Using neural network in plate frequency calculation

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Abstract— The general goal of this research is the determination natural regular frequency of a plate by artificial neural network with various supporting conditions. For the subject of neural network, training or learning algorithms are applied the most famous of which is back propagation algorithm.This algorithm is a systematic method for training multi layer artificial neural network. Back propagation algorithm is based on gradient descant which means that it moves downward on the error declination and regulates the weights for the minimum error. In this research, the real frequency is calculated first using ANSYS program and is defined as a goal function for neural network, so that all outputs of the network can be compared to this function and the error can be calculated. Then, a set of inputs including dimensions or specifications of plate are made using MATLAB program. After the determination of algorithm and quantification of the network, the phases of training and testing of the results are carried out and the output of the network is created. It is concluded that according to results, the performance of the neural network is optimum, and the errors are less than 7%, so the network can perform training in different manner.

Furthermore the time of frequency calculations in neural network is less than real analysis time that calculated by ANSYS software, and it's precision is acceptable(less than 10%).

Keywords— Artificial intelligence, Excitement function, Frequency, Learning function, Plate, Training function.

I. INTRODUCTION

PROVIDING a program to answer to multivariate problem as input and output is hard or impossible because we can' t considers all of variables and their effects. But it is practicable by artificial neural network and use software. Also modern programming methods are the methods which are sensitive to error in input data, because in artificial neural network, the training is on the base of experience and it can tolerate against errors [6].

Artificial neural networks are used in different researching fields and professions, and are made by cooperation of scientists in different fields such as computer engineering, electronic, structure, biology and so many different branches of science [10, 11]. Previous studies of some researchers e.g. Szewczyk Z., et. al. [4] and also Rajab, M.I et al. [9] are the samples of approaching the best nural net work in this field.

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Some of the important usages of neural network are classification of data, recognition of letters and figures, estimation of functions and etc [7]. Use of neural network in the structure engineering is developing and will develop more and more [8]. In the field of structure engineering, it used for optimization, analysis and designing, anticipate of results for soil and concrete, graphs theory and etc.

II. PROBLEM FORMULATION

A. *Elements of plates in flexural state*

It's probable that isoparameter hexahedron limited, so a dimension is small versus two other dimensions. In this case, hexahedron changed to shell element or plane [1, 2]. For analysis of flat plane, it's necessary to limit reformed dimensions to put them in a single area. This part allocated to isoparametric hexahedron H20, which change to flexural tetrahedral plane, PBQ8. The figure (1a) shows the main member of H20.It defined by geometrical interpolated quadratics .For perceive of required constraints for change it to flexural elements, we make a flat cuboids with natural coordinates, ζ ,η, ξ with small dimension , ζ , perpendicularly.

Obtained element is shown in (1b) and is as a rectangular pattern, PQR8, from PBQ8 element before constriction. It must be remembered that that three nodal groups are located in angles, but two nodal groups are in the middle of side in PQR8 element. In the fig, 1, we see that with special constraints instigation, we can change each group and twin nodal to single nodal in the middle of area[3].

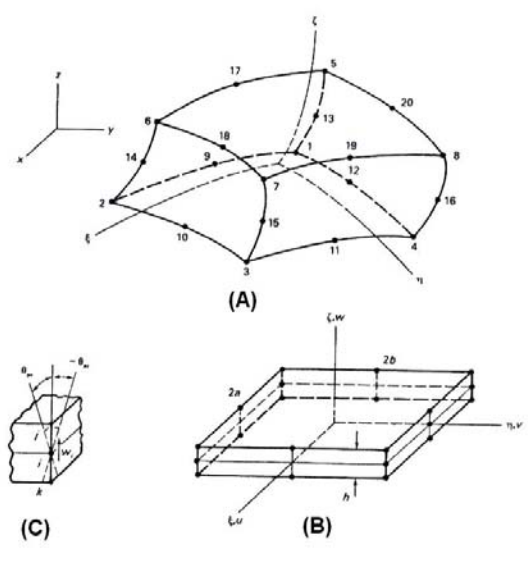

Fig.1 special manner of hexahedron

B. *Making* ***an artificial neural network for approximation of plate's frequency***

For network training, 160 plates were chose. Each of them had six parameters: length, width, thickness, Young's modulus, Poisson's ratio and density. Three of them (length, width, thickness) are based on plate dimensions and another (Young's modulus, Poisson's ratio and density) are based on plate quality. The alteration for plate length is 0/5 to 12 m and for width is 0/5 to 4 m.

Also, the alteration for thickness is 0/002 to 0/22.Because plates are steel, their quality coefficients are fixed. So, Young's modulus is 2×10^6 kg/cm^2, Poisson's ratio is 0/3 and density is 7850 kg/m^3. Because mapping range for input parameters should be 0 and 1, the units changes for decrease of dispersion in input parameter, so we consider micrometer, nanometer, kg/cm^2, µg /hectometer^3 for length, width, thickness, elastomer and density , respectively.

Poisson's ratio is multiplied in 10^6.All of input parameters are divided to square of sum of square separately to network input mapping estimates between 0 to 1.All of results which obtained by plate analysis in ANSYS11 software chose as an objective function, to compare obtained output network with objective function and all errors can calculated In this formula:

Net= newff(PR,[$S_1S_2\ldots S_i$] ,{$TF_1TF_2\ldots TF_n$},BTF)

Where; *PR* is matrix of R×2 with minimum and maximum input elements, *si* is the size of i layer, *TFi* is the excitation of i layer (obtained by transfer function) with tansgin presupposition and *BTF* is the network conversion function with trainlm presupposition.

Network specifications are defined by network structures, number of layers, and number of neuron in each layer, transfer function in layers, learning function and performance evaluation.

With regard to back propagation neural network that used for plate frequency calculation, we should study newff, newcf, newelm structure and the best of them chose. In this paper, each of them is made separately, and has different layer (2-5 layers), and the structure with less error is used for optimum network.

In each structure we choose 6 plates for test, and their specifications are in table I. one of the test samples is part of training input and others are new inputs.

Table I: dimensions of plates for network test

Plate sample	Dimensions(m)			Natural frequency (hertz)
	length	width	thickness	
(1)	0/5	0/5	0/002	22/73
(2)	0/8	0/7	0/005	25/06
(3)	1/3	1	0/008	17/91
(4)	1/8	1/2	0/01	14/4
(5)	2/5	2	0/05	28/56
(6)	4	3	0/1	24/28

III. STUDY OF NEWFF, NEWCF NEWELM NURAL NETWORK

Here, the neural network with 2-5 layers with newff structure is studied, and 20 networks with different neurons are analyzed for each plate. Modulus network had 6 fixed neurons in input layer (plate variable parameters) and a neuron in output layer (plate frequency). The neural network with newelm and newef structure is studied and results are provided in table II.

Table II: results of neural network with 2 to 5 layers

network	Two layer network		Three layer network		Four layer network		Five layer network	
	Error percent	Test time average	Error percent	Test time average	Error percent	Test time average	Error percent	Test time
Newff	8/27	0/04	8/04	0/041	6/67	0/042	6/86	0/044
Newcf	13/22	0/026	10/39	0/027	7/88	0/039	10/27	0/058
newelm	9/39	0/032	4/74	0/031	5/34	0/029	5/4	0/038

According to newelm, newcf and newff neural network output with 2 to 5 layers , we found that by mathematical complex relations for regulation of interplay weight, we can't anticipated that with increase of layers, the network precision increases, but we should get optimum network by trail and error. newelm neural network with 3 layers and error of 4/74 % has the best performance, so another stages will continue.

IV. EFFECTS ON NURON NUMBER (NURAL CELL) IN NEWELM IN NURAL NETWORK LAYERS

Neuron number in each layer is important, so if the number of layer is low, neural network can't reflect nonlinear mapping for input and output .On the other hand, if they are more than required, the network produces nonlinear mapping with unsatisfactory performance.

Because neurons number get by trial and error, so newelm three layer neural networks has studied, separately.

It's clear that three layer newelm neural network and 8 neurons in input layer and 8 neurons in the middle layer has less error.

Figure 2 shows the error percent and neuron number in inner layer.

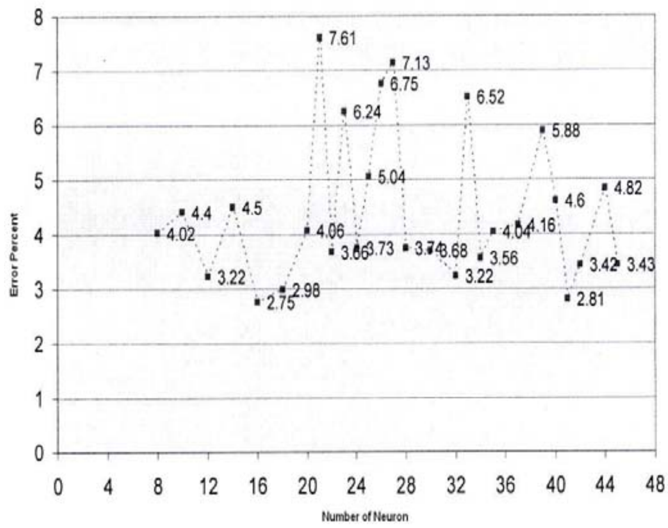

Fig.2 effect of neuron number in inner layer on amount of error

V. THE EFFECT OF EXCITEMENT, TRAINING AND LEARNING FUNCTION IN NEWELM THREE LAYER NEURAL NETWORKS

A. Excitement

Usually, network processing is by excitement and is as a logical or crescent (sigmoid).Although it's not necessary to choose excitation function for all neurons in layer, but the excitement function is same for neurons in layer and most of the time, nonlinear excitement function is used to maximize efficiency of multilayer networks.
In this paper, excitement functions such as purelin, logsig and tansig are back propagation algorithm that have studied (table III).

Table III: effect of excitation function in newelm three layer networks

Excitation function composition	Average error percent	Average testing time(s)
Tansig-logsig-purelin	2/8	0/031
Tansig- Tansig -purelin	3/38	0/026
logsig -Tansig -purelin	3/21	0/031
Logsig- logsig -purelin	5/96	0/023

B. Training

The goal of training is finding an optimum answer of network, so that output arises from real answer. In network training, each input vector and opposite output vector make a couple. Usually, a neural network trains with more couple. In neural network, primary weights are important because this comparison is depended on different elements such as input data, weights number, goal error parameter and the aim of network usage.
In table IV, the results of comparison between different training function in newelm network are shown.

So, we found that Train cgb has less error (2/32%) and it's performance is better than other functions.

Table IV: effect of training function

Kind of training function	Average error percent	Average testing time(s)
Train lm	5/76	0/047
Train bfg	3/98	0/032
Train cgb	2/32	0/028
Train cgf	5/11	0/034
Train cgp	5/42	0/029
Train oss	2/64	0/026
Train rp	10/78	0/029
Train scg	3/54	0/031

C. Learning

the neural network, all of calculations are related to each layer, and the output can estimated. At first, output of neural cells in a layer calculated and the result used as an input for another layer. After that, according to input, the second layer output is calculated. This process continues to output make output vector. Learning functions are important, so the effect of learning function on newelm neural network is studied (table V).

Table V: effect of learning function

Kind of training function	Average error percent	Average testing time(s)
Learn gdm	5/84	0/031
Learn gd	7/82	0/034
Learn som	3/8	0/036
Learn p	2/32	0/029
Learn os	6/45	0/031
Learn lv_1	7/2	0/026
Learnlv_2	5/74	0/032
Learn con	6/11	0/034
Learn k	5/69	0/039
Learn I_s	6/51	0/047
Learn h	2/81	0/096
Learn hd	4/30	0/089
Learn wh	16/05	0/016

According table V, learn P function (error=2/32%) has better performance. In this function, training input functions binary. After training, the network accepts continuous input and produces output.

VI. EFFECT OF PERFORMANCE EVALUATION ON NEWELM THREE LAYERS NURAL NETWORK

In performance evaluation, we want to study how a network performs by trained and new (untrained) input.
Amount of training and network performance calculated by different parameters and methods .Each of them studied separately and the best functions chose. (Table VI)

Table VI: effect of error function

Kind of training function	Average error percent	Average testing time(s)
mae	41/13	0/016
mse	7/82	0/013
Msereg	39/45	0/013
sse	3/88	0/013

According the results, sse function has the best performance.

VII. PROPOSED NURAL NETWORK

By analysis, this neural network is suggested for calculation of plate frequency:
net= newelm (maxmin(p),[8 8 1],{'tansig' 'logsig' 'purelin'};'traincgb','learn p', 'sse').

VIII. NETWORK TESTING FOR DIFFERENT PLATES

Plates with different models (according to place of supports and fixed supports) analyzed by ANSYS11 software, and their real frequency determined. They tested by proposed network and their efficiency determined by errors. Some samples of output results are given in table VII, VIII, IX and fig. 3, 4, 5 and fig 6.

Table VII: plate analysis by support in around the plate

Plate No.	Real frequency	Analysis time(s)	Network frequency	Training time(s)	Testing time(s)	Error percent
1	22/73	0/6	21/48	28/47	0/062	6/95
2	25/06	1/37	26/91	16/34	0/031	0/04
3	17/91	3/21	18/19	21/11	0/016	7/65
4	14/4	5/36	14/11	12/47	0	2/01
5	28/56	12/46	28/07	31/73	0	2/87
6	24/28	30	25/1	17/56	0/016	3/79

Table VIII: plate analysis by support two opposite side

Plate No.	Real frequency	Analysis time(s)	Network frequency	Training time(s)	Testing time(s)	Error percent
1	13/65	0/63	11/99	21/05	0/015	12/16
2	13/3	1/41	13/93	27/5	0	4/96
3	8/04	3/27	8/58	32/14	0/016	6/72
4	5/24	5/44	5/18	12/36	0/016	1/14
5	13/56	12/58	13/07	20/91	0	3/61
6	10/57	30/2	10/29	4/92	0	2/65

Table IX: plate analysis by support in corners of the plate

Plate No.	Real frequency	Analysis time(s)	Network frequency	Training time(s)	Testing time(s)	Error percent
1	6/35	0/65	5/59	16/27	0/031	11/97
2	6/69	1/44	6/8	9/78	0/016	1/64
3	4/21	3/32	4/22	33/59	0	0/24
4	2/85	5/5	2/56	15/59	0/015	10/18
5	6/51	12/68	6/5	13/32	0/016	0/15
6	5/08	30/34	4/92	13/34	0/016	3/15

Table X: punched plate analysis by support two opposite side

Plate No.	Real frequency	Analysis time(s)	Network frequency	Training time(s)	Testing time(s)	Error percent
1	14/45	0/69	13/59	11/22	0	5/95
2	18/25	1/19	17/65	18/53	0	3/29
3	14/19	2/54	13/84	11/28	0/016	3/15
4	12/38	3/39	11/84	7/95	0/016	4/36
5	22/22	7/14	22/5	21/61	0/016	1/26
6	19/65	13/01	20/15	12/76	0/016	2/54

Table XI: analysis of different plate

Average error percent	Average testing time in network(s)	Average real analysis time(s)	Position of plate support
3/88	0/021	8/83	Support in around
5/21	0/008	8/92	Support in tow opposite side
4/55	0/016	8/99	Support in angel
3/42	0/011	4/67	Punched plate with support in tow opposite side

Hitherto, according to different supports for plate, the first frequency output in neural network has been studied. Now, we study the first and second frequency output for plates with support in the corners, and first to fifth frequency output for plates with supports in the opposite side to calculated proposed network power for higher frequency (tables VIII and IX)and (fig. 7 and 8).

Also the compared results of this study are given in tables X to XIII.

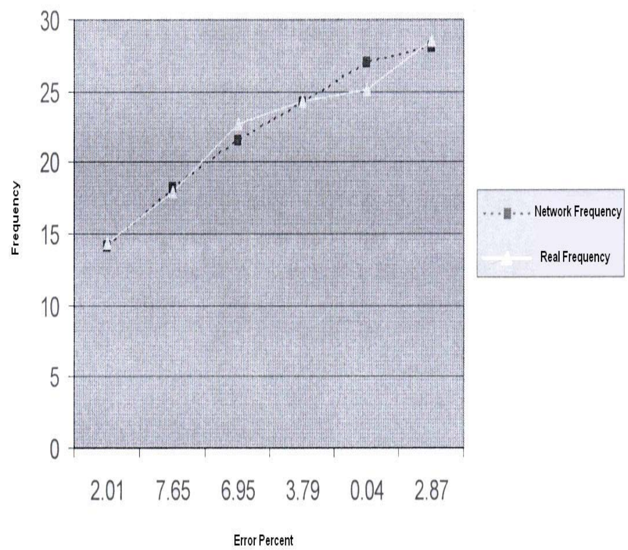

Fig.3 compare of calculated and approximate (support on two opposite side)

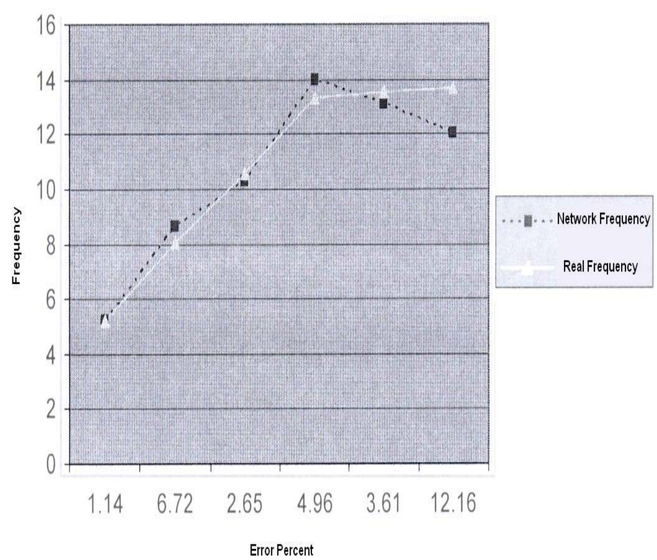

Fig.4 compare of calculated and approximate (around support plate)

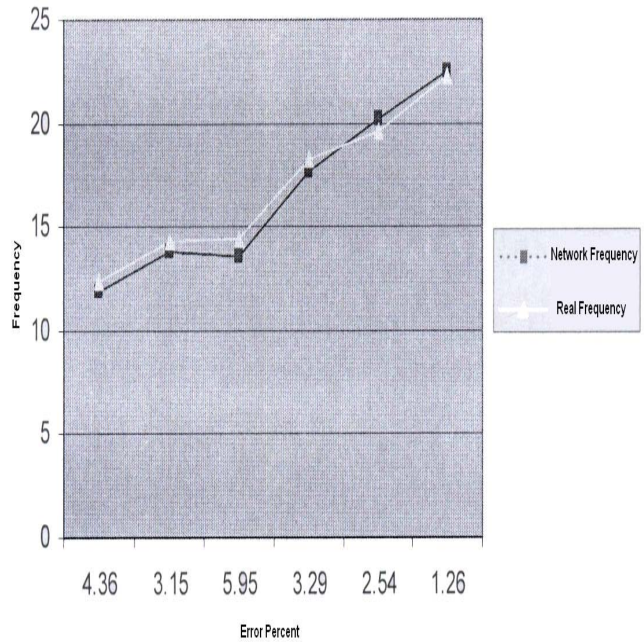

Fig. 5 compare of calculated and approximate (punched plate)

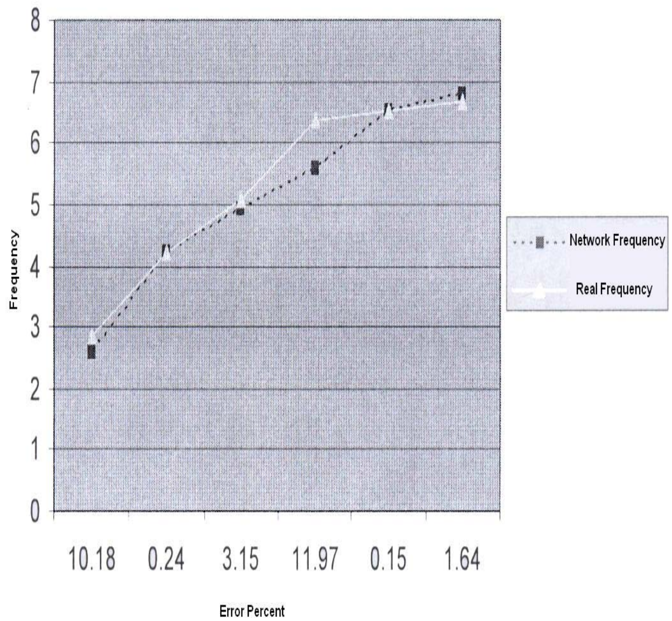

Fig.6 compare of calculated and approximate (Plate support at corners)

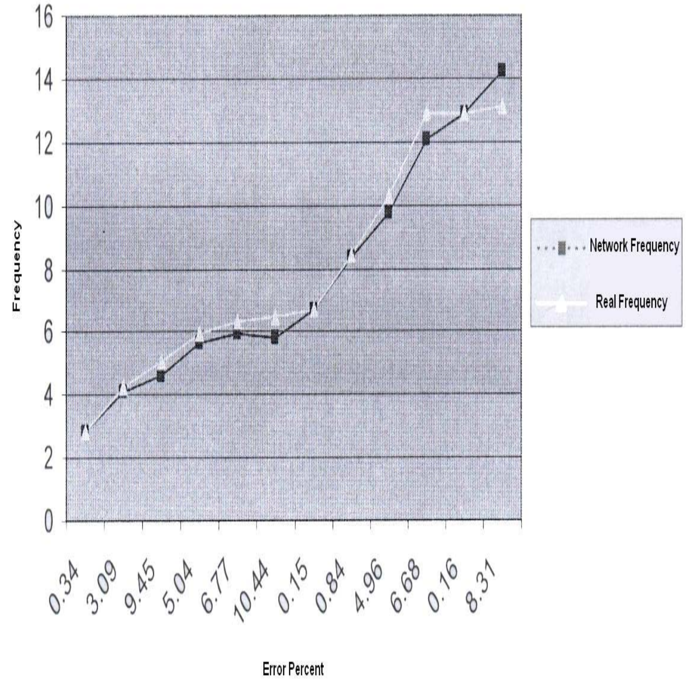

Fig.7 compare of calculated and approximate results (first to second)

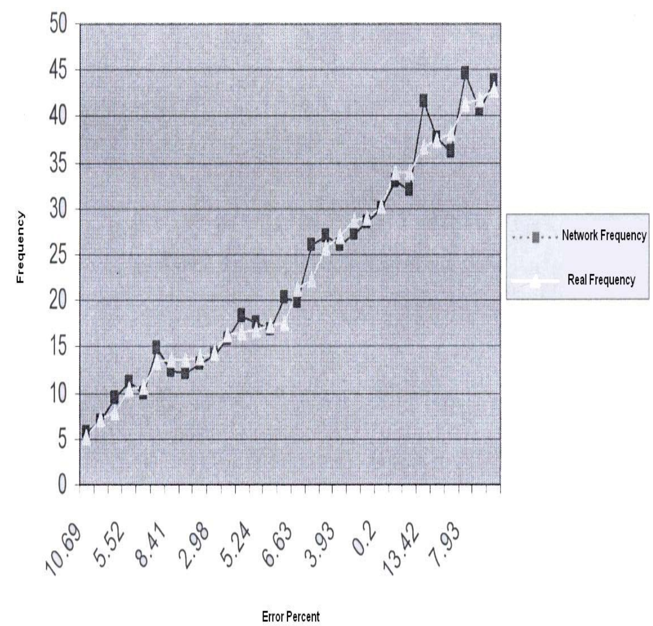

Fig.8 compare of calculated and approximate results (first to fifth)

Table XII: the results of first and second frequency

Average error percent	Average testing time in network(s)	Average real analysis time(s)	Plate support
4/68	0/039	8/99	Support in the angles

Table XIII: first and second frequency output results for plate with support in corners

Plate No.	Real frequency	Analysis time(s)	Network frequency	Training time(s)	Testing time(s)	Error percent
1	6/35	0/65	5/92	68/05	0/047	6/77
	12/88		12/02			6/68
2	6/69	1/44	6/68	32/69	0/032	0/15
	13/11		14/2			8/31
3	4/21	3/32	4/08	59/27	0/031	3/09
	8/38		8/31			0/84
4	2/85	5/5	2/86	41/89	0/047	0/34
	5/95		5/65			5/04
5	6/51	12/68	5/83	31/41	0/046	10/44
	12/89		12/91			0/16
6	5/08	30/34	4/6	52/97	0/031	9/45
	10/27		9/76			4/96

IX. Conclusion

A set of inputs including dimensions or specifications of plate are made using MATLAB computer program. After the determination of algorithm and quantification of the network, the phases of training and testing of the results are carried out and the output of the network is created.

Regarded to complex mathematical relations for regulation of weights in neural network output optimization, we can't anticipated that increasing of layers improve the network output.

So, after study of 2 to 5 layer network, three layer networks with newlem function has the best answer, so we use the three layer network in this study.

Usually, network data processes by excitement function and neural output signal produce.

Change of structure functions can change the network output. As we can see it in the presented results, when the position of the plates supports or the type of the plates are changed, the obtained results are also changed as the values of the tables.

With regard to effect of excitement functions combination in neural network, tansig is suitable for the first hidden layer, logsig is suitable for the second hidden layer and porelin is suitable for the third hidden layer.

During network training, network weights converge, so with regard to input vector, the out put vector produced and network output convergence with goal function (real frequency) obtained by traincgb training function.

Powerful network can answer to trained and new (un trained) input.

It calculated by learning function and performance evaluation function, sse, are the best output for neural network as we can see it among the results of this study.

The research shows that kind of plate and its condition are ineffective for final results of network. With change of support conditions, we found natural frequency.

According to analysis, estimation of frequency with neural network is unlimited and outputs are accessible, but because structure elementary frequencies have more effects on dynamical analysis, they have studied.

With artificial neural network, structure neural frequencies are estimated rapidly and exactly (less than 10%). So, after network training, we don't need plate analysis.

Also the isoparameter hexahedron limited can be used, so a dimension is small versus two other dimensions. In this case, hexahedron changed to shell element or plane. For analysis of flat plane, it's necessary to limit reformed dimensions to put them in a single area. It is concluded that according to results, the performance of the neural network is optimum, and the errors are less than 7%, so the network can perform training in different manner

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