habibi, M. (2021a), "Frequency characteristics and sensitivity analysis of a size-dependent laminated nanoshell", *Adv. Nano Res.*, **10**(2), 175-189. https://doi.org/10.12989/anr.2021.10.2.175.

Dai, Z., Zhang, L., Bolandi, S.Y. and Habibi, M. (2021b), "On the vibrations of the non-polynomial viscoelastic composite open-type shell under residual stresses", *Compos. Struct.*, **263**, 113599. https://doi.org/10.1016/j.compstruct.2021.113599.

Dlodlo, N. and Kalezhi, J. (2015). "The internet of things in agriculture for sustainable rural development", *Proceedings of the 2015 International Conference on Emerging Trends in Networks and Computer Communications (ETNCC)*, Windhoek, Namibia, May.

Do, D.T.T., Nguyen-Xuan, H. and Lee, J. (2020), "Material optimization of tri-directional functionally graded plates by using deep neural network and isogeometric multimesh design approach", *Appl. Math. Modell.*, **87**, 501-533. https://doi.org/10.1016/j.apm.2020.06.002.

Ebrahimi, F., Habibi, M. and Safarpour, H. (2019a), "On modeling of wave propagation in a thermally affected GNP-reinforced imperfect nanocomposite shell", *Eng. Comput.*, **35**(4), 1375-1389. https://doi.org/10.1007/s00366-018-0669-4.

Ebrahimi, F., Hajilak, Z.E., Habibi, M. and Safarpour, H. (2019b), "Buckling and vibration characteristics of a carbon nanotube-reinforced spinning cantilever cylindrical 3D shell conveying viscous fluid flow and carrying spring-mass systems under various temperature distributions", *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*. **233**(13), 4590-4605. https://doi.org/10.1177/0954406219832323.

Ebrahimi, F., Mohammadi, K., Barouti, M.M. and Habibi, M. (2019c), "Wave propagation analysis of a spinning porous graphene nanoplatelet-reinforced nanoshell", *Wave. Random Complex.*, 1-27. https://doi.org/10.1080/17455030.2019.1694729.

Ebrahimi, F., Hashemabadi, D., Habibi, M. and Safarpour, H. (2020), "Thermal buckling and forced vibration characteristics of a porous GNP reinforced nanocomposite cylindrical shell", *Microsyst. Technol.*, **26**(2), 461-473. https://doi.org/10.1007/s00542-019-04542-9.

Elangovan, K., Sathiya Narayanan, C. and Narayanasamy, R. (2010), "Modelling of forming limit diagram of perforated commercial pure aluminium sheets using artificial neural network", *Comput. Mater. Sci.*, **47**(4), 1072-1078. https://doi.org/10.1016/j.commatsci.2009.12.016.

Esmailpoor Hajilak, Z., Pourghader, J., Hashemabadi, D., Sharifi Bagh, F., Habibi, M. and Safarpour, H. (2019), "Multilayer GPLRC composite cylindrical nanoshell using modified strain gradient theory", *Mech. Based Des. Struct.*, **47**(5), 521-545. https://doi.org/10.1080/15397734.2019.1566743.

Fazaeli, A., Habibi, M. and Ekrami, A.A. (2016), "Experimental and finite element comparison of mechanical properties and formability of dual phase steel and ferrite - pearlite steel with the same chemical composition", *Metall. Eng.*, **19**(2), 84-93. https://doi.org/10.22076/me.2017.41458.1064.

Garg, R., Garg, R. and Eddy, N.O. (2021), "Influence of pozzolans on properties of cementitious materials: A review", *Adv. Nano Res.*, **11**(4), 423-436. https://doi.org/10.12989/anr.2021.11.4.423.

Ghabussi, A., Habibi, M., NoormohammadiArani, O., Shavalipour, A., Moayedi, H. and Safarpour, H. (2020), "Frequency characteristics of a viscoelastic graphene nanoplatelet–reinforced composite circular microplate", *J. Vib. Control*, **27**(1-2), 101-118. https://doi.org/10.1177/1077546320923930.

Ghabussi, A., Ashrafi, N., Shavalipour, A., Hosseinpour, A., Habibi, M., Moayedi, H., Babaei, B. and Safarpour, H. (2021), "Free vibration analysis of an electro-elastic GPLRC cylindrical shell surrounded by viscoelastic foundation using modified length-couple stress parameter", *Mech. Based Des. Struct.*, **49**(5), 738-762. https://doi.org/10.1080/15397734.2019.1705166.

Ghazanfari, A., Assempour, A., Habibi, M. and Hashemi, R. (2016), "Investigation on the effective range of the through thickness shear stress on forming limit diagram using a modified Marciniak–Kuczynski model", *Modares Mech. Eng.*, **16**(1), 137-143.

Ghazanfari, A., Soleimani, S.S., Keshavarzzadeh, M., Habibi, M., Assempuor, A. and Hashemi, R. (2020), "Prediction of FLD for sheet metal by considering through-thickness shear stresses", *Mech. Based Des. Struct.*, **48**(6), 755-772. https://doi.org/10.1080/15397734.2019.1662310.

Guo, Y., Mi, H. and Habibi, M. (2021), "Electromechanical energy absorption, resonance frequency, and low-velocity impact analysis of the piezoelectric doubly curved system", *Mech. Syst. Signal Pr.*, **157**, 107723. https://doi.org/10.1016/j.ymssp.2021.107723.

Habibi, M., Hashemi, R., Sadeghi, E., Fazaeli, A., Ghazanfari, A. and Lashini, H. (2016), "Enhancing the mechanical properties and formability of low carbon steel with dual-phase microstructures", *J. Mater. Eng. Perform.*, **25**(2), 382-389. https://doi.org/10.1007/s11665-016-1882-1.

Habibi, M., Ghazanfari, A., Assempour, A., Naghdabadi, R., & Hashemi, R. (2017), "Determination of forming limit diageram using two modified finit element models", *Mech. Eng.*, **48**(4), 141-144.

Habibi, M., Hashemi, R., Ghazanfari, A., Naghdabadi, R. and Assempour, A. (2018a), "Forming limit diagrams by including the M–K model in finite element simulation considering the effect of bending", *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*. **232**(8), 625-636. https://doi.org/10.1177/1464420716642258.

Habibi, M., Hashemi, R., Tafti, M.F. and Assempour, A. (2018b), "Experimental investigation of mechanical properties, formability and forming limit diagrams for tailor-welded blanks produced by friction stir welding", *J. Manuf. Proc.*, **31**, 310-323. https://doi.org/10.1016/j.jmapro.2017.11.009.

Habibi, M., Hashemabadi, D. and Safarpour, H. (2019a), "Vibration analysis of a high-speed rotating GPLRC nanostructure coupled with a piezoelectric actuator", *Eur. Phys. J. Plus*, **134**(6), 307. https://doi.org/10.1140/epjp/i2019-12742-7.

Habibi, M., Mohammadgholiha, M. and Safarpour, H. (2019b), "Wave propagation characteristics of the electrically GNP-reinforced nanocomposite cylindrical shell", *J. Brazil. Soc. Mech. Sci. Eng.*, **41**(5), 221. https://doi.org/10.1007/s40430-019-1715-x.

Habibi, M., Taghdir, A. and Safarpour, H. (2019c), "Stability analysis of an electrically cylindrical nanoshell reinforced with graphene nanoplatelets", *Compos. Part B Eng.*, **175**, 107125. https://doi.org/10.1016/j.compositesb.2019.107125.

Habibi, M., Mohammadi, A., Safarpour, H., Shavalipour, A. and Ghadiri, M. (2019d), "Wave propagation analysis of the laminated cylindrical nanoshell coupled with a piezoelectric actuator", *Mech. Based Des. Struct.*, 1-19. https://doi.org/10.1080/15397734.2019.1697932.

Habibi, M., Safarpour, M. and Safarpour, H. (2020), "Vibrational characteristics of a FG-GPLRC viscoelastic thick annular plate using fourth-order Runge-Kutta and GDQ methods", *Mech. Based Des. Struct.*, 1-22. https://doi.org/10.1080/15397734.2020.1779086.

Habibi, M., Darabi, R., Sa, J.C.D. and Reis, A. (2021a), "An innovation in finite element simulation via crystal plasticity assessment of grain morphology effect on sheet metal formability", *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, **235**(8), 1937-1951. https://doi.org/10.1177/14644207211024686.

Habibi, M., Mohammadi, A., Safarpour, H. and Ghadiri, M. (2021b), "Effect of porosity on buckling and vibrational characteristics of the imperfect GPLRC composite nanoshell", *Mech. Based Des. Struct.*, **49**(6), 811-840. https://doi.org/10.1080/15397734.2019.1701490.

Hashemi, H.R., Alizadeh, A.a., Oyarhossein, M.A., Shavalipour, A., Makkiabadi, M. and Habibi, M. (2019), "Influence of imperfection on amplitude and resonance frequency of a reinforcement compositionally graded nanostructure", *Wave. Random Complex.*, 1-27. https://doi.org/10.1080/17455030.2019.1662968.

He, X., Ding, J., Habibi, M., Safarpour, H. and Safarpour, M. (2021), "Non-polynomial framework for bending responses of the multi-scale hybrid laminated nanocomposite reinforced circular/annular plate", *Thin Wall. Struct.*, **166** 108019. https://doi.org/10.1016/j.tws.2021.108019.

Heirati, A., Zandi, Y., Tafreshi, S.T. and Behruyan, M. (2021), "Analysis of the superplasticizer demand using computer simulation", *Adv. Nano Res.*, **11**(5), 565-579. https://doi.org/10.12989/anr.2021.11.5.565.

Hou, F., Wu, S., Moradi, Z. and Shafiei, N. (2021), "The computational modeling for the static analysis of axially functionally graded micro-cylindrical imperfect beam applying the computer simulation", *Eng. Comput.*, 1-19. https://doi.org/10.1007/s00366-021-01456-x.

Huang, X., Hao, H., Oslub, K., Habibi, M. and Tounsi, A. (2021a), "Dynamic stability/instability simulation of the rotary size-dependent functionally graded microsystem", *Eng. Comput.*, 1-17. https://doi.org/10.1007/s00366-021-01399-3.

Huang, X., Zhang, Y., Moradi, Z. and Shafiei, N. (2021b), "Computer simulation via a couple of homotopy perturbation methods and the generalized differential quadrature method for nonlinear vibration of functionally graded non-uniform micro-tube", *Eng. Comput.*, 1-18. https://doi.org/10.1007/s00366-021-01395-7.

Huang, X., Zhu, Y., Vafaei, P., Moradi, Z. and Davoudi, M. (2021c), "An iterative simulation algorithm for large oscillation of the applicable 2D-electrical system on a complex nonlinear substrate", *Eng. Comput.*, 1-13. https://doi.org/10.1007/s00366-021-01320-y.

Huo, J., Zhang, G., Ghabussi, A. and Habibi, M. (2021), "Bending analysis of FG-GPLRC axisymmetric circular/annular sector plates by considering elastic foundation and horizontal friction force using 3D-poroelasticity theory", *Compos. Struct.*, **276**, 114438. https://doi.org/10.1016/j.compstruct.2021.114438.

Hussain, M., Naeem Muhammad, N., Tounsi, A. and Taj, M. (2019), "Nonlocal effect on the vibration of armchair and zigzag SWCNTs with bending rigidity", *Adv. Nano Res.*, **7**(6), 431-442. https://doi.org/10.12989/anr.2019.7.6.431.

Jang, J.R. (1993), "ANFIS: Adaptive-network-based fuzzy inference system", *IEEE T. Syst. Man Cy.*, **23**(3), 665-685. https://doi.org/10.1109/21.256541.

Jermsittiparsert, K., Ghabussi, A., Forooghi, A., Shavalipour, A., Habibi, M., won Jung, D. and Safa, M. (2020), "Critical voltage, thermal buckling and frequency characteristics of a thermally affected GPL reinforced composite microdisk covered with piezoelectric actuator", *Mech. Based Des. Struct.*, 1-23. https://doi.org/10.1080/15397734.2020.1748052.

Jiang, F., Jiang, Y., Zhi, H., Dong, Y., Li, H., Ma, S., Wang, Y., Dong, Q., Shen, H. and Wang, Y. (2017), "Artificial intelligence in healthcare: Past, present and future", *Stroke Vascul. Neurol.*, **2**(4), 230-243. https://doi.org/10.1136/svn-2017-000101.

Jiao, J., Ghoreishi, S.M., Moradi, Z. and Oslub, K. (2021), "Coupled particle swarm optimization method with genetic algorithm for the static–dynamic performance of the magneto-electro-elastic nanosystem", *Eng. Comput.*, 1-18. https://doi.org/10.1007/s00366-021-01391-x.

Kim, H., Lee, E., Kwon, D. and Ju, H. (2017). "Chemical laboratory safety management service using IoT sensors and open APIs", *Proceedings of the 2017 International Conference on Information and Communications (ICIC)*, Hanoi, Vietnam, June.

Ley, S.V., Fitzpatrick, D.E., Ingham, R.J. and Nikbin, N. (2015), "The internet of chemical things", *Beilstein Mag.*, **1**(2). https://doi.org/10.3762/bmag.2.

Li, B., Dong, Q., Downen, R.S., Tran, N., Jackson, J.H., Pillai, D., Zaghloul, M. and Li, Z. (2019), "A wearable IoT aldehyde sensor for pediatric asthma research and management", *Sensor*

Actuat. B Chem., **287**, 584-594. https://doi.org/10.1016/j.snb.2019.02.077.

Li, J., Tang, F. and Habibi, M. (2020a), "Bi-directional thermal buckling and resonance frequency characteristics of a GNP-reinforced composite nanostructure", *Eng. Comput.*, 1-22. https://doi.org/10.1007/s00366-020-01110-y.

Li, Y., Li, S., Guo, K., Fang, X. and Habibi, M. (2020b), "On the modeling of bending responses of graphene-reinforced higher order annular plate via two-dimensional continuum mechanics approach", *Eng. Comput.*, 1-22. https://doi.org/10.1007/s00366-020-01166-w.

Liu, Z., Su, S., Xi, D. and Habibi, M. (2020a), "Vibrational responses of a MHC viscoelastic thick annular plate in thermal environment using GDQ method", *Mech. Based Des. Struct.*, 1-26. https://doi.org/10.1080/15397734.2020.1784201.

Liu, Z., Wu, X., Yu, M. and Habibi, M. (2020b), "Large-amplitude dynamical behavior of multilayer graphene platelets reinforced nanocomposite annular plate under thermo-mechanical loadings", *Mech. Based Des. Struct.*, 1-25. https://doi.org/10.1080/15397734.2020.1815544.

Liu, H., Shen, S., Oslub, K., Habibi, M. and Safarpour, H. (2021a), "Amplitude motion and frequency simulation of a composite viscoelastic microsystem within modified couple stress elasticity", *Eng. Comput.*, 1-15. https://doi.org/10.1007/s00366-021-01316-8.

Liu, H., Zhao, Y., Pishbin, M., Habibi, M., Bashir, M.O. and Issakhov, A. (2021b), "A comprehensive mathematical simulation of the composite size-dependent rotary 3D microsystem via two-dimensional generalized differential quadrature method", *Eng. Comput.*, 1-16. https://doi.org/10.1007/s00366-021-01419-2.

Liu, Y., Wang, W., He, T., Moradi, Z. and Larco Benítez, M.A. (2021c), "On the modelling of the vibration behaviors via discrete singular convolution method for a high-order sector annular system", *Eng. Comput.*, 1-23. https://doi.org/10.1007/s00366-021-01454-z.

Lori, E.S., Ebrahimi, F., Supeni, E.E.B., Habibi, M. and Safarpour, H. (2020), "Frequency characteristics of a GPL-reinforced composite microdisk coupled with a piezoelectric layer", *Eur. Phys. J. Plus*, **135**(2), 144. https://doi.org/10.1140/epjp/s13360-020-00217-x.

Lu, T. and Neng, W. (2010). "Future internet: The Internet of Things", *Proceedings of the 2010 3rd International Conference on Advanced Computer Theory and Engineering(ICACTE)*, Chengdu, China, August.

Ma, L., Liu, X. and Moradi, Z. (2021), "On the chaotic behavior of graphene-reinforced annular systems under harmonic excitation", *Eng. Comput.*, 1-25. https://doi.org/10.1007/s00366-020-01210-9.

Massoumi, F., Taheri, M., Mohammadi, A. and Amelirad, O. (2018), "Evaluation of the effect of buccolingual and apicocoronal positions of dental implants on stress and strain in alveolar bone by finite element analysis", *J. Dentistry*, **15**(1), 10.

Matouk, H., Bousahla Abdelmoumen, A., Heireche, H., Bourada, F., Bedia, E.A.A., Tounsi, A., Mahmoud, S.R., Tounsi, A. and Benrahou, K.H. (2020), "Investigation on hygro-thermal vibration of P-FG and symmetric S-FG nanobeam using integral Timoshenko beam theory", *Adv. Nano Res.*, **8**(4), 293-305. https://doi.org/10.12989/anr.2020.8.4.293.

Moayedi, H., Habibi, M., Safarpour, H., Safarpour, M. and Foong, L.K. (2019), "Buckling and frequency responses of a graphene nanoplatelet reinforced composite microdisk", *Int. J. Appl. Mech.*, **11**(10), 1950102. https://doi.org/10.1142/S1758825119501023.

Moayedi, H., Aliakbarlou, H., Jebeli, M., Noormohammadiarani, O., Habibi, M., Safarpour, H. and Foong, L.K. (2020a), "Thermal buckling responses of a graphene reinforced composite micropanel structure", *Int. J. Appl. Mech.*, **12**(1), 2050010. https://doi.org/10.1142/S1758825120500106.

Moayedi, H., Darabi, R., Ghabussi, A., Habibi, M. and Foong, L.K. (2020b), "Weld orientation effects on the formability of tailor welded thin steel sheets", *Thin Wall. Struct.*, **149**, 106669. https://doi.org/10.1016/j.tws.2020.106669.

Moayedi, H., Ebrahimi, F., Habibi, M., Safarpour, H. and Foong, L.K. (2021), "Application of nonlocal strain–stress gradient theory and GDQEM for thermo-vibration responses of a laminated composite nanoshell", *Eng. Comput.*, **37**(4), 3359-3374. https://doi.org/10.1007/s00366-020-01002-1.

Mohammadgholiha, M., Shokrgozar, A., Habibi, M. and Safarpour, H. (2019), "Buckling and frequency analysis of the nonlocal strain–stress gradient shell reinforced with graphene nanoplatelets", *J. Vib. Control*, **25**(19-20), 2627-2640. https://doi.org/10.1177/1077546319863251.

Mohammadi, A., Lashini, H., Habibi, M. and Safarpour, H. (2019), "Influence of viscoelastic foundation on dynamic behaviour of the double walled cylindrical inhomogeneous micro shell using MCST and with the aid of GDQM", *J. Solid Mech.*, **11**(2), 440-453. https://doi.org/10.22034/jsm.2019.665264.

Moradi, Z., Davoudi, M., Ebrahimi, F. and Ehyaei, A.F. (2021), "Intelligent wave dispersion control of an inhomogeneous micro-shell using a proportional-derivative smart controller", *Wave. Random Complex.*, 1-24. https://doi.org/10.1080/17455030.2021.1926572.

Najaafi, N., Jamali, M., Habibi, M., Sadeghi, S., Jung, D.w. and Nabipour, N. (2021), "Dynamic instability responses of the substructure living biological cells in the cytoplasm environment using stress-strain size-dependent theory", *J. Biomol. Struct. Dyn.*, **39**(7), 2543-2554. https://doi.org/10.1080/07391102.2020.1751297.

Narayana, P.L., Lingamdinne, L.P., Karri, R.R., Devanesan, S., AlSalhi, M.S., Reddy, N.S., Chang, Y.Y. and Koduru, J.R. (2022), "Predictive capability evaluation and optimization of Pb(II) removal by reduced graphene oxide-based inverse spinel nickel ferrite nanocomposite", *Environ. Res*, **204**, 112029. https://doi.org/10.1016/j.envres.2021.112029.

Nascimento, C.A.O., Giudici, R. and Guardani, R. (2000), "Neural network based approach for optimization of industrial chemical processes", *Comput. Chem. Eng.*, **24**(9), 2303-2314. https://doi.org/10.1016/S0098-1354(00)00587-1.

Orak, M. and Sajedi, F. (2021), "Investigating the effect of using three pozzolans separately and in combination on the properties of self-compacting concrete", *Adv. Nano Res.*, **11**(2), 141-155. https://doi.org/10.12989/anr.2021.11.2.141.

Oyarhossein, M.A., Alizadeh, A.A., Habibi, M., Makkiabadi, M., Daman, M., Safarpour, H. and Jung, D.W. (2020), "Dynamic response of the nonlocal strain-stress gradient in laminated polymer composites microtubes", *Sci. Rep.*, **10**(1), 5616. https://doi.org/10.1038/s41598-020-61855-w.

Pourjabari, A., Hajilak, Z.E., Mohammadi, A., Habibi, M. and Safarpour, H. (2019), "Effect of Porosity on free and forced vibration characteristics of the GPL reinforcement composite nanostructures", *Comput. Math. Appl.*, **77**(10), 2608-2626. https://doi.org/10.1016/j.camwa.2018.12.041.

Prabhu, G.R.D., Witek, H.A. and Urban, P.L. (2019), "Telechemistry: Monitoring chemical reactions via the cloud using the Particle Photon Wi-Fi module", *React. Chem. Eng.*, **4**(9), 1616-1622. https://doi.org/10.1039/C9RE00043G.

Prabhu, G.R.D., Yang, T.H., Hsu, C.Y., Shih, C.P., Chang, C.M., Liao, P.H., Ni, H.T. and Urban, P.L. (2020), "Facilitating chemical and biochemical experiments with electronic micro-controllers and single-board computers", *Nature Protocols*, **15**(3), 925-990. https://doi.org/10.1038/s41596-019-0272-1.

Qiuping, W., Shunbing, Z. and Chunquan, D. (2011), "Study on key technologies of internet of things perceiving mine", *Procedia Eng.*, **26**, 2326-2333. https://doi.org/10.1016/j.proeng.2011.11.2442.

Raghupathi, V. and Raghupathi, W. (2017), "Preventive healthcare: A neural network analysis of behavioral habits and chronic diseases", *Healthcare*, **5**(1), 8. https://doi.org/10.3390/healthcare5010008.

Safaei, B., Khoda, F.H. and Fattahi, A. (2019), "Non-classical plate model for single-layered graphene sheet for axial buckling", *Adv. Nano Res.*, **7**(4), 265-275. https://doi.org/10.12989/anr.2019.7.4.265.

Safarpour, H., Ali Ghanizadeh, S. and Habibi, M. (2018), "Wave propagation characteristics of a cylindrical laminated composite nanoshell in thermal environment based on the nonlocal strain gradient theory", *Eur. Phys. J. Plus*, **133**(12), 532. https://doi.org/10.1140/epjp/i2018-12385-2.

Safarpour, H., Esmailpoor Hajilak, Z. and Habibi, M. (2019a), "A size-dependent exact theory for thermal buckling, free and forced vibration analysis of temperature dependent FG multilayer GPLRC composite nanostructures restring on elastic foundation", *Int. J. Mech.Mater. Des.*, **15**(3), 569-583. https://doi.org/10.1007/s10999-018-9431-8.

Safarpour, H., Pourghader, J. and Habibi, M. (2019b), "Influence of spring-mass systems on frequency behavior and critical voltage of a high-speed rotating cantilever cylindrical three-dimensional shell coupled with piezoelectric actuator", *J. Vib. Control*, **25**(9), 1543-1557. https://doi.org/10.1177/1077546319828465.

Safarpour, M., Ghabussi, A., Ebrahimi, F., Habibi, M. and Safarpour, H. (2020), "Frequency characteristics of FG-GPLRC viscoelastic thick annular plate with the aid of GDQM", *Thin Wall. Struct.*, **150**, 106683. https://doi.org/10.1016/j.tws.2020.106683.

Safarpour, M., Ebrahimi, F., Habibi, M. and Safarpour, H. (2021), "On the nonlinear dynamics of a multi-scale hybrid nano-composite disk", *Eng. Comput.*, **37**(3), 2369-2388. https://doi.org/10.1007/s00366-020-00949-5.

Shao, Y., Zhao, Y., Gao, J. and Habibi, M. (2021), "Energy absorption of the strengthened viscoelastic multi-curved composite panel under friction force", *Arch. Civil Mech. Eng.*, **21**(4), 141. https://doi.org/10.1007/s43452-021-00279-3.

Shariati, A., Ghabussi, A., Habibi, M., Safarpour, H., Safarpour, M., Tounsi, A. and Safa, M. (2020a), "Extremely large oscillation and nonlinear frequency of a multi-scale hybrid disk resting on nonlinear elastic foundation", *Thin Wall. Struct.*, **154** 106840. https://doi.org/10.1016/j.tws.2020.106840.

Shariati, A., Jung, D.W., Mohammad-Sedighi, H., Żur, K.K., Habibi, M. and Safa, M. (2020b), "On the vibrations and stability of moving viscoelastic axially functionally graded nanobeams", *Materials*, **13**(7), 1707. https://doi.org/10.3390/ma13071707.

Shariati, A., Jung, D.W., Mohammad-Sedighi, H., Żur, K.K., Habibi, M. and Safa, M. (2020c), "Stability and dynamics of viscoelastic moving rayleigh beams with an asymmetrical distribution of material parameters", *Symmetry*. **12**(4), 586. https://doi.org/10.3390/sym12040586.

Shariati, A., Habibi, M., Tounsi, A., Safarpour, H. and Safa, M. (2021), "Application of exact continuum size-dependent theory for stability and frequency analysis of a curved cantilevered microtubule by considering viscoelastic properties", *Eng. Comput.*, **37**(4), 3629-3648. https://doi.org/10.1007/s00366-020-01024-9.

Shi, X., Li, J. and Habibi, M. (2020), "On the statics and dynamics of an electro-thermo-mechanically porous GPLRC nanoshell conveying fluid flow", *Mech. Based Des. Struct.*, 1-37. https://doi.org/10.1080/15397734.2020.1772088.

Shokrgozar, A., Safarpour, H. and Habibi, M. (2019), "Influence of system parameters on buckling and frequency analysis of a spinning cantilever cylindrical 3D shell coupled with piezoelectric actuator", *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, **234**(2), 512-529. https://doi.org/10.1177/0954406219883312.

Shokrgozar, A., Ghabussi, A., Ebrahimi, F., Habibi, M. and Safarpour, H. (2020), "Viscoelastic dynamics and static responses of a graphene nanoplatelets-reinforced composite cylindrical microshell", *Mech. Based Des. Struct.*, 1-28. https://doi.org/10.1080/15397734.2020.1719509.

Takagi, T. and Sugeno, M. (1985), "Fuzzy identification of systems and its applications to modeling and control", *IEEE T. Syst. Man Cy.*, **SMC-15**(1), 116-132. https://doi.org/10.1109/TSMC.1985.6313399.

Tzounis, A., Katsoulas, N., Bartzanas, T. and Kittas, C. (2017), "Internet of Things in agriculture, recent advances and future challenges", *Biosyst. Eng.*, **164**, 31-48. https://doi.org/10.1016/j.biosystemseng.2017.09.007.

Vijayakumar, N. and Ramya, R. (2015). "The real time monitoring of water quality in IoT environment", *Proceedings of the 2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS)*, Coimbatore, India, March.

Wang, Z., Yu, S., Xiao, Z. and Habibi, M. (2020), "Frequency and buckling responses of a high-speed rotating fiber metal laminated cantilevered microdisk", *Mech. Adv. Mater. Struct.*, 1-14. https://doi.org/10.1080/15376494.2020.1824284.

Wen, F., He, T., Liu, H., Chen, H.Y., Zhang, T. and Lee, C. (2020), "Advances in chemical sensing technology for enabling the next-generation self-sustainable integrated wearable system in the IoT era", *Nano Energy*, **78**, 105155. https://doi.org/10.1016/j.nanoen.2020.105155.

Xu, L.D., He, W. and Li, S. (2014), "Internet of Things in industries: A Survey", *IEEE T. Ind. Inform.*, **10**(4), 2233-2243. https://doi.org/10.1109/TII.2014.2300753.

Xu, W., Pan, G., Moradi, Z. and Shafiei, N. (2021), "Nonlinear forced vibration analysis of functionally graded non-uniform cylindrical microbeams applying the semi-analytical solution", *Compos. Struct.*, **275**, 114395. https://doi.org/10.1016/j.compstruct.2021.114395.

Yanzhen, Q., Zandi, Y., Rahimi, A., Pourkhorshidi, S., Roco-Videla, A., Khadimallah, M.A., Jameel, M., Kasehchi, E. and Assilzadeh, H. (2021), "Nano-SiO_2 for efficiency of geotechnical properties of fine soils in mining and civil engineering", *Adv. Nano Res.*, **11**(3), 301-312. https://doi.org/10.12989/anr.2021.11.3.301.

Yegnanarayana, B. (2009), *Artificial neural networks*, PHI Learning Pvt. Ltd.

Yin, Y., Zeng, Y., Chen, X. and Fan, Y. (2016), "The internet of things in healthcare: An overview", *J. Ind. Inform. Integration*, **1**, 3-13. https://doi.org/10.1016/j.jii.2016.03.004.

Yu, X., Maalla, A. and Moradi, Z. (2022), "Electroelastic high-order computational continuum strategy for critical voltage and frequency of piezoelectric NEMS via modified multi-physical couple stress theory", *Mech. Syst. Signal Pr.*, **165**, 108373. https://doi.org/10.1016/j.ymssp.2021.108373.

Zare, R., Najaafi, N., Habibi, M., Ebrahimi, F. and Safarpour, H. (2020), "Influence of imperfection on the smart control frequency characteristics of a cylindrical sensor-actuator GPLRC cylindrical shell using a proportional-derivative smart controller", *Smart Struct. Syst.*, **26**(4), 469-480. https://doi.org/10.12989/sss.2020.26.4.469.

Zhang, L., Chen, Z., Habibi, M., Ghabussi, A. and Alyousef, R. (2021a), "Low-velocity impact, resonance, and frequency responses of FG-GPLRC viscoelastic doubly curved panel", *Compos. Struct.*, **269**, 114000.

https://doi.org/10.1016/j.compstruct.2021.114000.
Zhang, X., Shamsodin, M., Wang, H., NoormohammadiArani, O., Khan, A.M., Habibi, M. and Al-Furjan, M.S.H. (2021b), "Dynamic information of the time-dependent tobullian biomolecular structure using a high-accuracy size-dependent theory", *J. Biomol, Struct, Dyn.*, **39**(9), 3128-3143. https://doi.org/10.1080/07391102.2020.1760939.
Zhang, Y., Wang, Z., Tazeddinova, D., Ebrahimi, F., Habibi, M. and Safarpour, H. (2021c), "Enhancing active vibration control performances in a smart rotary sandwich thick nanostructure conveying viscous fluid flow by a PD controller", *Wave. Random Complex.*, 1-24. https://doi.org/10.1080/17455030.2021.1948627.
Zhao, Y., Moradi, Z., Davoudi, M. and Zhuang, J. (2021), "Bending and stress responses of the hybrid axisymmetric system via state-space method and 3D-elasticity theory", *Eng. Comput.*, 1-23. https://doi.org/10.1007/s00366-020-01242-1.
Zhou, C., Zhao, Y., Zhang, J., Fang, Y. and Habibi, M. (2020), "Vibrational characteristics of multi-phase nanocomposite reinforced circular/annular system", *Adv. Nano Res.*, **9**(4), 295-307. https://doi.org/10.12989/anr.2020.9.4.295.

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