SSRG International Journal of Mechanical Engineering
ISSN: 2348 – 8360 /doi:10.14445/23488360/IJME-V8I6P102

Volume 8 Issue 6, 4-8, June, 2021

Artificial Neural Network Analysis For Domestic Refrigerator With Hydrocarbon Refrigerant Mixtures

D.V. Raghunatha Reddy [#1], P. Bhramara [2], K. Govindarajulu [3]

[1]*Department of Mechanical Engineering, Research Scholar JNTUA Ananathapur, 5150 02, India*
[2] *JNTUH College of Engineering Hyderabad, 500072, India*
[3]*JNTUA College of Engineering Ananthapur, 515002, Andhra Pradesh, India,*

Received Date: 05 May 2021
Revised Date: 08 June 2021
Accepted Date: 15 June 2021

Abstract:
This study deals with the usage of Artificial Neural Network (ANN) modeling to predict the domestic refrigerator performances such as refrigeration affects power consumption and the coefficient of performance with hydrocarbon refrigerant mixtures (H.C.M.). Experimental work has conducted to obtain the data to train and test the models. The back-propagation algorithms used as a learning algorithm of ANN in the multilayered feedforward networks. Based on the design of experiments, Taguchi's L25 orthogonal array are used by varying Mass of refrigerant (Mf) length of the capillary tube (Lc) Evaporating temperature(Te) and condenser temperature(Tc) were used as input parameters. To develop ANN model has checked for adequacy and significance to systems performance. Finally, the results of the ANN model were compared and analyzed with experimental values. It is shown that while ANN model was good approaches were deficient in predicting desired output parameters, more accurate results were obtained with experimental results.

Keywords: *H.C.M., Lc, Mf, Artificial Neural Network, Domestic Refrigeration System, Power consumption, and Coefficient of performance.*

I. INTRODUCTION

At present, the domestic refrigeration system works with an R134a as a refrigerant; it has excellent thermal properties. However, the global warming potential (GWP)1300 is very high. This high GWP and ODP create emission to damage the ozone layer; it is considered a significant cause of ozone layer depletion. From this context, the H.C.Ms are considered a refrigerant in the domestic refrigeration system. Because the H.C.Ms are natural and eco-friendly refrigerants. Research has proved that the hydrocarbon mixtures Sare used in a refrigerant domestic refrigeration system has a promising potential for competing with the R134a refrigerant. Compared with the R134a domestic refrigeration system, H.C.M.s used the refrigeration system to benefit from saving power consumption and increasing the refrigeration effect.

However, only a few studies were observed to obtain the optimum ratio and mass fraction of Hydro Carbon (H.C.) refrigerants used for the system's better and safe performance. According to the Kyoto Protocol, they aimed to protect the environment from ODP and GWP substances. Based on the above subject, the investigation concentrated was to find an alternative for R134a refrigerant for a domestic application.T. Tasi [1] has been started before to find an alternative to R134a, and similar work was reviewed by many authors [2–3]. Reddy et al. and R. Radermacher [4-5] present the effect of capillary tube length on a domestic system with a change in evaporator temperature.

II. LITERATURE REVIEW

Somachi Wongwises et al. [6] have carried out an experimental study with H.C. refrigerants, viz., R290, R600, and R600a, along with R134a. The baseline test was conducted with a 239L domestic refrigerator's capacity at an ambient temperature of 250C with R134a. Experimental outcomes presented the R290/R600(60/40 wt %) gives the best suitable substitute refrigerant compared to R134a. They had reported that the use of the above combination of Hydrocarbon Refrigerant mixture was saved the energy consumption around 8.6% less when compared to R134a. The refrigerant charge of the H.C. Refrigerant mixture system was found to be around 50% of that of the R134a system (120g) and reported that there was no need to change the refrigeration system set up to accommodate H.C. refrigerants. Mani et al. [7]. have conducted a trial work on the VCR system and demonstrated that the refrigerant mixture R290/R600a (68/32 wt %) is a 19.9% to 50.1% higher refrigerating effect than R12 and 28.6% to 87.2% higher than R134a for a 190L capacity of a local fridge at 270c. At a higher dissipating temperature of R12, refrigerant expanded somewhat more vitality than R134a. Mohanraj et al. [8] have conducted experimental work on hydrocarbon refrigerant mixture of R290&R600a (45.2/54.8 wt%) to substitute for R134a in a 200L capacity domestic refrigerator. M.Y. Lee et al. [9] have conducted experimentally on the refrigerator with R290/R600a (55/45wt %). The refrigerant charge optimized is nearly 50% of that of the R134a. Reddy et al.[10] the refrigerator's performance was enhanced by optimizing the capillary tube length with a different mass and evaporator temperatures for a small capacity refrigeration system. Fatouh et al. [11] have conducted experimental work on hydrocarbon blends as a substitute to R134a in local fridges through a reproduction investigation. The execution parameters are blower control, Refrigeration impact, and C.O.P. The results show that the mass hydrocarbon mixtures are half lesser than R134a and the ternary mixture gives the substitute for R134a. Ching-Song Jwo et al. [12] has suggested an alternative for R134a with a zoetropic blend of 50%R290/50%R600a. The analyses were done on a 440L household cooler with 150g of R134a refrigerant. The aggregate devoured vitality spared to 4.4%, and the mass of refrigerant is lesser than by 40%. Reddy et al.[13] have proposed Hydrocarbon refrigerants, mainly propane, butane, and isobutene mixtures as environment-friendly refrigerants. Rasti et al. [14] have proposed (R290/R600a) (54/46 wt %) mixture to substitute for R134a for a domestic refrigerator. The results show the energy consumption of R436A and R600a is the lower power consumption by 14% and 7% than R134a.C.C Yu and T.P Teng [15] had recommended the blended mass proportions of the H.C. refrigerants, R290 and R600a,(65/35% wt%). The results showed that the HC1 gives the best-optimized values compared to R134a. Deepak Paliwal and S.P.S.Rajput [16] had proposed retrofitting the framework with various blend proportions of unadulterated hydrocarbons; R290 and R600a in the 200L limit of the local refrigeration framework by rolling out specific improvements in the condenser and capillary tube length of 3.5M length and 0.036 inches was considered. The result gives the 80g blend of R600a/R290 (60/40 wt %). Colbourne et al. [17] revealed that the R600a/R290 (60/40 by wt %) blend is considered a substitute for HFC134a. It is also discovered that with the expansion of the fine's length in the framework, the hydrocarbon blend gives better outcomes. According to the Kalogirou [18] and Pacheco-Vega et al., ANN was applied to the energy systems [19]. To create a model for a domestic refrigeration system to find an optimum heat transfer coefficient. Bechtler et al. [20] had developed an ANN technique for the heat pump to predict the system with altered refrigerants. Arcaklioglu [21] has applied an ANN to analyze the irreversibility factor and C.O.P. of a system. Islamoglu [22] developed an ANN model for a domestic refrigerator to optimize its quantity flow rate and inlet temperature. Ertunc and Hosoz [23] have created a model to optimize the VCRS with an evaporative condenser by different operating conditions. Sozen et al. and Reddy et al. [24-25] have investigated using to estimate the faulty conditions of VCRs. Furthermore, the ANN used to predict the variables and related to investigational parameters.

Che Wan Mohd Noor et al. [26] had investigated on marine diesel; this study deals with an artificial neural network (ANN) modeling for a marine diesel engine performance prediction such as the brake power (B.P.), brake specific fuel consumption (BSFC), brake thermal efficiency (B.T.E.), volumetric efficiency (V.E.), exhaust gas temperature (E.G.T.) and nitrogen oxide (N.O.X.) emissions. Input data for network training were gathered from laboratory engine testing operated at various speeds, loads, and fuel blends. ANN prediction model was developed based on standard back-propagation with the Levenberg-Marquardt training algorithm. The model's performance was validated by comparing the prediction datasets with the experimental data and the mathematical model's output. Results showed that the ANN model provided an excellent agreement to the experimental data with the coefficient of determinations (R^2) of 0.99. The mean absolute prediction error (MAPE) of ANN and the mathematical model is between 1.57-9.32% and 4.06-28.35%. Based on the results that the developed ANN model is more reliable and accurate than the mathematical model.

Abhijit Sarkar et al. [27**]** had conducted experiments on welding technology and determining the quality of welding, particularly in high heat input processes. This research paper presents the development of multiple regression analysis (M.R.A.) and artificial neural network (ANN) models to predict weld bead geometry and H.A.Z. Width in the submerged arc welding process. The experiment design of experiments based on Taguchi's L16 orthogonal array by varying wire feed rate, transverse speed, and stick-out to develop a multiple regression model has been checked for adequacy and significance. Finally, the results of the two prediction models were compared and analyzed. It was found that the error related to the prediction of bead geometry and H.A.Z. Width is smaller in ANN than M.R.A.

Erdi Tosun et al. [28] have conducted on diesel engine with the usage of linear regression (L.R.) and artificial neural network(ANN) modeling to predict engine performance; torque, and exhaust emissions; and carbon monoxide, oxides of nitrogen (C.O., NOx) of a naturally aspirated diesel engine fueled with standard diesel, peanut biodiesel (P.M.E.) and biodiesel-alcohol (E.M.E., M.M.E., P.M.E.) mixtures. Experimental work was conducted to obtain data to train and test the models. The back-propagation algorithm was used as a learning algorithm of ANN in the multilayered feedforward networks. Engine speed (rpm)and fuel properties, cetane number (C.N.), lower heating value (L.H.V.), and density (q) were used as input parameters in order to predict performance and emission parameters. Based on the results, the linear regression modeling approach was deficient in predicting desired parameters; more accurate results were obtained using ANN.

Faezehossadat et al. [29] had developed a concrete material model to find compressive strength employing cores cut from hardened concrete acknowledged as the most common method. However, it is challenging to predict the compressive strength of concrete since it is affected by many factors such as different mix designs, methods of mixing, curing conditions, compaction, etc. In this paper, considering the experimental results, three different models of multiple linear regression model (M.L.R.), artificial neural network (ANN), and adaptive neuro-fuzzy inference system (ANFIS) are established, trained, and tested within the Mat lab programming environment for predicting the 28 days compressive strength of concrete with 173different mix designs. Finally, these three models are compared with each other and resulted in the fact that ANN and ANFIS models enable us to reliably evaluate the compressive strength of concrete with different mix designs. However, multiple linear regression model is not feasible in this area because of the nonlinear relationship between the concrete mix parameters. Finally, the sensitivity analysis (S.A.) for two different sets of parameters on the concrete compressive strength prediction was carried out.

Muammer Nalbant et al. [30] Surface roughness, an indicator of surface quality, is one of the most specified customer requirements in machining parts. In this study, the experimental results corresponding to the effects of different insert nose radii of cutting tools (0.4, 0.8, 1.2 mm), various depth of cuts (0.75, 1.25, 1.75, 2.25, 2.75 mm), and different feed rates (100, 130, 160, 190, 220 mm/min) on the surface quality of the AISI 1030 steel workpieces have been investigated using multiple regression analysis and artificial neural networks (ANN). Regression analysis and neural network-based models to predict surface roughness were compared for various cutting conditions in turning. The data set obtained from the surface roughness measurements was employed to and tested the neural network model. The trained neural network models were used in predicting surface roughness for cutting conditions. A comparison of neural network models with the regression model was carried out. The coefficient of determination was 0.98 in the multiple regression model. The scaled conjugate gradient (S.C.G.) model with 9 neurons in the hidden layer has produced an absolute fraction of variance (R2) values of 0.999 for the training data and 0.998 for the test data. The RMSE values are 0.00058 and 0.0033, respectively, and the mean error values are 2.42% and 2.71%, respectively. The predictive neural network model showed better predictions than various regression models for surface roughness.

Based on the above research review, the present research focuses on developing ANN technique recommended to optimize the refrigeration system with H.C.M.s. The system works under steady-state conditions. The ANN model can be formed with experimental data to predict output parameters as RE, P.C.and C.O.P. finally compared with experimental values.

Table 1.Thermodynamic Properties of various alternative mixtures

Refrigerant Description	Configuration by mass	ODP	GWP (100years)
R134a	Pure fluid	0	1300
R600a	Pure fluid	0	20
R290	Pure fluid	0	20
HCM1 R290/R600a)	(44/56)	0	<20
HCM2 R290/R600a)	(50/50)	0	<20
HCM3 R290/R600a)	(54/46)	0	<20
HCM4 (R290/R600a)	(64/36)	0	<20
HCM5 (R290/R600a)	(74/26)	0	<20

III. MATERIALS AND METHODS

The experiments were performed on a 175L household fridge utilizing R134a as a working liquid. Fig.2 represents the refrigeration system; first, the designed lengths of hair-like tubes are settled with a channel with brazing assistance. All the tubes were kept a constant diameter of 0.78 mm and different lengths of 4M, 4.5M, 5M, 5.5M & 6M. R134a is utilized as a base refrigerant, and later the examinations are performed by changing the Hydrocarbon refrigerant mixtures' mass fractions. Domanski&Didion [18] outcomes presented the hydrocarbon refrigerant mixtures improved C.O.P. than that of R134a. The performance factor, such as the C.O.P. of the system, is high compared to hydrocarbon refrigerant mixtures.

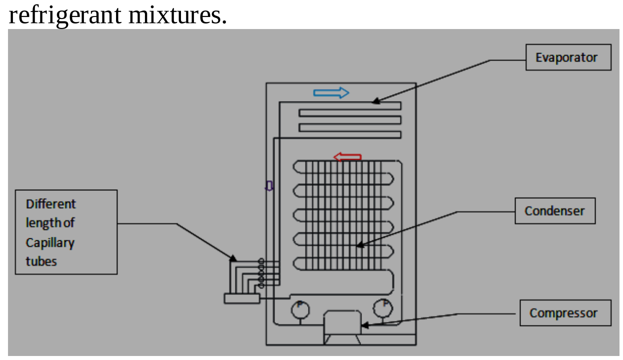

Fig. 1: **Experimental Test Rig**

Table 2 Technical specifications of the domestic refrigerator test rig

S.No.	Description	Range
1	Storage Volume	175L
2	Current rating	1.1 amp max
3	Voltage	220-240V
4	Frequency	50Hz
5	No. of. doors	1
6	Refrigerant type	R134a
7	Defrost System	Auto defrost
8	Refrigerant charged	180g

A. Experimental Procedure

Experiments were performed as per ISO 8187 [19].In this experiment, the hydrocarbon refrigerant blends were utilized, and P.O.E. as lubricant oil. The number of mixed hydrocarbon refrigerants was measured with an electronic weighing machine with an accuracy is ±0.01g. According to the technique, the evaluations was performed with pure R134a and Hydrocarbon refrigerant Mixtures (R290/R600a) with (HCM1 44/56, HCM2 50/50, HCM3 54/46, HCM4 64/36, and HCM5 74/26 by %) At first, the experiments start with base refrigerants such as R134a and the selected hydrocarbon refrigerant mixtures such as (HCM1 44/56, HCM2 50/50, HCM3 54/46, HCM4 64/36 and HCM5 74/26 by %) are worked at a constant ambient temperature of 29^{0C}. While experimenting, the same lubricating oil was used for both R134a and Hydrocarbon refrigerant mixtures. The output parameter was evaluated as C.O.P. of the system at different evaporator temperatures, refrigerant mass, and different capillary tubes.

IV. PERFORMANCE PREDICTION USING NEURAL NETWORK

In this analysis, different evaporator temperatures, the refrigerant mass, and capillary tube lengths are considered the input parameters. The three-layer neural network having three input parameters, a hidden layer with six neurons and a single output layer, as shown in Fig.1. The error in ANN calculation lies in the range of 0–5%, which found the reasonableness of the neural network. It is illustrious that while the COP rises with the increase in Mf, whereas Le rise gradual at a specific limit then reduced in the domestic refrigeration system.

V. RESULTS AND DISCUSSIONS

The outcomes initiated from the investigations conducted on the domestic refrigeration system, the performance evaluation, and simulation with the neural network were summarized in this chapter.

A. Prediction of C.O.P. by using ANN for R134a and H.C.M.

The expected standards from ANN are equated with the investigation values. The justification is founded on the investigational values of C.O.P. for R134a and Hydrocarbon refrigerants. The details are shown in Fig 3 and Fig.4. Based on the errorInvestigation, the ANN procedure provides the most satisfactory outcomes when equated to investigational values.

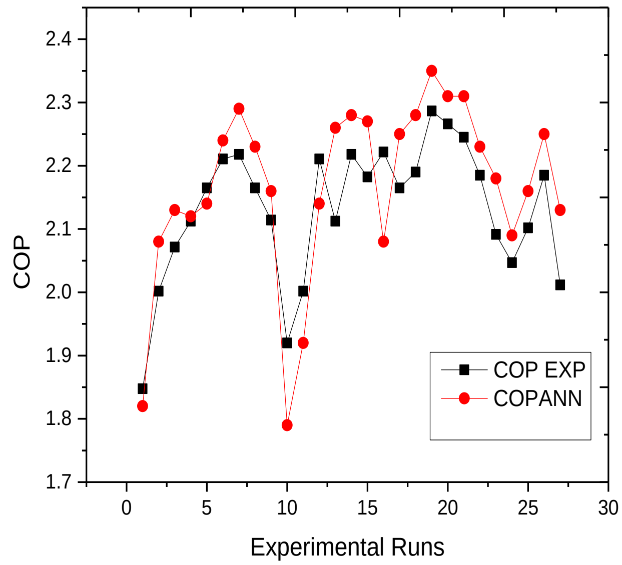

Fig.2: Comparison of test data, ANN Values of C.O.P. for R134a

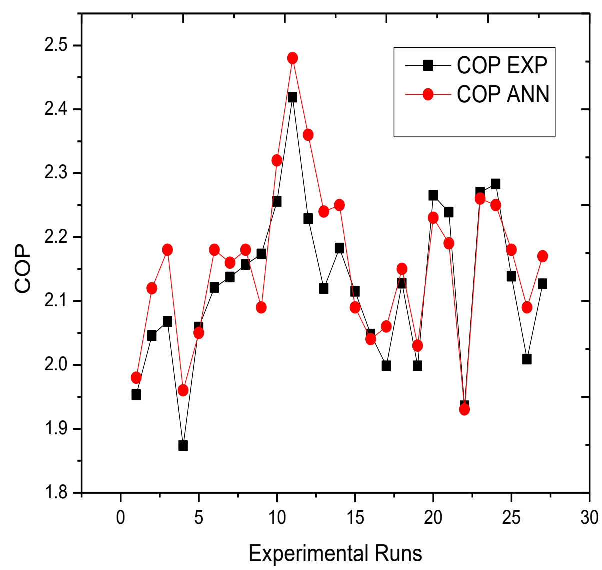

Fig.3: Comparison of test data, ANN Values of C.O.P. for Hydrocarbon Refrigerant Mixtures

VI. CONCLUSION

Theoretical approaches are typically complex since they are massive essential data with engineering effort and may assume incorrect outcomes. To avoid such mistakes and difficulties to suggest the method. The performance and optimizations mainly on the adjustable mass of refrigerant, changes in the capillary tube, and Evaporator Temperature. The output value C.O.P. is expected with the ANNusing a back-propagation algorithm.

The following conclusion is determined based on the theoretical and analytical methods.

a. Hydrocarbon refrigerants were successfully used for a domestic refrigeration system with varying capillary tube length and different mass ratios with different evaporator temperature conditions.
b. C.O.P. of a domestic refrigeration system mainly depends on process constraints are largely impelling the input factors. It can be determined that, amongst all the elements, Mf is the most significant important as an increasing system's performance.
c. ANN is effectively useful in this analysis to forecast and simulate the system's C.O.P. under several test circumstances inside and outside the investigational field. The expected investigational parameter of COP demonstration respectable covenant confirms the extraordinary ability of a well-trained ANN for these categories of developments.

REFERENCES

[1] T. Tasi, 2005 An overview of environmental hazards and exposure and explosive risk of hydrofluorocarbon HFCs, Chemosphere 61, 1539–1547.
[2] E. Johnson, Global warming from HFC, 1998 Environ. Impact Assessment Rev. 18, 485–492.
[3] P. Ashford, D. Clodic, A. McCulloch, L. Kuijpers, 2004 Emission profiles from the foam and refrigeration sectors comparison with atmospheric concentrations, Part 2: Results and discussion, Int. J. of Refrig. 27, 701– 716.
[4] Reddy, DVR., Bhramara, P., &Govindarajulu, K., 2012 Performance, and Optimization of Capillary Tube Length In a Split Type Air Conditioning System, International Journal of Engineering Research &Technology (IJERT), 1 (7), 1-11.
[5] R. Radermacher, K. Kim, 1996 Domestic refrigerators: recent developments, Int. J. Refrig. 19, 61–69.
[6] SomchaiWongwises and Nares Chimres 2005 “Experimental study of hydrocarbon mixtures to replace HFC-134a in a domestic refrigerator”, Energy Conversion and Management, Energy Conversion and Management, Vol.46, pp. 85-100.
[7] Mani K and Selladurai V, 200, Experimental analysis of new refrigerant mixture as a drop-in replacement for CFC12 and HFC134a. International Journal of Thermal Science, Vol.47, pp.1490-500.
[8] M. Mohanraj., S. Jayaraj., C. Muraleedharanand P. Chandrasekar 2009, Experimental investigation of R290/R600a mixture as an alternative to R134a in a domestic refrigerator, International Journal of Thermal Sciences, Vol.48, pp.1036-1042.
[9] M.Y. Lee., D.Y. Lee and Y. Kim, 2008 “Performance characteristics of a small-capacity direct cool refrigerator using R290/R600a (55/45)”, International Journal of Refrigeration, Vol.31, pp.734-741.
[10] Reddy DVR, Bhramara P, and Govindarajulu K. 2018, Experimental evaluation of the effect of refrigerant charge and capillary tube length on the performance of household refrigerator with different configurations of R290 and R600a. Mater Today: Proc.5: 11845–11852.
[11] M. Fatouh and M Kafary 2006 Assessment of propane/commercial butane mixtures as possible alternatives to R134a in domestic refrigerators, Energy Conservation and Management, 47, 2644-2658.
[12] Ching-Song Jwo., Chen-ChingTing, and Wei-Ru Wang, 2009 Efficiency analysis of home refrigerators by replacing hydrocarbon refrigerants," Measurement, 42, 697-70.
[13] Reddy DVR, P. Bhramara, K. Govindarajulu, 2016 , Hydrocarbon refrigerant mixtures as an alternative to R134a in the domestic refrigeration system: the state-of-the-art review, Int. J. Scientific Eng. Res. 7 (6) 87–93 (2016).
[14] Mehdi Rasti, Aghamiriand Mohammad Sadegh, 2013, Energy efficiency enhancement of a Domestic refrigerator using R436A and R600a as alternative refrigerants to R134a, International Journal of Thermal Sciences, 74, 86-94.
[15] Chao-Chieh Yu & Tun-Ping Ting, 2014, Retrofit assessment of refrigerator using hydrocarbon refrigerants, Applied Thermal Engineering, 6, 507-518.
[16] Deepak Paliwal and S.P.S.Rajput 2015, Experimental Analysis of Hydrocarbon Mixtures as the new Refrigerant In Domestic Refrigeration System, International Journal of Scientific & Engineering Research, 6, 623-627.
[17] D. Colbourne, T.J. Ritter, 2000 Compatibility of non-metallic materials with hydrocarbon refrigerants and lubricant mixtures, I.I.F.–I.I.R. Commission B1, B2, E1 and E2, Purdue University, U.S.A.
[18] Kalogirou SA. 200 Application of artificial neural-networks for energy systems. Appl Energy ;67: 17–35.
[19] Pacheco-Vega A, Sen M, Yang KT, McClain RL. 2014 Neural network analysis of fin-tube refrigerating heat exchanger with limited experimental data. Int J Heat Mass Transfer ;44: 763–770.
[20] Bechtler H, Browne MW, Bansal PK, Kecman V. Neural networks a new approach to model vapor-compression heat pumps. Int J Energy Res 2001; 25:591–599.
[21] Arcaklioglu E. 2004 Performance comparison of C.F.C.s with their substitutes using artificial neural networks. Int J Energy Res ;28: 1113–25.
[22] Islamoglu Y. 2005 Performance prediction for non-adiabatic capillary tube suction-line heat exchanger: an artificial neural network approach. Energy Convers Manage ; 46: 223–32.
[23] Ertunc HM, Hosoz M. 2008 Artificial neural network analysis of a refrigeration system with an evaporative condenser. Appl Therm Eng, in press.
[24] Adnan Sozen, ErolArcaklio glu, Ali Erisen, and M. Ali Akcayol, 2003 Performance prediction of a vapor-compression heat-pump, Elsevier,
[25] Reddy DVR, P. Bhramara, K. Govindarajulu, 2020 A Comparative Study of Multiple Regression and Artificial Neural Network models for a domestic refrigeration system with a hydrocarbon refrigerant mixtures, Materials today proceedings No. 22P4, Feb- 2020, 1545-1553
[26] Che Wan Mohd Noor, RizalmanMamat and Ali Najah Ahmed , 2018, Comparative Study Of Artificial Neural Network and Mathematical Model On Marine Diesel Engine Performance Prediction, International Journal of Innovative Computing, Information and Control, 14(3) 959-969
[27] Abhijit Sarkar, Prasenjit Dey, R N Rai And Subhas Chandra Saha, 2016 A comparative study of multiple regression analysis and back propagation neural network approaches on plain carbon steel in submerged-arc welding, Indian Academy of Sciences, 41 (5) 549–559
[28] Erdi Tosun, KadirAydin , Mehmet Bilgili, 2016, Comparison of linear regression and artificial neural network model of a diesel engine fueled with biodiesel-alcohol mixtures, Alexandria Engineering Journal, 55, 3081–3089
[29] Faezehossadat KHADEMI , Mahmoud AKBARI, Sayed Mohammadmehdi JAMAL, Mehdi NIKOO, 2017, Multiple linear regression, artificial neural network, and fuzzy logic prediction of 28 days compressive strength of concrete, Springer Verlag Berlin Heidelberg, 1-10
[30] MuammerNalbant, HasanGokkaya, Thsan Toktas¸ 2007, Comparison of Regression and Artificial Neural Network Models for Surface Roughness Prediction with the Cutting Parameters in CNC Turning, Hindawi Publishing Corporation Modeling and Simulation in Engineering, 1-14