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Implementation of Backpropagation Neural Network for Prediction Magnetocaloric Effect of Manganite

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Abstract - In the field of magnetic cooling technology, there is still much to learn about the magnetocaloric properties of magnetic cooling materials. Research into magnetocaloric manganites exhibiting a significant maximum magnetic entropy change in the vicinity of ambient temperature yields encouraging outcomes for the advancement of magnetic refrigeration apparatus. Through a combination of chemical substitutions, changes in the amount of oxygen present, and different synthesis techniques, these manganites undergo lattice distortions that result in pseudocubic, orthorhombic, and rhombohedral structures instead of perovskite cubic structures. The present investigation used backpropagation neural networks (BPNNs) to investigate the correlations among maximum magnetic entropy change (MMEC), Curie temperature, lanthanum manganite compositions, lattice properties, and dopant ionic radii. Simbrain 3.07 was used to execute the BPNN model, and the suggested model accuracy was examined using coefficient determination. As a result, the model's predicted values for the mean absolute error, root mean square, and coefficient correlation for MMEC are 0.012, 0.022, and 0.9861, respectively. The model predicts that the Curie temperature mean absolute error, root mean square, and coefficient correlation will be 0.015, 0.021, and 0.9947, respectively.

Keywords: backpropagation neural network, simbrain, manganites, magnetocaloric effect, curie temperature.

I. INTRODUCTION

The use of refrigeration has become a very common occurrence in modern society. Until now, the use of compressed refrigerant materials is still the main choice in cooling applications. The use of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are refrigerant materials that are not environmentally friendly. One solution is a magnetic refrigerant that can be used as an alternative to replace refrigerant materials that are pollutants and, in its use, does not require the use of compressors. Moreover, the magnitude of cooling efficiency by magnetic refrigerant (MR) has a higher value compared to conventional refrigerants. This efficiency is visible even on a small scale, making it possible to make small, portable refrigeration devices that can use a battery power supply. The use of MR materials does not produce releases that harm the environment, so this technology can be said to be environmentally friendly. MR materials have been applied in various industries and commercial refrigeration such as air conditioning, heat exchangers, waste separation, and others [1]. Research that focuses on exploring extraordinary characteristics such as colossal magnetoresistance (CMR) and magnetocaloric effect (MCE) in the ferromagnetic-paramagnetic phase transition temperature range is still a trending topic in the field of condensed matter. MCE characteristics are intrinsic properties of a magnetic material that can be utilized as a magnetic refrigerant. MR materials that are currently widely recognized are gadolinium and its alloys. Gadolinium and its alloys have magnetocaloric characteristics at room temperature but have the disadvantage that they are expensive and require a magnetic field of more than 5 T to operate, making them uneconomical [2]. Another alloy that has magnetocaloric characteristics at room temperature is lanthanum manganite. Manganite alloys, in general, have a formula that can be written as $R_{(1-x)}M_xMnO_3$, where R is a rare earth metal ion, and M is an alkaline earth divalent ion. The magnetocaloric material must have a Curie temperature of close to room temperature (Tc) and demonstrate a significant magnetic entropy change (ΔSm) over considerable temperature fluctuations in order to be fabricated into an operable magnetic refrigerator at room temperature. Manganite alloys have been researched for various applications such as magnetic refrigerants [3], catalysts [4], sensor applications [5], solid oxide fuel cell electrodes [6], hydrogen storage [7], solar cells [8] and biomedical [9]. Ferromagnetic lanthanum manganite with significant MCEs and useful Tc values has garnered a lot of interest among candidates for magnetocaloric materials.

The Back Propagation Network is one Artificial Neural Network model that is used for solving problems [10]. This model is employed because it can typically identify the necessary pattern and predict when the facts or phenomena will recur before they do. Although the architecture of the backpropagation network can theoretically have multiple hidden layers depending on system needs, it only has one hidden layer. On the other hand, the number of input patterns and the number of output patterns dictate how many vertices are connected to the input layer and the output layer. Finding the right weighting value is the goal of training a neural network. Many researchers have applied the concept of backpropagation from ANN in a material characteristic application, such as [11] and [12] have applied the backpropagation algorithm to predict the mechanical performance of the material.

Experiments, mostly by varying synthesis methods (solid-state reaction, wet chemistry, and sol-gel), morphologies (particle size and shape), crystalline states, and final forms (powder, pellet, and film), have been used to examine the effect of dopant types and levels on the maximum magnetic entropy change (MMEC) of lanthanum manganites [13, 14]. Analysis has been done on manganites with a wide working temperature range and a large MCE around Tc [15–18]. The present study examines the statistical relationships between MMEC, Curie temperature, compositions of lanthanum manganites, lattice characteristics, and ionic radii of dopants. Since there are certain descriptive features present, the model generalizes well enough for intelligent algorithms to pick up on the patterns and recognize them. These effectively aid in the prediction of MMEC and Curie temperature at low cost, and they may further our understanding of it through the use of lattice parameters, ionic radii, and compositions. To find bulk manganites with promising MMEC and Tc, one can use this model as a reference. The model ought to be employed in machine learning to facilitate comprehension of magnetic phase transitions in various forms of doped manganite.

II. METHOD

This research uses inputs of as many as 15 variables, with a total of 49 data used as training data and test data. The processing group was varied into 1, 2 and 3 hidden layers with a total number of 45 nucleons. The first processing group is with one hidden layer that consists of 45 nucleons (P1). The second variation for the processing group is two hidden layers with the formation of 15 nucleons and 30 nucleons (P2). The last variation uses three hidden layers, with each hidden layer consisting of 15 nucleons (P3). The BPNN was done in Simbrain 3.07, with the architecture illustration for P3 that has one hidden layer given in Fig. 1.

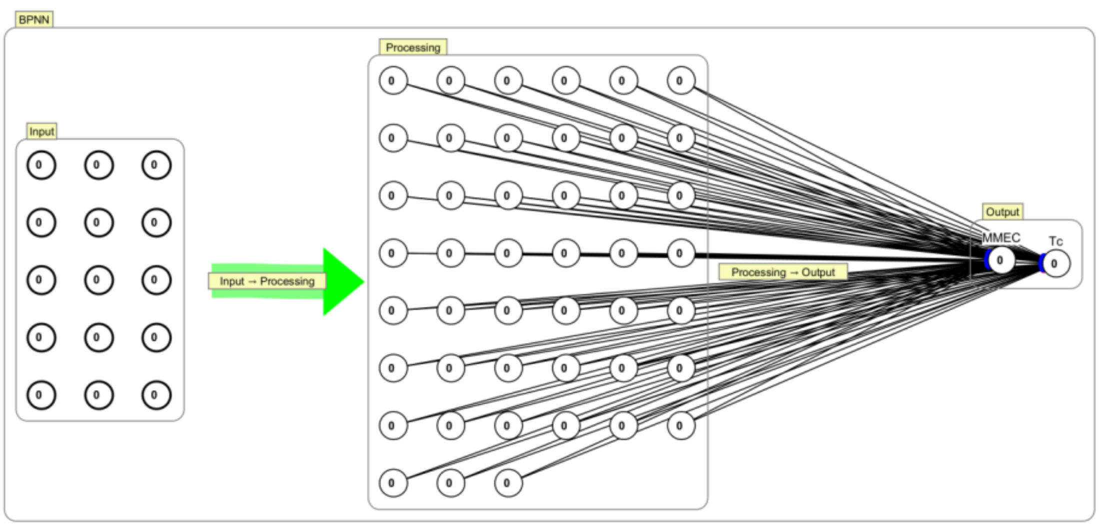


Fig. 1. Backpropagation neural network architecture (P3) for predicting manganite magnetocaloric effect and Curie temperature.

The learning rate parameter used is 0.25, with a momentum of 0.9. The activation function used is binary sigmoidal. The activation function is a logistic function, and it can be differentiable with an output will vary around 0 to 1. The predicted outputs are two variables, namely maximum magnetic entropy change (MMEC) and Curie temperature (Tc). The data used for training and testing is given in Table I. Data for 15 variables were taken from the references listed respectively.

TABEL I

EXPERIMENTAL DATA FOR MAXIMUM MAGNETIC ENTROPY CHANGE AND CURIE TEMPERATURE OF MANGANITE

No	Manganites	a	b	c	Major Lanthanide		Minor Lanthanide		Divalent		Monovalent		Transition metal or others		Additional		Experimental		References
					r	at	r	at	r	at	r	at	r	at	r	at	MMEC	Tc	
		(Å)	(Å)	(Å)	(pm)		(pm)		(pm)		(pm)		(pm)		(pm)		J/(Kg.K)	(K)	
1.	$(La_{0.56}Ce_{0.14})Sr_{0.3}MnO_3$	5.5037	5.5037	13.3452	112.6	0.56	119.6	0.14	131.0	0.30	0	0	0	0	0	0	4.78	357	[19]
2.	$La_{0.57}Nd_{0.1}Sr_{0.33}Mn_{0.95}Sn_{0.05}O_3$	5.4951	5.4951	13.3520	112.6	0.57	116.3	0.10	131.0	0.33	0	0	69.0	0.050	0	0	2.80	282	[20]
3.	$La_{0.57}Nd_{0.1}Sr_{0.33}Mn_{0.9}Sn_{0.1}O_3$	5.5394	5.5394	13.4236	112.6	0.57	116.3	0.10	131.0	0.33	0	0	69.0	0.100	0	0	3.22	224	[19]
4.	$La_{0.5}Sm_{0.2}Sr_{0.3}Mn_{0.8}Fe_{0.15}O_3$	5.5038	7.7388	5.4746	112.6	0.50	113.2	0.20	131.0	0.30	0	0	64.5	0.150	0	0	0.77	94	[21]
5.	$La_{0.5}Sm_{0.2}Sr_{0.3}Mn_{0.95}Fe_{0.05}O_3$	5.5036	7.7252	5.4678	112.6	0.50	113.2	0.20	131.0	0.30	0	0	64.5	0.050	0	0	2.93	253	[19]
6.	$La_{0.5}Sm_{0.2}Sr_{0.3}Mn_{0.9}Fe_{0.1}O_3$	5.5027	7.7403	5.4740	112.6	0.50	113.2	0.20	131.0	0.30	0	0	64.5	0.100	0	0	2.22	136	[22]
7.	$La_{0.5}Sm_{0.2}Sr_{0.3}MnO_3$	5.5019	7.7321	5.4696	112.6	0.50	113.2	0.20	131.0	0.30	0	0	0	0	0	0	3.06	278	[23]
8.	$La_{0.67}Ba_{0.33}Mn_{0.98}Ti_{0.02}O_3$	3.9119	3.9119	3.9119	112.6	0.67	0	0	147.0	0.33	0	0	60.5	0.020	0	0	3.24	314	[24]
9.	$La_{0.67}Ba_{0.33}MnO_3$	3.9075	3.9075	3.9075	112.6	0.67	0	0	147.0	0.33	0	0	0	0	0	0	1.48	350	[25]
10.	$La_{0.67}Ca_{0.33}Mn_{0.75}Cr_{0.25}O_3$	5.4419	7.6921	5.4608	112.6	0.67	0	0	118.0	0.33	0	0	61.5	0.250	0	0	2.20	189	[26]
11.	$La_{0.67}Ca_{0.33}Mn_{0.98}Ni0.02O_3$	5.4545	5.4545	13.3922	112.6	0.67	0	0	118.0	0.33	0	0	60.0	0.020	0	0	8.00	244	[20]
12.	$La_{0.67}Ca_{0.33}Mn_{0.9}Cr_{0.1}O_3$	5.4486	7.7000	5.4673	112.6	0.67	0	0	118.0	0.33	0	0	61.5	0.100	0	0	3.50	215	[27],[28]
13.	$La_{0.67}Sr_{0.33}MnO_3$	5.4879	5.4879	13.3622	112.6	0.67	0	0	131.0	0.33	0	0	0	0	0	0	5.15	375	[22]
14.	$La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{0.7}Ni_{0.3}O_3$	5.4813	7.6853	5.4519	112.6	0.60	117.9	0.10	147.0	0.30	0	0	60.0	0.300	0	0	0.65	131	[29]
15.	$La_{0.6}Pr_{0.1}Ba_{0.3}Mn_{0.9}Ni_{0.1}O_3$	5.5032	7.7200	5.4690	112.6	0.60	117.9	0.10	147.0	0.30	0	0	60.0	0.100	0	0	1.31	162	[30]
16.	$La_{0.6}Pr_{0.1}Ba_{0.3}MnO_3$	5.5121	7.7508	5.4859	112.6	0.60	117.9	0.10	147.0	0.30	0	0	0	0	0	0	1.97	215	[31],[29]
17.	$La_{0.7}Ba_{0.3}MnO_3$	3.9084	3.9084	3.9084	112.6	0.70	0	0	147.0	0.30	0	0	0	0	0	0	2.70	335	[32],[30]
18.	$La_{0.7}Pb_{0.3}Mn_{0.8}Ru_{0.2}O_3$	5.5365	5.5365	13.4237	112.6	0.70	0	0	135.0	0.30	0	0	56.5	0.200	0	0	3.06	335	[31],[23]
19.	$La_{0.7}Pb_{0.3}Mn_{0.9}Ru_{0.1}O_3$	5.5372	5.5372	13.4117	112.6	0.70	0	0	135.0	0.30	0	0	56.5	0.100	0	0	3.15	313	[29]
20.	$La_{0.7}Pb_{0.3}MnO_3$	5.5176	5.5176	13.4116	112.6	0.70	0	0	135.0	0.30	0	0	0	0	0	0	3.17	336	[20]
21.	$La_{0.7}Sr_{0.25}Na_{0.05}Mn_{0.8}Ti_{0.2}O_3$	5.5312	5.5312	13.4161	112.6	0.70	0	0	131.0	0.25	124.0	0.05	60.5	0.200	0	0	2.03	125	[33]
22.	$La_{0.7}Sr_{0.25}Na_{0.05}Mn_{0.9}Ti_{0.1}O_3$	5.5271	5.5271	13.4021	112.6	0.70	0	0	131.0	0.25	124.0	0.05	60.5	0.100	0	0	2.38	155	[23]
23.	$La_{0.7}Sr_{0.25}Na_{0.05}MnO_3$	5.5062	5.5062	13.3602	112.6	0.70	0	0	131.0	0.25	124.0	0.05	0	0	0	0	4.34	363	[29]
24.	$La_{0.7}Sr_{0.3}Mn_{0.9}Ti_{0.1}O_3$	5.5256	5.5256	13.3899	112.6	0.70	0	0	131.0	0.30	0	0	60.5	0.100	0	0	2.94	210	[34]
25.	$La_{0.7}Sr_{0.3}MnO_3$	5.4932	5.4932	13.3657	112.6	0.70	0	0	131.0	0.30	0	0	0	0	0	0	2.30	370	[20]
26.	$La_{0.7}Sr_{0.3}MnO_3$	5.4883	5.4883	12.3275	112.6	0.70	0	0	131.0	0.30	0	0	0	0	0	0	3.43	370	[35]
27.	$Nd_{0.67}Ba_{0.33}Mn_{0.98}Fe_{0.02}O_3$	5.4917	7.7602	5.5196	116.3	0.67	0	0	147.0	0.33	0	0	64.5	0.020	0	0	2.97	131	[29]
28.	$Nd_{0.67}Ba_{0.33}MnO_3$	5.4915	7.7591	5.5519	116.3	0.67	0	0	147.0	0.33	0	0	0	0	0	0	3.91	150	[25]
29.	$Pr_{0.3}Sm_{0.25}Sr_{0.45}MnO_3$	5.4623	5.4387	7.6779	117.9	0.30	113.2	0.25	131.0	0.45	0	0	0	0	0	0	4.92	225	[36]
30.	$Pr_{0.4}Sm_{0.15}Sr_{0.45}MnO_3$	5.4718	5.4399	7.6773	117.9	0.40	113.2	0.15	131.0	0.45	0	0	0	0	0	0	3.98	261	[35]
31.	$Pr_{0.6}La_{0.2}Sr_{0.2}MnO_3$	5.4937	5.4634	7.7656	117.9	0.60	112.6	0.20	131.0	0.20	0	0	0	0	0	0	2.17	150	[35]
32.	$Pr_{0.6}Sr_{0.3}Ca_{0.1}Mn_{0.025}Fe_{0.075}O_3$	5.4427	5.4669	7.6919	117.9	0.60	0	0	131.0	0.30	0	0	64.5	0.075	118.0	0.10	3.12	112	[25]
33.	$Pr_{0.7}Ca_{0.3}Mn_{0.08}Co_{0.02}O_3$	5.4303	7.6729	5.4599	117.9	0.70	0	0	118.0	0.30	0	0	54.0	0.020	0	0	2.18	106	[32],[30]
34.	$Pr_{0.7}Ca_{0.3}Mn_{0.95}Co_{0.05}O_3$	5.4299	7.6696	5.4572	117.9	0.70	0	0	118.0	0.30	0	0	54.0	0.050	0	0	2.96	105	[21]
35.	$Pr_{0.7}Ca_{0.3}Mn_{0.95}Co_{0.05}O_3$	5.4314	7.6711	5.4591	117.9	0.70	0	0	118.0	0.30	0	0	54.0	0.050	0	0	3.10	105	[37]
36.	$Pr_{0.7}Ca_{0.3}Mn_{0.95}Cr_{0.05}O_3$	5.4300	7.6679	5.4572	117.9	0.70	0	0	118.0	0.30	0	0	61.5	0.050	0	0	2.76	140	[37]
37.	$Pr_{0.7}Ca_{0.3}Mn_{0.95}Cr_{0.05}O_3$	5.4300	7.6679	5.4572	117.9	0.70	0	0	118.0	0.30	0	0	61.5	0.050	0	0	2.92	140	[38]
38.	$Pr_{0.7}Ca_{0.3}Mn_{0.95}Fe_{0.05}O_3$	5.4321	7.6743	5.4648	117.9	0.70	0	0	118.0	0.30	0	0	64.5	0.050	0	0	2.39	90	[26]
39.	$Pr_{0.7}Ca_{0.3}Mn_{0.95}Ni_{0.05}O_3$	5.4295	7.6708	5.4508	117.9	0.70	0	0	118.0	0.30	0	0	60.0	0.050	0	0	3.10	110	[24]
40.	$Pr_{0.7}Ca_{0.3}Mn_{0.9}Co_{0.1}O_3$	5.4306	7.6705	5.4484	117.9	0.70	0	0	118.0	0.30	0	0	54.0	0.100	0	0	3.20	116	[34]
41.	$Pr_{0.7}Ca_{0.3}Mn_{0.9}Cr_{0.1}O_3$	5.4293	7.6691	5.4552	117.9	0.70	0	0	118.0	0.30	0	0	61.5	0.100	0	0	2.81	150	[39]
42.	$Pr_{0.7}Ca_{0.3}Mn_{0.9}Fe_{0.1}O_3$	5.4319	7.6753	5.4646	117.9	0.70	0	0	118.0	0.30	0	0	64.5	0.100	0	0	2.10	80	[40],[24]
43.	$Pr_{0.7}Ca_{0.3}Mn_{0.9}Ni_{0.1}O_3$	5.4328	7.6892	5.4195	117.9	0.70	0	0	118.0	0.30	0	0	60.0	0.100	0	0	2.94	118	[22]
44.	$Pr_{0.8}K_{0.15}Na_{0.05}MnO_3$	5.5641	5.4661	7.7374	117.9	0.80	0	0	0	0	155.0	0.15	0	0	124.0	0.05	3.31	134	[41]
45.	$Pr_{0.8}Na_{0.2}MnO_3$	5.4460	5.4481	7.7113	117.9	0.80	0	0	0	0	124.0	0.20	0	0	0	0	3.40	92	[39]
46.	$Pr_{0.8}Na_{0.2}MnO_3$	5.4483	5.4359	7.6855	117.9	0.80	0	0	0	0	124.0	0.20	0	0	0	0	5.35	92	[42]
47.	$Pr_{0.8}Sr_{0.2}MnO_3$	5.4893	5.4795	7.7413	117.9	0.80	0	0	131.0	0.20	0	0	0	0	0	0	3.54	150	[43],[37]
48.	$Pr_{0.8}Sr_{0.2}MnO_3$	5.4711	7.7333	5.4858	117.9	0.80	0	0	131.0	0.20	0	0	0	0	0	0	4.09	150	[39]
49.	$Sm_{0.45}Pr_{0.1}Sr_{0.45}MnO_3$	5.4427	5.4415	7.6800	113.2	0.45	117.9	0.10	131.0	0.45	0	0	0	0	0	0	7.14	132	[44]

The training was stopped when the iterations reached 10000. The performance of BPNN is evaluated by mean absolute error (MAE), root mean square error (RMSE) and correlation coefficient (CC) given by the following equations [45],

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|x_i^{exp} - x_i^{pred}\right| \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i^{exp} - x_i^{pred}\right)^2} \quad (2)$$

$$CC = \frac{\sum_{i=1}^{n}\left(x_i^{exp} - \overline{x^{exp}}\right)\left(x_i^{pred} - \overline{x^{pred}}\right)}{\sqrt{\sum_{i=1}^{n}\left(x_i^{exp} - \overline{x^{exp}}\right)^2 \sum_{i=1}^{n}\left(x_i^{pred} - \overline{x^{pred}}\right)^2}} \quad (3)$$

whereas n is the total number of data, x_i^{exp} is the i-th experimental data for MMEC and Tc, and its average value is $\overline{x^{exp}}$. The i-th predicted value for MMEC and Tc is denoted by x_i^{pred}, and its average value is $\overline{x^{pred}}$. The interpretation for the correlation coefficient given in Tabel II [46].

TABLE II

INTERPRETATION FOR CORRELATION COEFFICIENT

Correlation coefficient	Interpretation
0.9 – 1	Very high
0.7 – 0.899	High
0.4 – 0.699	Enough
0.2 – 0.399	Low
< 0.2	Very low

III. RESULT AND DISCUSSION

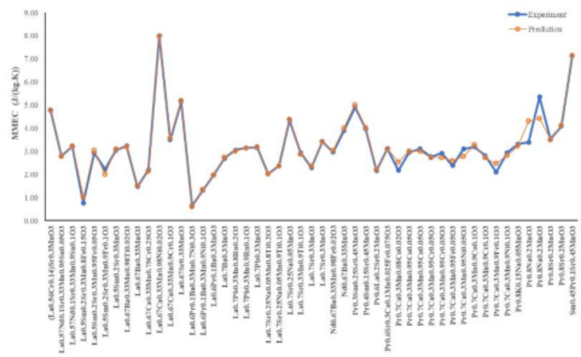
A set of 49 data is given to each BPNN processing group in the form of inputs that consist of 15 variables and outputs as many as two variables. The training process was carried out as high as 10,000 iterations, and the amount of RMSE for the training data was given in Table III. The sensitivity of BPNN for the predicted values at different hidden layers in the processing group is given in Table III as well.

TABLE III

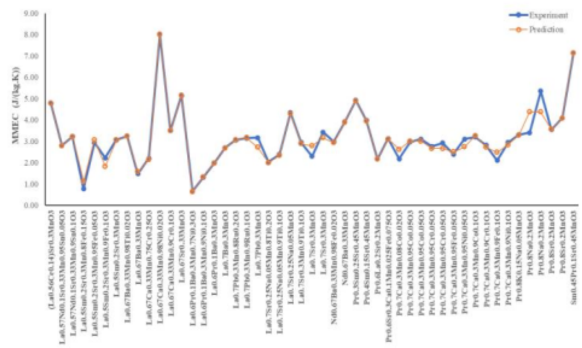
SENSITIVITIES OF BACKPROPAGATION NEURAL NETWORK

Code	Hidden layer nucleon formation	Training MSE at 10,000 iterations	Prediction					
			CC		MAE		RMSE	
			MMEC	Tc	MMEC	Tc	MMEC	Tc
P1	45	0.0005	0.9861	0.9947	0.012	0.015	0.022	0.021
P2	15-30	0.0006	0.9807	0.9945	0.014	0.010	0.026	0.020
P3	15-15-15	0.0006	0.9818	0.9942	0.012	0.010	0.025	0.020

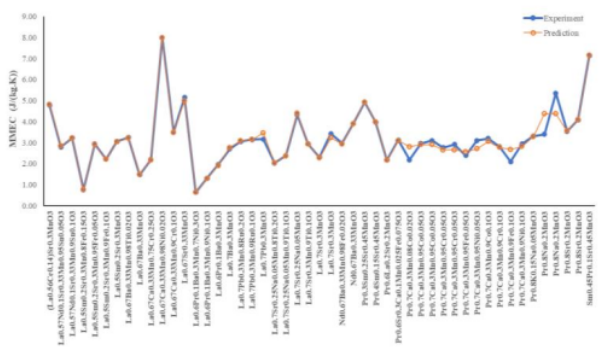
The formation of the hidden layer affects the sensitivity of the BPNN so that the value obtained from the prediction is closer to the experimental data. In P1, the correlation coefficient values for MMEC and Tc are the best compared to P2 and P3. However, all of the correlation coefficients for P1, P2 and P3 show an interpretation in the very high category. The predicted values of Tc in P2 and P3 for MAE and RMSE values are slightly lower than those of P1. For more details, the comparison of predicted values with experimental data is described in Fig. 2 to Fig. 5. The very high correlation coefficient between the predicted and experimental data MMEC and Tc, the low prediction root mean square error and mean absolute error, and stable model performance suggest the usefulness of BPNN modeling and understanding the relationship between among the input and output variables [47].



(a)



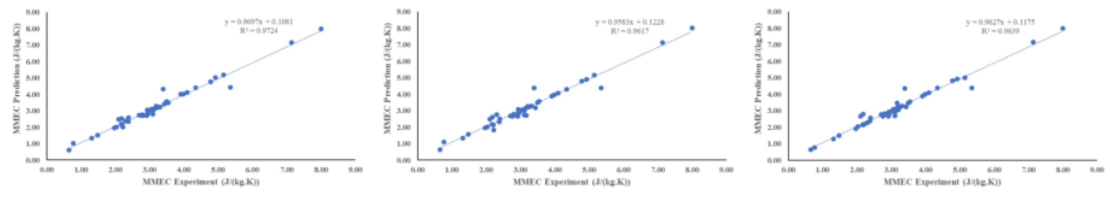
(b)



(c)

Fig. 2. Maximum magnetic entropy change for manganite, comparison prediction to experimental value (a) P1, (b) P2 and (c) P3.

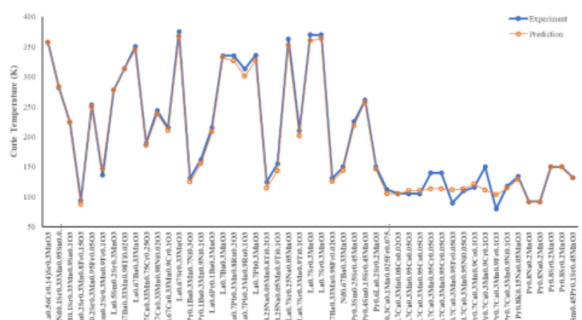
A comparison of the MMEC predicted values with the experimental data is given in Figure 2. It can be seen that the predicted values are close to the experimental data. Significant differences are seen at two points, which are both $Pr_{0.8}Na_{0.2}MnO_3$ manganite for all processing groups, although one predicted value is lower and the other higher compared to the experimental data. Another difference is for $Pr_{0.7}Ca_{0.3}Mn_{0.08}Co_{0.05}O_3$ manganite that, the prediction value showed became less far from the experimental data. Differences can also be seen for $La_{0.7}Pb_{0.3}MnO_3$ manganite that in P1, the prediction value is near to experimental data. For P2, the prediction value is below the experimental data and for P3, the prediction value is above its experimental data.



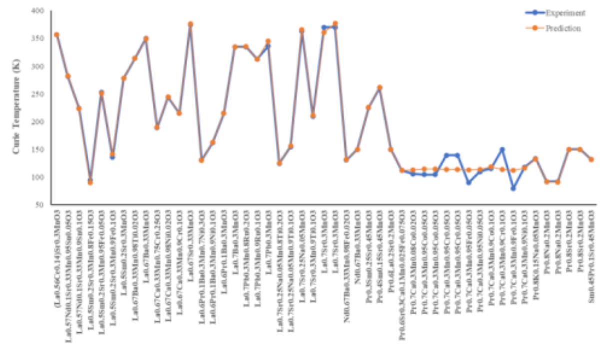
(a) (b) (c)

Fig. 3. Linearity correlation of predicted ~~and experimental~~ values for maximum magnetic entropy change (a) P1, (b) P2 and (c) P3.

More details of the relationship between predicted values and experimental data of MMEC on manganite can be described through the linearity of the correlation. It can be seen that the data distribution is around the trendline with a good coefficient of determination (R^2) of 0.9724 for P1, 0.9617 for P2 and 0.9639 for P3. The value of the correlation coefficient (CC) for MMEC is given in Table III. For manganite, which has a large difference, it can be seen that the data points move away from the trendline.



(a)



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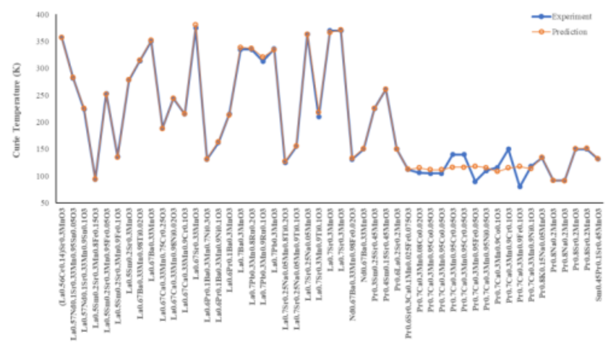
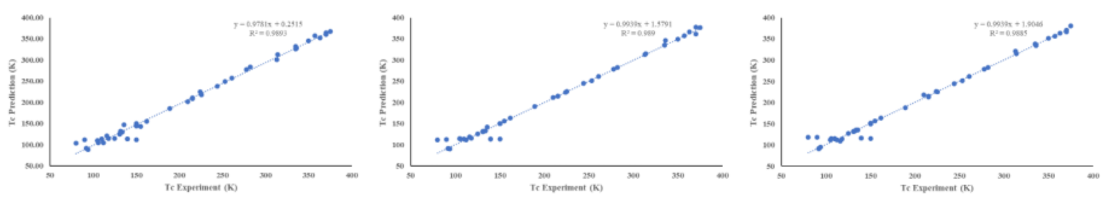


(c)

Fig. 4. Curie temperature for manganite comparison prediction to experimental value (a) P1, (b) P2 and (c) P3.

Curie temperature predictions for each manganite are given in Figure 4. It can be seen that significant differences between predictions and experiments occur in five types of manganites for P1. Two data for the same type of manganite, namely $Pr_{0.7}Ca_{0.3}Mn_{0.95}Cr_{0.05}O_3$, then $Pr_{0.7}Ca_{0.3}Mn_{0.9}Cr_{0.1}O_3$, which are the three types of manganites, the predicted value is lower than the experimental data. Meanwhile, the manganite types $Pr_{0.7}Ca_{0.3}Mn_{0.95}Fe_{0.05}O_3$ and $Pr_{0.7}Ca_{0.3}Mn_{0.9}Fe_{0.1}O_3$ have higher predicted values than their experimental data. The prediction becomes better for Currie temperature, as seen for P2 and P3.



(a) (b) (c)

Fig. 5. Linear correlation of predicted and experimental values for curie temperature (a) P1, (b) P2 and (c) P3.

The linearity of the predicted value and experimental data of Curie temperature is given in Figure 5. The straight trendline has a good coefficient of determination (R^2) of 0.9893 for P1, 0.9890 for P2 and 0.9885 for P3. Thus, the correlation coefficient (CC) is given in Table III. There are clearly visible data points from manganite with large differences in predicted value and experimental data. The data points for the manganite that have relatively large value differences move away from the straight trendline.

Of the three processing models seen to be able to show good accuracy to predict the value of MMEC and Tc. This model can be used to generalize the preparation of manganite so as to obtain a material that has the desired maximum magnetic entropy change and Curie temperature. Thus, it will minimize the cost of developing manganite magnetic materials.

IV. CONCLUSION

From this study, it was found that BPNN can be used in the determination of MMEC and Tc characteristics of manganite. The BPNN is very effective in making predictions, but in the analysis, it is strongly influenced by the accuracy of parameter determination. Using 15 variables consisting of lattice parameters and manganite alloy composition has provided excellent predictions of MMEC and Tc values. However, there are several types of manganites whose predicted values still need to be precise. Processing group P1 with 45 neurons in a single hidden layer provides a very small training RMSE and provides MAE and RMSE prediction values for MMEC of 0.012 and 0.015 and Tc of 0.022 and 0.021. For processing group P2, it gives MAE and RMSE prediction values for MMEC of 0.014 and 0.010 and Tc of 0.026 and 0.020. While the processing group P3 provides MAE and RMSE prediction values for MMEC of 0.012 and 0.010 and Tc of 0.025 and 0.020. Considering the accuracy of the values obtained, the use of BPNN has very potential to be applied in predicting the characteristics of manganite before conducting experiments. By predicting the desired MMEC and Tc, it is expected to facilitate the design of manganite materials and can reduce research costs.

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Article Error You may need to remove this article.

S/V This subject and verb may not agree. Proofread the sentence to make sure the subject agrees with the verb.

Proper Noun If this word is a proper noun, you need to capitalize it.

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Run-on This sentence may be a run-on sentence. Proofread it to see if it contains too many independent clauses or contains independent clauses that have been combined without conjunctions or punctuation. Look at the "Writer's Handbook" for advice about correcting run-on sentences.

P/V You have used the passive voice in this sentence. Depending upon what you wish to emphasize in the sentence, you may want to revise it using the active voice.

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Wrong Form You may have used the wrong form of this word.

Prep. You may be using the wrong preposition.

PAGE 5

Article Error You may need to use an article before this word. Consider using the article **the**.

Article Error You may need to use an article before this word.

PAGE 6

Article Error You may need to remove this article.

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