NMAMIT

NITTE

Annual Research Journal

Volume 6 December 2016 ISSN 2249-0426

Published by:
NMAM Institute of Technology
An Autonomous Institution Under VTU, Belagavi
(A Unit of Nitte Education Trust)
NITTE - 574 110, UDUPI DIST., KARNATAKA
www.nitte.edu.in/nmamit
www.research.nitte.edu.in

EDITORIAL

Welcome!

Indian engineering education is at the crossroads. With the establishment of large number of engineering colleges in the country in the last decade, there is no dearth of fresh engineering personnel to meet the requirement of not only the Indian industries but that of other countries as well. However, quality of all these youngsters coming out of these innumerable engineering colleges is questionable, what with large number of surveys carried out by various agencies pointing to the low level of employability of our graduates. The spirit of questioning, exploring the unknown, and probing for new knowledge which are the qualities which make a nation great, are conspicuous by their absent.

The arrival of accreditation process like NBA and NAAC were expected to bring in new lease of life to engineering education, but alas, they only have been able to add to the woes of the faculty members, and did nothing much to improve the quality. The present set of ideas prevalent in engineering colleges are expected to keep them as community colleges where focus is more on completion of the curriculum, yearlong fun and frolic, and placement in lowly paid companies.

There is also the problem of trying to achieve fast research parameters and in the process research carried out prove to be of low quality and devoid of practical application. Semblance of leadership enjoyed by our nation in the area of technology could be sustained by very quickly aiming for cutting edge research and very series academic pursuit in the campuses with focus on innovation and research.

In this issue we have deviated a little by inviting articles from erudite scholars. However, our usual practice of publishing original research papers has been persisted with.

I am glad to hand you this issue of the journal. Happy reading.

Dr. Sudesh Bekal
Editor

MEMBERS OF EDITORIAL BOARD

NMAMIT

Annual Research Journal

Volume 6

December 2016

ISSN 2249-0426

Published by:

NMAM Institute of Technology

An Autonomous Institution Under VTU, Belagavi

(A Unit of Nitte Education Trust)

NITTE - 574 110, UDUPI DIST., KARNATAKA

www.nitte.edu.in/nmamit

NMAMIT Annual Research Journal Volume No. 6

December 2016

ISSN : 2249-0426

Published by :

NMAM Institute of Technology

Nitte, 574 110

Udupi district, Karnataka State, India

Printed by :

Praveena Mudrana

Karkala 574104,

Udupi district, Karnataka State

email: praveenamudrana@gmail.com

Use of PSO optimized Radial Basis Function Neural Network for improved modeling

Vruksha R Shetty[#1], Rashmi P Shetty[#2], Srinivasa Pai P[#3]
[#]*Student, Department of Mechanical Engineering*
NMAMIT, Nitte, Karkala, Udupi, Karnataka - 574110, Affiliated to VTU, Belgaum.
[1]shettyvruksha@gmail.com
[#]*Asst Prof. Department of Mechanical Engineering*
NMAMIT, Nitte, Karkala, Udupi, Karnataka - 574110, Affiliated to VTU, Belgaum.
[2]iprashmi@nitte.edu.in
[#]*Prof. Department of Mechanical Engineering*
NMAMIT, Nitte, Karkala, Udupi, Karnataka - 574110, Affiliated to VTU, Belgaum.
[3]srinivasapai@nitte.edu.in

***Abstract*— In this paper an effort has been made in developing a Radial basis function (RBF) neural network model that uses hybrid Particle Swarm Optimization based Fuzzy C Means (PSO-FCM) clustering algorithm and Extreme Learning Machine (ELM) algorithm for learning. The centers and width of the RBF units of the developed model have been optimally selected using Particle Swarm Optimization (PSO). Extreme learning machine algorithm (ELM) is a single epoch fast learning algorithm that overcomes many drawbacks of gradient descent learning. Three standard datasets Balloon, Iris and Cancer have been used for validating the performance of the developed RBF neural network model. The results for training and testing have been compared with that obtained from [1] and the proposed model has been found to be more effective.**

***Keywords*—RBF neural network, PSO-FCM, ELM, PSO.**

I. INTRODUCTION

Artificial neural networks (ANN) are information processing paradigms inspired by biological nervous system. It resembles the human brain in two respects; the knowledge is acquired by the network through a learning process, and interneuron connection strengths known as synaptic weights are used to store the knowledge [2]. ANN is used to estimate or approximate functions that depend on a large number of inputs and are generally unknown. It finds application in broad spectrum of areas such as data mining, image processing signal processing, operational analysis etc. Feed forward neural networks have been used extensively in different fields owing to several reasons such as their ability to approximate complex nonlinear mappings directly from input samples. Radial basis function neural networks (RBFNN) is a simple single hidden layer ANN that uses nonlinear Gaussian activation function. Due to better generalization capacity, simplicity and strong tolerance to input noise RBFNN have increasingly attracted interest in engineering applications [3].

The three layers – the input layer, the hidden layer and the output layer of the RBFNN has entirely three different roles. The coordinates of the input vector is transmitted to each of the units in the hidden layer by the input layer. Each unit in the hidden layer then applies a nonlinear transformation function from input space to hidden space. Finally, each unit in the output layer computes a linear weighted combination of the activations of the hidden units. How RBFNN reacts to a given input stimulus is completely determined by the activation functions associated with the hidden units and the weights associated with the links between the hidden layer and the output layer. Depending on how the centers of the radial basis functions are specified, there are different learning strategies in the design of an RBF network. For proper selection of the location and the number of centers of the radial functions, self-organized selection that uses clustering algorithms are found to be advantageous. Clustering is a classification technique that partitions the data objects, according to certain predefined criterion, into a set of disjoint clusters in such a way that objects in the same cluster are more similar to each other than to the objects in different clusters. The clustering algorithm partitions the given set of data points into homogeneous subgroups. After the fuzzy theory was introduced by Zadeh (1978) [4], it has been extensively applied to clustering. Bezdek (1984) proposed the most popular fuzzy c-means (FCM) clustering algorithm [5] and is extensively used in a wide range of applications. FCM suffers from some major issues such as it is sensitive to initial values of the cluster centers and can be easily trapped into local minima. Hence it calls for modifications to the algorithm to improve its performance. Many modifications of FCM are proposed in the literature [6-9]. Attempts have been done in using evolutionary algorithms in clustering problems. Use of algorithms such as Genetic Algorithm (GA), Ant Colony Optimization (ACO), Coral Reefs Optimization (CRO), Tabu

search (TS), Particle Swarm Optimization (PSO) etc. in clustering are found to be successful [10-17]. Particle Swarm Optimization (PSO) that is inspired by the flocking and schooling patterns of birds and fish, was formulated by Russell Eberhart and James Kennedy in 1995 [18]. PSO being a global optimization algorithm has many advantages such as it requires less number of parameters, it is simple and has shorter computation time and thus finds extensive use in a wide range of applications. Thus combination of PSO and FCM results in an efficient clustering algorithm since it overcomes the drawbacks of the FCM and is found to be effective [19-23]. In developing a RBFNN, fixing the number of centers and width of the RBF is most important and is usually done on a trial and error basis, which is a time consuming process. Many efforts in use of optimization algorithms for the above purpose can be found in literature [24-27]. Application of PSO for the above purpose can be found in [28].

The unique feature of ANN that it learns from the environment. Learning is a process of improving the performance of an ANN by updating its weights and bias levels. Gradient descent based learning methods have been used in past decades which have many shortcomings. They are very slow due to improper learning steps or may easily converge to local minima. To obtain better performance many iterative learning steps may be required. All the above issues are successfully overcome by Extreme Learning Machine (ELM) algorithm, proposed by G.B Huang (2002) [29]. ELM being an extremely fast non iterative algorithm has good generalization ability and hence been applied in many research applications [30-32]. The combined use of PSO, FCM and ELM in RBF neural network model building can lead to better performance of the model along with quick learning.

In the present work an RBF model has been developed by using hybrid PSO-FCM clustering algorithm and ELM learning. The model is further optimized with respect to centers and width of the RBF units by using PSO.Three standard datasets Balloon, Iris and Cancer have been used for validating the performance of the newly proposed model. The results obtained have been compared with that obtained from [1]. Thus the proposed RBFNN model using PSO, FCM and ELM not only optimizes the parameters of the network but also results in fast learning. This model proposes a fully automatic, quick learning RBF neural network model, which is the novelty of this work.

II. RADIAL BASIS FUNCTION (RBF) NEURAL NETWORK

It is a special type of neural networks, where the design of the network is viewed as curve fitting problem in a high dimensional space [33]. It is a three layer feed forward neural network. Out of the three layers, input layer, hidden layer and output layer, the RBF network mainly differs from other type of neural networks mainly in the hidden layer. The hidden layer applies a non-linear transformation usually a Gaussian function, from the input space to a hidden space. The nodes in the hidden layer have centers that determine the structure of the network.

The output V_j of j^{th} RBF unit in the hidden layer for an input pattern x is given by equation (1)

$$V_j(x) = \exp\left(-\frac{\|x-c_j\|^2}{2\sigma_j^2}\right) \qquad (1)$$

where c_j and σ_j are respectively the center and width of the j^{th} RBF unit, j= 1,2,…J are the number of centers, $\|\ \|$ is the Euclidean distance.
The network output Y_k is given by equation (2)

$$Y_k = \sum_{k=1}^{K} w_{jk} V_j(x) \qquad (2)$$

where w_{jk} is the connection weight between the j^{th} neuron and k^{th} output neuron in the network k=1,2,…K are the number of output neurons.
In the present study, RBF centers have been selected using PSO based FCM. In the learning phase of the network, an efficient ELM algorithm using a generalized (Moore- Penrose) inverse operation to the hidden layer outputs has been used to obtain the output weight (w_{jk}) matrix .

A. Extreme Learning Machine (ELM)

ELM is a simple and efficient learning algorithm that can be used for single hidden layer feed forward neural network. It is entirely different from traditional gradient descent algorithm and has numerous advantages. Learning in ELM follows a non-iterative process where the output weights are analytically determined through simple generalized Moore – Penrose generalized inverse operation of the hidden layer output matrices. The vector of output weights β between the hidden layer and output layer is calculated according to equation (3).

$$\beta = H^{\dagger}T \qquad (3)$$

where $H^{\dagger}$ is the Moore – Penrose generalized inverse of the matrix H and T is the output vector. Hence learning in ELM takes one epoch which makes it extremely faster and is the major advantage. It has also been observed that the use of ELM improves the generalization performance in comparison to gradient based learning.

III.PSO-FCM CLUSTERING ALGORITHM

FCM is a most popular objective function based fuzzy clustering algorithm that assigns membership to each data point corresponding to each cluster center on the basis of distance between the cluster center and the data point. The objective in FCM is to minimize the sum of the distance between the data points and the center as given in equation (4).

$$J = \sum_{k=1}^{N} \sum_{j=1}^{c} u_{kj}^{m} \| X_k - V_j \|^2 \qquad (4)$$

where u_{ki} ,membership value, denotes the degree that X_k belongs to cluster j , m is fuzziness parameter usually set to be 2, $X=\{X_1,X_2,\ldots X_N\}$ are the classification samples, V_i is the cluster center , c is the number of clusters. The membership values satisfy the condition in equation (5)

$$\sum_{j=1}^{c} u_{kj} = 1 \qquad (5)$$

The centers and the membership values are calculated using equations (6) and (7)

$$V_j = \frac{\sum_{k=1}^{N} u_{kj}^{m} X_k}{\sum_{k=1}^{N} u_{kj}^{m}} \qquad (6)$$

$$u_{kj} = \frac{1}{\sum_{i=1}^{c} \left(\frac{\| X_k - V_j \|}{\| X_k - V_i \|} \right)^{\frac{2}{(m-1)}}} \qquad (7)$$

FCM has certain limitations such as getting trapped in the local minimum and slow convergence and its performance is greatly influenced by the initial value of the membership functions. To overcome these shortcomings, PSO a simple and global optimization algorithm has been introduced into FCM and is found to be successful.

PSO is a population based stochastic optimization algorithm. It uses the number of particles which are created randomly and move in the multidimensional space to reach optima. The two primary operators of Particle Swarm are: Velocity (u) update and Position (s) update. The particles update the position based on its own best (pbest) and entire swarms best (gbest) position using equations (8) and (9).

$$u_i^{t+1} = w * u_i^t + C_1 \text{rand1}(\text{pbest}_i - s_i^t) + C_2 \text{ rand2}(\text{gbest} - s_i^t) \qquad (8)$$

$$s_i^{t+1} = s_i^t + u_i^{t+1} \qquad (9)$$

where rand1 and rand2 are uniformly distributed random variables, C_1 and C_2 are acceleration factors and w is inertia weight.PSO-FCM algorithm is given in Appendix A [23].

IV. PSO FOR OPTIMIZING RBFNN ARCHITECTURE

Fixing of centers and width of the RBF units play a critical role in performance of the RBFNN model. Though the use of best clustering algorithm has some impact on improving the performance of a model, fixing the centers and width of the RBF units have a major role to play in this regard. This task is usually done on a trial and error basis, but is a very tedious, inefficient and time consuming task. Use of optimization algorithm for the above purpose can reduce considerable effort. An attempt has been done in using PSO optimization algorithm for fixing the number of centers and width of the RBF units. The objective function here is to maximize the sum of prediction accuracies on training and test data. Model optimization Algorithm is shown in Appendix B.

V. MODELLING OF DATASETS

The three datasets used in this study are classification data and were obtained from the machine learning repository [34]. Each dataset was divided into training (85%) and test (15%) data. The RBFNN model has been developed using customized MATLAB codes. The simulations have been carried out using matlabR2012a [35] environment running in an Intel i-3, 2.6 GHZ CPU. A suitable normalization procedure has been used to normalize the data (training and test) between (0, 1). Details of the datasets used with respect to the number of training and test data has been presented in Table I. Mean Square Error (MSE) as given in equation (10) has been used as the performance metric in the present study, where X_i and $\widetilde{X}_i$ are the i^{th} component of the actual and predicted values respectively and n is the length of the vector.

$$\text{MSE} = \frac{1}{n} \sum_{i=1}^{n} \left(X_i - \widetilde{X}_i \right)^2 \qquad (10)$$

TABLE I
DETAILS OF THE DATASETS

Dataset	Training Data	Test Data	Optimal Network Configuration
Balloon	17	3	4-2-1
Cancer	594	105	9-2-1
Iris	128	22	4-4-3

VI. RESULTS AND DISCUSSION

The results of the study carried out on the proposed RBFNN model for three data sets namely Balloon, Cancer and Iris have been presented in this section. To implement PSO some parameters need to be initialized. The values of the parameters that have been set for the present study are as given in Table II.

TABLE II
EXECUTION PARAMETERS FOR PSO

Parameter	Value
Population Size	10
Iterations	100
W	0.9
C1	1.49
C2	1.49

A. Balloon dataset

This dataset has been used in cognitive psychology experiments. It consists of four datasets, each representing different conditions of an experiment. The attributes are alike for all the datasets. Out of that one of the dataset has been made use in the present study. It has 4 attributes and 20 instances. As shown in Table III the best result of 100% accuracy on both training and test dataset were achieved for 2 centers and a width value of 0.1520 with MSE of 0.0369 reached during training that was performed in a single epoch. The range for number of centers and width has been set to be 1- 17 and 0.01- 1 respectively. The variation of fitness with number of iterations has been shown in Fig. 1.

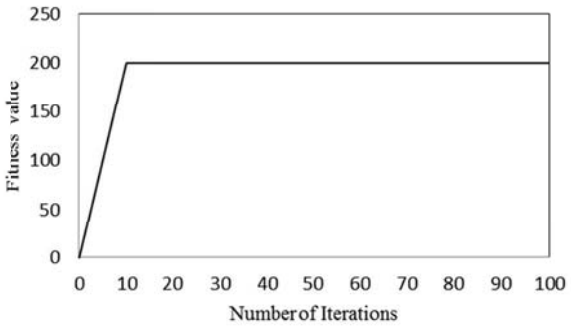


Fig. 1 Variation of fitness with number of iterations for Balloon dataset

TABLE III
RESULTS FOR BALLOON DATASET

	Training data	Test data
Classification Accuracy (%)	100	100
MSE	0.0369	0.1128
Number of epochs	1	1

B. Cancer dataset

This dataset is the classification of a tumor as either benign or malignant based on cell descriptions obtained by microscopic examination. The data set contains 9 attributes and 699 instances, out of which 485 are benign and the rest malignant. The simulation results have been presented in Table IV. It can be observed from the table that accuracies of 97.47% and 93.33% have been achieved on training and test datasets respectively for 2 centers and a width of 0.9754 with MSE of 0.0327 reached during training that was attained in a single epoch. The range for number of centers and width has been set to be 1- 50 and 0.01- 1 respectively. The variation of fitness with number of iterations is shown in Fig. 2.

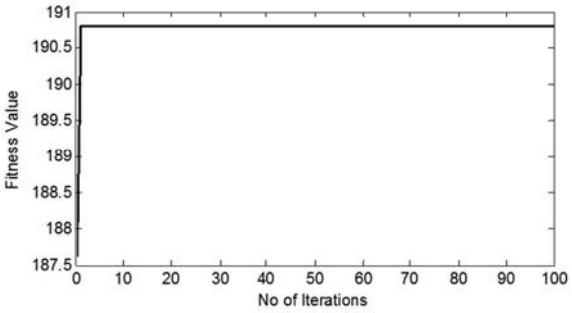


Fig. 2 Variation of fitness with number of iterations for Cancer database

TABLE IV
RESULTS OF CANCER DATASET

	Training data	Test data
Classification Accuracy (%)	97.47	93.33
MSE	0.0327	0.05801
Number of epochs	1	1

C. Iris dataset

This dataset is used to classify the Iris plant into three classes- Iris sesota, Iris versicolor, and Iris virginica. There are four attributes –sepal length, sepal width, petal length, and petal width. The three classes referring to the type of iris plant contains 50 instances each. The results have been tabulated in Table V. It can be seen from the table that accuracies of 96.04% and 95.45% on training and test datasets respectively have been achieved for 4 centers and a width of 0.3142 with MSE of 0.0296 reached during training that was performed in a single epoch .The range for number of centers and width has been set to be 1- 25 and 0.01- 1 respectively.

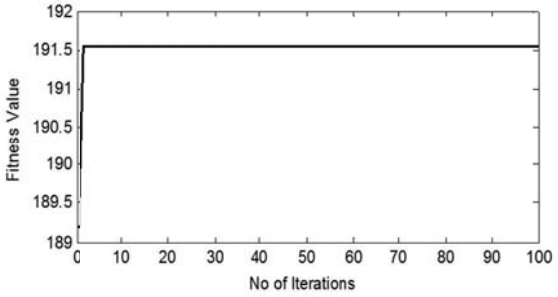


Fig. 3 Variation of fitness with number of iterations for Iris dataset

TABLE V
RESULTS OF IRIS DATASET

	Training data	Test data
Classification Accuracy (%)	96.04	95.45
MSE	0.0296	0.0315
Number of epochs	1	1

D. Comparison of Modeling Performance

In this section an effort has been done to compare the results of the present study with that of a similar work carried out by S. N. Qasem et al (2009) [1] for these three standard datasets. S. N. Qasem et al incorporated PSO in RBF network for optimizing the centers, the widths and the weights of network which used gradient descent learning. The k-means algorithm was used for initial selection of centers. The parameter values that were set for PSO implementation are as shown in Table VI. The comparison of the results has been shown in Table VII. It can be observed from the table that for Balloon dataset an increased accuracy of 100% on both training and test datasets have been achieved in the present study in comparison with 95.05% and 78.95% of accuracies of the previous work. In both the work, the network configuration is same. It is worth noting that the present study took only one epoch in contrast to 3161 epochs in the previous work that depicts the superiority of the current model. This has been possible due to the implementation of ELM in the present work and thus it greatly reduces the training time. For Cancer dataset, the accuracy on test data is 93.33% with a MSE of 0.05801, which is much higher compared to 71.72% prediction accuracy on test data at a lower value of MSE, when compared to 0.27464. But for Iris dataset the performances of the proposed model is comparable to that of the previous work, except that this model required only one epoch when compared to 3774 epochs required for the previous case.

All the results of the present study have been obtained for the stopping criteria of 100 iterations in PSO. It is in contrast to 10000 iterations for the previous work and thus there is a huge difference in the number of iterations, which proves the superiority of the present model. The use of PSO for optimizing the FCM algorithm, is an additional improvement in the current model, when compared to the previous model. Thus the proposed RBF neural network model which use PSO, FCM and ELM in optimizing the model performance has virtually outperformed the PSO-RBF model proposed by S. N. Qasem et al [1].

TABLE VI
EXECUTION PARAMETERS FOR PSO [S. N. QASEM ET AL (2009)]

Parameter	Value
Population Size	20
Iterations	10000
W	0.9,0.4
C1	2.0
C2	2.0

TABLE VII
COMPARISION OF MODELING PERFORMANCE

	Model	PSO-RBFN-ELM			PSO-RBF[S. N. Quasem et al]		
	Dataset	Balloon	Cancer	Iris	Balloon	Cancer	Iris
Training	Error Convergence	0.0369	0.0327	0.02968	0.004993	0.018117	0.049995
	Classification accuracy (%)	100	97.47	96.04	95.05	97.65	95.48
	No. of epochs	1	1	1	3161	10000	3774
Testing	Error Convergence	0.1128	0.05801	0.0315	0.16599	0.27464	0.03999
	Classification accuracy (%)	100	93.33	95.45	78.95	71.72	95.64
	No. of epochs	1	1	1	1	1	1

VII. CONCLUSIONS

This study presents the use of PSO algorithm in improving the clustering efficiency and also optimal selection of RBF parameters namely number of centers and width value of RBF units. ELM has been used as the learning algorithm. Study has been conducted by using three standard datasets. The results have been compared with a similar work carried out by S. N. Qasem et al. [1]. The results show that the proposed model resulted in better prediction accuracy for

Balloon and Cancer datasets and comparable accuracy for Iris datasets. Due to the implementation of ELM quick learning in only one epoch have been observed as the major advantage in comparison with thousands of epochs required in case of the previous reported work. The stopping criteria of PSO for the present study also have been observed to be quite small in comparison with that of the previous reported work. Thus the use of PSO in both clustering as well as optimizing the center and width of the RBF unit in combination with ELM can result in a more efficient RBF neural network model.

REFERENCES

[1] S.N.Qasem and S.M.Shamsuddin, "*Improving Performance of Radial Basis Network based with Particle Swarm Optimization*", IEEE Congress on Evolutionary Computation, pp.3149-3156, 2009.

[2] S. A. Kalogirou, "Artificial neural networks in renewable energy systems applications: a review", Renewable and Sustainable Energy Reviews, vol. 5. pp. 373–401, 2001.

[3] Y.J.oyang, S.C.Hwang, C.Yu and Z.Chen,"Data classification with radial basis function networks based on a novel kernel density estimation algorithm", *IEEE Transactions on Neural Networks*, vol.16. pp. 225-236, 2005.

[4] L.A. Zadeh. "Fuzzy sets as a basis for theory of possibility", Fuzzy Sets and Systems, vol.1.pp.3-28, 1978

[5] J. Bezdek, R. Ehrlich, and W. Full, "FCM: The fuzzy c-means clustering algorithm", *Computers & Geosciences*, vol. 10, no.2, pp. 191-203, April 1984.

[6] N. Pal, K. Pal, J. Keller, and J. Bezdek, "A possibilistic fuzzy c-means clustering algorithm",

IEEE Trans. Fuzzy Syst, vol. 13, no. 4, pp. 517– 530, Aug. 2005.

[7] J.Li; X.Gao; H.Ji, "A feature weighted FCM clustering algorithm based on evolutionary strategy Intelligent Control and Automation, *Proceedings of the 4th World Congress* on Year: vol.2. pp. 1549 - 1553. 2002.

[8] K. K. Chintalapudi and M. Kam , "A noise-resistant fuzzy c means algorithm for clustering", Fuzzy Systems Proceedings, *IEEE World Congress on Computational Intelligence*, vol.2, pp 1458 - 1463, 1998.

[9] C.C.Hung, S.Kulkarni and B.C.Kuo, "A New Weighted Fuzzy C-Means Clustering Algorithm for Remotely Sensed Image Classification" , *IEEE Journal of Selected Topics in Signal Processing*, vol.5. no.3, pp.543 - 553, 2011.

[10] L.E.Agust, S.S.Sanz, S.J.Fernández, L.C.Calvo, J.D.Ser, and J.A.P.Figueras, "A new grouping genetic algorithm for clustering problems", *Expert Systems with Applications*, vol. 39, no.10, pp. 9695-9703, 2012.

[11] T. Niknam, M. Nayeripour and B.B. Firouzi, "Application of a new hybrid optimization algorithm on cluster analysis", *Proceedings of world academy of science, engineering and technology*, vol. 36, pp.741-746, December. 2008.

[12] O.M.Jafar and R.Sivakumar, "A Study of Bio-inspired Algorithm to Data Clustering using Different Distance Measures", *International Journal of Computer Applications*, vol. 66, no. 12, pp. 33-44, 2013.

[13] Y. Kao and K. Cheng, "*An ACO-based clustering algorithm*", In Ant Colony Optimization and Swarm Intelligence, pp. 340-347, 2006.

[14] Y. Liu, Y. Liu,L. Wang and K.Chen,"*A hybrid tabu search based clustering algorithm*" Knowledge-Based Intelligent Information and Engineering Systems. pp. 186-192, September. 2005.

[15] K.S.Al-Sultan, "*A tabu search approach to the clustering problem*", Pattern Recognition, vol.28, no.9, pp.1443-1451, 1995.

[16] S.Rana, S. Jasola and R.Kumar, "A hybrid sequential approach for data clustering using K-Means and particle swarm optimization algorithm," *International Journal of Engineering, Science and Technology*, vol. 2, no.6, pp. 167-176, 2010.

[17] I.G.Medeiros, J.C.Xavier-Junior and A.M. Canuto, "Applying the Coral Reefs Optimization algorithm to clustering problems", *International Joint Conference on Neural Networks (IJCNN)*, pp. 1-8, July. 2015

[18] R.C.Eberhart and J. Kennedy, "A new optimizer using particle swarm theory", *Proceedings of the sixth international symposium on micro machine and human science*, vol. 1, pp. 39-43, October. 1995.

[19] A.Mekhmoukh and K.Mokrani, "Improved Fuzzy C-Means based Particle Swarm Optimization (PSO) initialization and outlier rejection with level set methods for MR brain image segmentation" , *Computer methods and programs in biomedicine*, vol.122,no. 2, pp. 266-281, 2015.

[20] L. Hongpo,S. Jun, W.Hai, T.Shuhua and T. Zhiguo, "High Resolution Sonar Image Segmentation by PSO based Fuzzy Cluster Method", *Fourth International Conference on Genetic and Evolutionary Computing (ICGEC),* pp. 18-21, December. 2010.

[21] J. Chrouta, A. Zaafouri and M.Jemli, "Identification of an irrigation station using hybrid fuzzy clustering algorithms based on particle swarm optimization", *12th International Multi-Conference on Systems, Signals & Devices (SSD)*, pp. 1-7. March. 2015.

[22] E. Sivaraman, S. Arulselvi and K.Babu, "March. Data driven fuzzy c-means clustering based on particle swarm optimization for pH process", *International Conference on Emerging Trends in Electrical and Computer Technology (ICETECT)*, pp. 220-225, 2011.

[23] H.C. Liu, J.M. Yih, D.B. Wu and S.W. Liu, "Fuzzy C-mean clustering algorithms based on Picard iteration and particle swarm optimization", *International Workshop on Geoscience and Remote Sensing. ETT and GRS* vol. 2, pp. 838-842, December. 2008.

[24] Z.Q.Zhao and D.S. Huang, "A mended hybrid learning algorithm for radial basis function neural networks to improve generalization capability", *Applied Mathematical Modelling*, vol. 31,no.7, pp.1271-1281, 2007.

[25] S.M.R.Loghmanian, H. Jamaluddin, R. Ahmad, R. Yusof and M. Khalid, " Structure optimization of neural network for dynamic system modeling using multi-objective genetic algorithm", *Neural Computing and Applications,* vol. 21, no.6, pp.1281-1295, 2012.

[26] X.Z. Xu, S.F. Ding, Z.Z. Shi and H. Zhu ,"Optimizing radial basis function neural network based on rough sets and affinity propagation clustering algorithm", *Journal of Zhejiang University SCIENCE*, vol. 13, no. 2, pp.131-138, 2012.

[27] N. Qu, H. Mi, B. Wang and Y. Ren, "Application of GA-RBF networks to the nondestructive determination of active component in pharmaceutical powder by NIR spectroscopy", *Journal of the taiwan Institute of Chemical Engineers*, vol. 40, no. 2, pp.162-167, 2009.

[28] Z.H.A.O.ZhongQiu, W.U. XinDong, L.U. CanYi, H. Glotin and G.A.O. Jun, "Optimizing widths with PSO for center selection of Gaussian radial basis function networks", *Science China Information sciences*, vol. 005, pp. 82-98, 2014.

[29] G.B.Huang, Q.Y. Zhu and C.K. Siew, "Extreme learning machine: a new learning scheme of feedforward neural networks", *IEEE International Joint Conference on Neural Networks*, vol. 2, pp. 985-990. July. 2004.

[30] O. Anicica, S. Jovića, H. Skrijelja and B. Nedićb, "Prediction of laser cutting heat affected zone by extreme learning machine", *Optics and Lasers in Engineering* , vol. 88, pp. 1–4 .2017,

[31] S. S. Mladenovića, M. Milovančevićb, I. Mladenovića and M. Alizamirc, "Economic growth forecasting by artificial neural network with extreme learning machine based on trade, import and export parameters", *Computers in Human Behavior*, vol. 65, pp. 43–45. 2016.

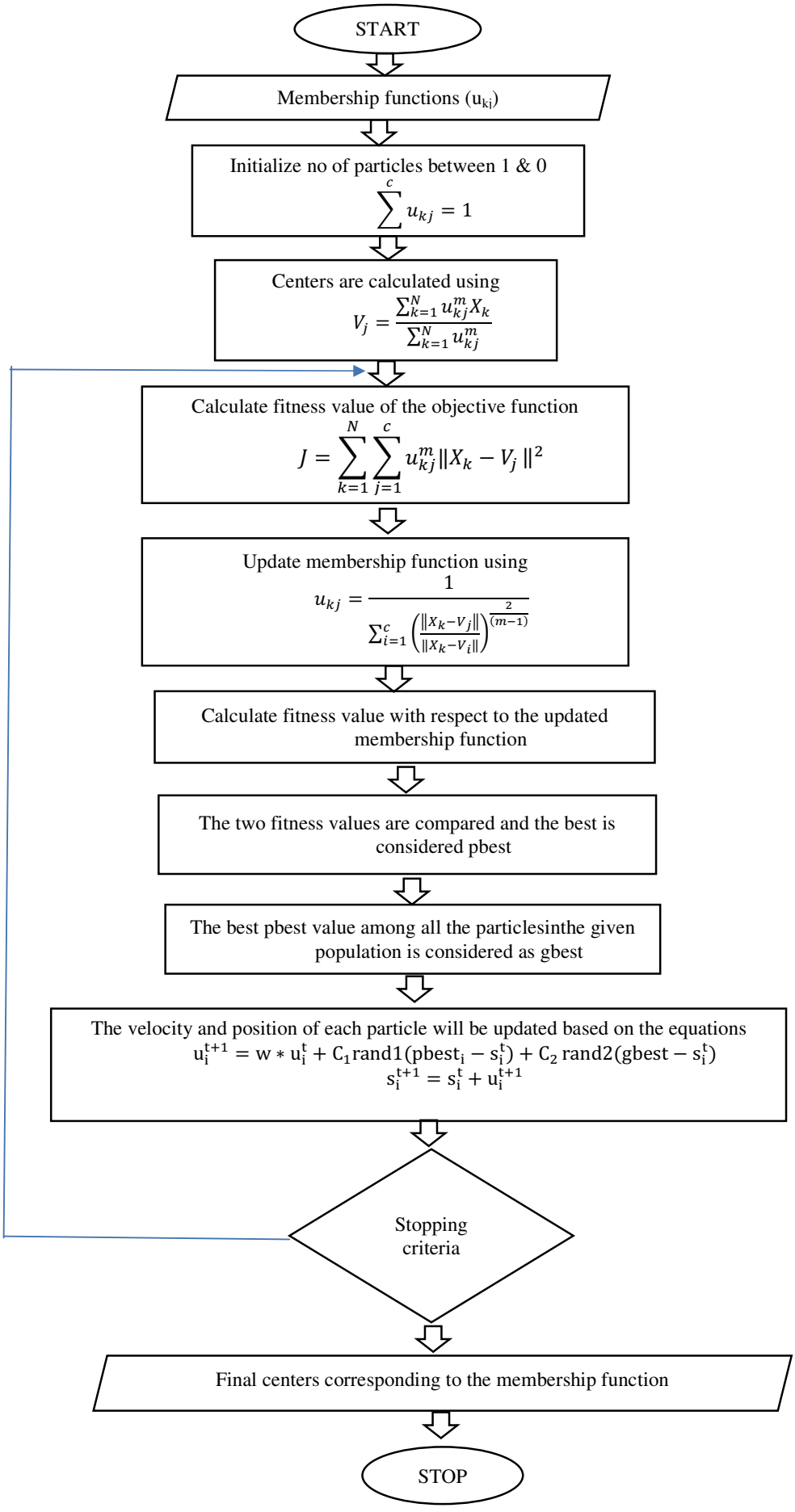
[32] J. S. Oro, A. Duarte and S. S. Sanz, "Robust total energy demand estimation with a hybrid Variable Neighborhood Search – Extreme Learning Machine algorithm", *Energy Conversion and Management*, vol.123, no.1, pp.445-452. 2016.

[33] Haykin, S, *A comprehensive foundation. Neural Networks*, Second edition, Person Education, 2004.

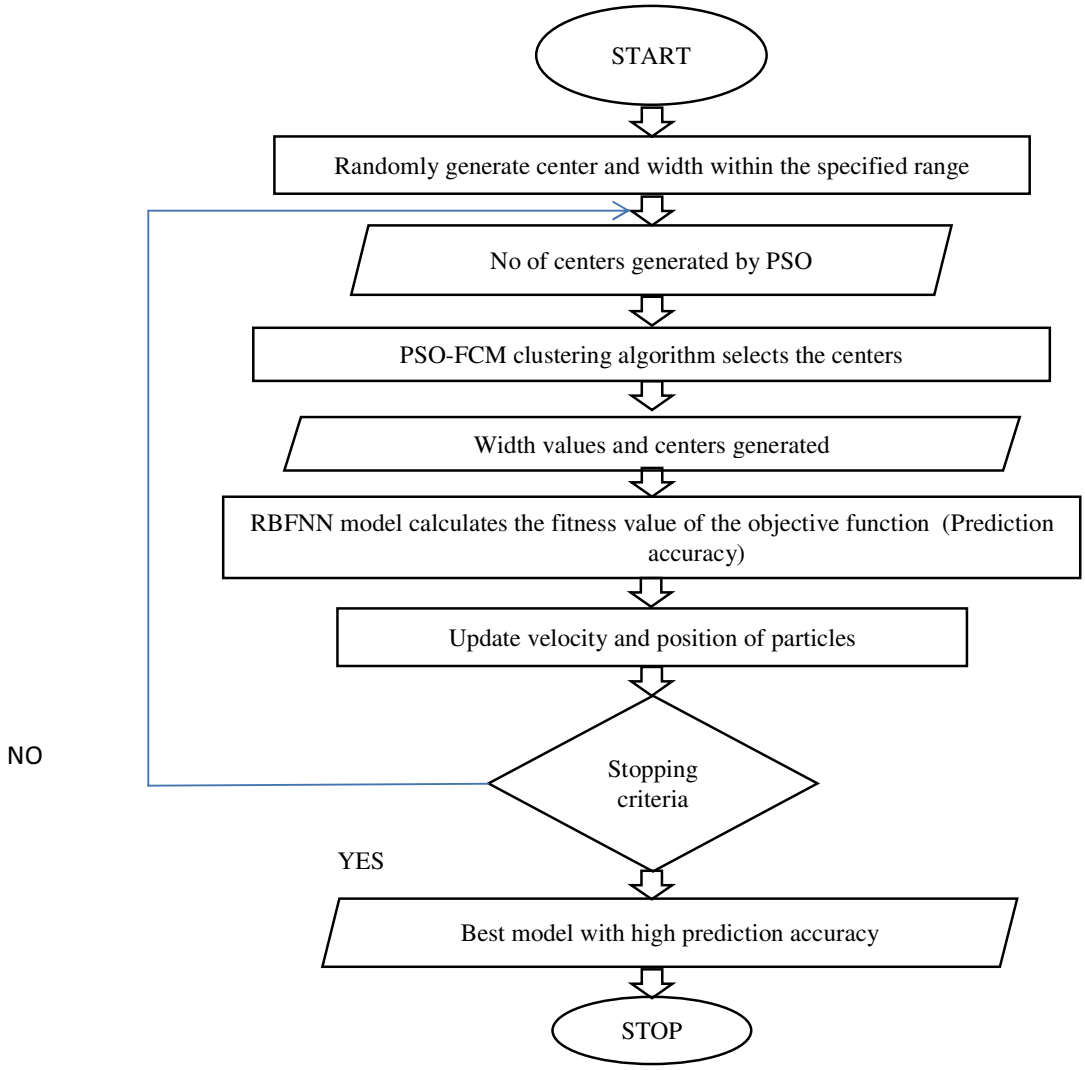
[34] C.Blake and C.J.Merz, "UCI Repository of Machine Learning Databases", http://www.ics.uci.edu/~MLRepository.html,1998

[35] MATLAB R2012a@R,www.mathworks.com

APPENDIX A: PSO-FCM ALGORITHM



APPENDIX B: MODEL OPTIMIZATION ALGORITHM



In Vitro Propagation and Molecular Characterization ofLocal Accessions of *Santalum Album*

Aparna B[#1], Bharathi A[#2], Yashas K[#3], Rashmi KV[#4]

[1, 2, 3#]*Student, Department of Biotechnology,*
[#]*Assistant Professor, Department of Biotechnology,*
Sir M Visvesvaraya Institute of Technology, Bangalore, Karanataka- 562157, Affiliated to VTU, Belgaum.
[4]rashmikvbt@gmail.com

***Abstract*—Callus induction studies and optimization of shoot induction from the callus is carried out in *Santalum album* along with , Molecular Phylogenetic analysis of local varieties using chloroplast intergenic spacer region-trnH-psbA .Use of hormones Naphthaleneacetic acid (NAA), 2,4-Dichlorophenoxyacetic acid (2,4-D) and Kinetin (Kn) with concentration of 1mg/L in MS media for inter-nodal explants resulted in Rapid elongation , Callus induction and Multiple Shoot generation in relatively in short period of time. Molecular investigation using *trnH-psbA* region from the accessions collected from six different biogeographic areas of Karnataka showed no much diversity indicating no subspecies existing within the species.**

***Keywords*—*Santalum album*, plant tissue culture, phylogenetic analysis**

I. INTRODUCTION

Sandalwood (*Santalum album*) is a hemi root parasitic tree which grows upto 10-15m in height and 12m girth when it reaches the age of 60-80 years [1]. It grows widely in south India and is highly valued for its fragmented heartwood which contains sandal oil. The aroma of oil is due to alpha and beta santalols [2]. Harvesting of sandalwood for its commercial applications results in the removal of entire tree leading to the critical loss of genetic diversity [3,4]. Hence there is an urgent need to develop a efficient protocol for large scale production of high quality sandalwood.

Genetic variation is a important conservation strategy, which provides information about the given species adaptability to environmental changes, natural evolution and survival [5]. Knowledge of genetic variation between and within species plays an important role in appropriate management strategies of conservation [5]. Hence it is necessary to assess genetic variability. Molecular phylogenetic analysis will provide new perspectives on relationships and biogeographic patterns among the widespread and economically important verities [6]. The present study chloroplast *trnH-psbA* spacer region is used for molecular characterization. The sequence of chloroplast *trnH-psbA* intergenic spacer from *Santalum album* verities can be used as a potential DNA barcode to identify *Santalum album* varieties in global market [6]. The phylogenetic analysis carried out using chloroplast *trnH-psbA* spacer sequences aid in determining evolutionary relationship among the biogeographic variants. Here we report a tissue culture protocol to induce rapid elongation and multiple shoot generation from *Santalum album* in relatively short period of time. With further slight optimization, these protocols can be used for large scale propagation in future to meet the demand for better quality plantlets.

II. MATERIALS AND METHODS

A. In vitro propagation methods

Healthy young Inter-nodal and apical meristem explants are collected from the wildly grown 2 to 3 years old *Santalum album* plants at Sir MVIT college campus, Bangalore. These explants are surface sterilized with 0.05% (w/v) Bavistin for 5-6mins and 0.1% (w/v) mercuric chloride for 4-5 mins followed by thorough sterile distilled water washes to remove the traces of these chemicals. Murashige and Skoog media (MS media) with 3% sucrose and 0.8% agar, with different concentrations of growth regulators were used for direct and indirect organogenesis (Table I). Explants are inoculated on the semisolid media, incubated at a temperature of 25±2ºC and are provided with cool white fluorescent light with 16hrs photoperiod. Cultures are monitored for any contaminations or response. These cultures are sub cultured on

regular intervals under the conditions like medium depletion, shoot induction or root induction.

B. Molecular characterization methods

Chandana Sri plantations Devanahalli Bangalore, Mysore, Shimoga and Chikmagalur localities. DNA was isolated from these 6 accessions using Doyle & Doyle method [7] and rapid extraction protocol [8]. Isolated DNA quantified by 0.8% 0.1% Triton X-100, 1.0 U *Taq* DNA polymerase with 0.1µM *psbA*F-*trnH*R [9] primers.

Amplified products were sequenced in both forward and reverse directions at Eurofins Genomics India Pvt. Ltd. using ABI 3730XL (Applied BioSystems) sequencer following the manufacturer's protocols. Along with these sequences, 5 mores were retrieved from NCBI-Genbank (KC503281, JX856939, JX856938, GQ435374, GQ435375). Sequences obtained were exported to Molecular Evolutionary Genetics Analysis version 6.06 (MEGA-6.06) software for editing and alignment and for converting into nexus format [10]. The phylogenetic trees were reconstructed using Neighbour Joining method and bootstrap test of phylogeny with 1000 replications [11]. Obtained sequences were submitted to NCBI Genbank (KX164503 to KX164508).

TABLE I
DIFFERENT CONCENTRATIONS OF THE GROWTH HORMONES TRIED AND THE OBSERVED RESPONSE

Media	Concentration of growth regulator	Observed Response
MS+2 KN	2mg/L	Slight Callus induction
MS+2BAP	2mg/L	Multiple shoot regeneration and negligible callus
MS+NAA+2,4-D+KN	1mg/L	Multiple shoot regeneration and negligible callus
MS+NAA+2,4-D + KN+10% Coconut water	1mg/L	Multiple shoot regeneration and negligible callus

III. RESULTS

M.S media supplemented 2mg/L BAP induced little callus and multiple shoots were observed after 40 to 45 days (Fig.1). Similar response was observed when the media was supplemented with 2mg/L of Kn. Rapid elongation and high number of multiple shoot proliferation was observed in media supplemented with 1mg/L of NAA, 2,4-D, and Kn. Addition of 10% coconut water to the media with same hormone concentration showed rapid elongation of shoots in just 4 days and better growth was observed. However these observed shoots were fragile and our minimal attempts for root induction were not successful.

agarose gel electrophoresis followed by ethidium bromide staining. This DNA was used as template for amplifying the chloroplast *psbA-trnH* intergenic spacer region. Amplification was carried out in 0.025cm3 reaction mixture containing 0.3mM dNTP's, 10mM Tris-HCl, 3mM MgCl2, 50mM KCl

Multiple accessions of *S.album* were collected from different regions of Karnataka viz., Sir MVIT Campus Bangalore, Wood Science and Technology Bangalore, ,

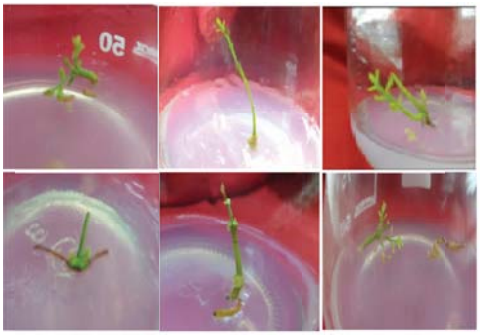


Fig. 1 Multiple shoot responses from *Santalam* internodal explants

The chloroplast *trn*H-*psb*Aspacer region gave an intense sharp amplification product of size ranging between 350 to 450bp (Fig.2). The G+C content was 25.2% indicating less conserved regions. In a total aligned length of 396 bp, 144 were conserved characters with 189 parsimony informative sites.

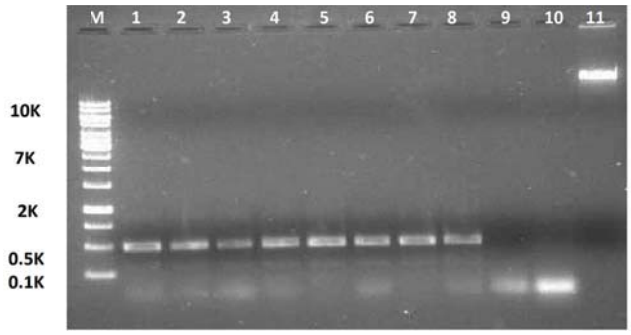


Fig. 2 Amplification profile of *trnH-psbA* region in *Santalum* accessions; M: 1KB Ladder; Lanes 1- 6: *Santalum* accessions; Lanes 7,8: Positive control; Lanes 9,10:Negative control; Lane 11: 100ng λDNA

The Neighbour Joining (NJ) tree with *Scleropyrum wallichianum* as outgroup showed all the accessions of *Santalum* used in the study are monophyletic (Fig. 3). All the

Indian accessions were clustered into one sub cluster, two of the Chinese accessions and one Kerala accession were observed in the second subcluster. This indicated that species *Santalum album* has nomajor subspecies.

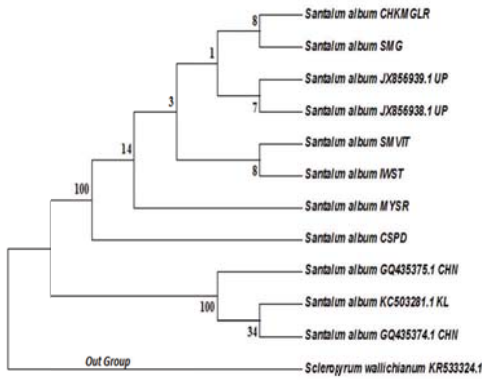


Fig.3 The Neighbour Joining Tree obtained from the *trnH-psbA*region of multiple *Sanatlum* accessions; Numbers on the branch is bootstrap percentage

IV. DISCUSSIONS

Study of shoot regeneration from inter-nodal explants of *Santalum album* done by Janartham and Sumathi [12] using BA ,Kn and 2-ip. This study reported plantlets regeneration in 45 days .however the present study with hormone combination of NAA , 2,4-D and Kn resulted in rapid shoot generation in relatively short period. Being a hemi-root parasitic plant *Santalum album* has always posed greater challenges in *in vitro* propagation [13,14]. The very few optimized protocols for *invitro* propagation are very promising towards mass regeneration of elite germplasm and disease free plants to satisfy the consumer demand for sandalwood products globally [15].

Study of phylogeny and biogeography of the sandalwoods done by Harbaugh and Baldwin [16], proposed based on congruent trees of maximum parsimony , maximum likelihood, and Bayesian methods support an origin of *Santalum album* in Australia. A large scale phylogenetic analysi on Indian varieties of *Santalum album* and comparison with world varieties will provide better insights on the origin of this species in India and its evolution in Indian biogeography. Genetic diversity analysis of *Santalum album* is also lacking data, where we find hardly few reports [17]. A large scale genetic diversity analysis will help to identify elite varieties which can be conserved and mass propagated using the *invitro* techniques. There is also scope to evaluate stress to evaluate stress induced response of essential oil production in such elite varieties to enhance the oil synthesis.

V. CONCLUSIONS

The present study concludes that, the MS medium with optimum concentrations of NAA, 2,4-D and Kn used in our protocols were responsive to induce multiple shoots in *Santalum album*. With further slight optimization, these protocols can be applied for large scale propagation in future to meet the demand for better quality plantlets.The sequences of chloroplast *trnH-psbA* intergenic spacer from *Santalum album* varieties can be used as a potential DNA barcode to identify *Santalum album* varieties in global market. The Phylogenetic analysis carried out using chloroplast *trnH-psbA* intergenic spacer sequences aid in determining evolutionary relationships among the biogeographic variants.

ACKNOWLEDGMENT

The authors acknowledge the support of KSCST, Bangalore, Sri Krishnadevaraya Educational Trust (Sri KET), Bangalore, Dr M S Indira, Principal, Sir M Visvesvaraya Institute of Technology, Bangalore and Dr H G Nagendra, HOD, Department of Biotechnology, Sir M Visvesvaraya Institute of Technology, Bangalore.

REFERENCES

[1] S.K. Ghosh, M. Balasundaran, and M.I.M. Ali, "Studies on spike disease of Sandal," *KFRI Research Report* No. 25, 15p,1985.

[2] K. H. Shankaranarayana, G. Ravikumar, C. R. Rangaswamy, and K. S. Theagarajan, "Sandalwood, HESP and ESPO Oils from the Heartwood of Santalum album L.*" in ACIAR proceedings, Australian Centre for International Agricultural Research*, pp. 89-92,1998.

[3] F. H. Mc Kinnell, "Status of management and silviculture research on Sandalwood in Western Australia and Indonesia.*," In Proceedings of the Symposium on Sandalwood in the Pacific* , 1990.

[4] A. Rugkhla, "Somatic embryogenesis and plantlet formation in Santalum album and S. spicatum", *Journal of Experimental Botany*, vol. 49, no. 320, pp. 563-571, 1998.

[5] J.Shaw, E.B. Lickey, E.E. Schilling, R.L. Small, "Comparison of whole chloroplast genome sequences to choose noncoding regions for phylogenetic studies in angiosperms: the tortoise and the hare III", *American journal of botany,* vol. 94, No. 3, pp. 275-88, Mar 2007.

[6] W.J.Kress, D.L.Erickson, "A two-locus global DNA barcode for land plants: the coding rbcL gene complements the non-coding trnH-psbA spacer region", Plos one, Vol. 2, No.6, pp. e508, Jun 2007.

[7] J.J. Doyle, L.J. Doyle, "Isolation of plant DNA from fresh tissue", *Focus*, Vol. 12, pp. 13-15, 1990.

[8] D. Bellstedt, M. Pirie, J. Visser, M. de Villiers and B. Gehrke, "A rapid and inexpensive method for the direct PCR amplification of DNA from plants", *American Journal of Botany,* 2010.

[9] T. Sang, D. Crawford, T. Stuessy, "Chloroplast DNA phylogeny, reticulate evolution, and biogeography of Paeonia (Paeoniaceae)", *American Journal of Botany,* Vol. 84, No. 8, pp. 1120-.1136, Aug 1997.

[10] K, Tamura, G, Stecher, D. Peterson, A. Filipski, S. Kumar, "MEGA6: molecular evolutionary genetics analysis version 6.0", Molecular biology and evolution, mst197, Oct 2013.

[11] N. Saitou, M.Nei, "The Neighbor-joining Method: A New Method for Reconstructing Phylogenetic Trees'," Mol. Biol. Evol., vol. 4, no. 4, pp. 406–425, 1987.

[12] E. Sumathi and B. Janarthana, "High frequency shoot regeneration from Internodal Explants of Santalum album L," *International Journal of Botany*, vol. 7, no. 3, pp. 249–254, Mar. 2011.

[13] G. Lakshmi Sita, N. V. Raghava Ram, and C. S. Vaidyanathan, "Differentiation of embryoids and plantlets from shoot callus of sandalwood," *Plant Science Letters*, vol. 15, no. 3, pp. 265–270, Jul. 1979.

[14] P. S. Rao and V. A. Bapat, "Vegetative propagation of sandalwood plants through tissue culture," *Canadian Journal of Botany*, vol. 56, no. 9, pp. 1153–1156, May 1978.

[15] Mujib, Abdul. "In vitro regeneration of Sandal (Santalum album L.) From leaves", *Turkish Journal of Botany*, vol 29, no. 1, pp 63-67, 2005.

[16] D. Harbaugh and B. Baldwin, "Phylogeny and biogeography of the sandalwoods (Santalum, Santalaceae): repeated dispersals throughout the Pacific", *American Journal of Botany*, vol. 94, no. 6, pp. 1028-1040, 2007

[17] S. Azeez, Abdul, R. Nelson, A. Prasadbabu, and M. Srinivas Rao. "Genetic diversity of Santalum album using random amplified polymorphic DNAs."A*frican Journal of Biotechnology* 8, no. 13, 2009.

Laterite Soil as A Binder in Concrete

Manjunatha M[#1], Gururaj Acharya.[#2], Shaik Kabeer Ahamed[#3]

[#]*Assistant Profesoor, Department of Civil Engineering,*
NMAMIT, Nitte, Karkala, Udupi, Karnataka - 574110, Affiliated to VTU, Belgaum.
[1]manjum@nitte.edu.in
[2]rajnitte@nitte.edu.in
[3]kabeer@nitte.edu.in

***Abstract*—Concrete is a major resources using worldwide in several infrastructural projects. In this experimental work, the laterite soil is used as binder material and partially replacing the cement up to 15%. The fresh properties and hardened properties of concrete specimen with laterite soil were studied. The compressive strength of cubes at 28 days is increasing at all replacement level when compared with referral mix compressive strength. The split tensile strength is maximum at 10% replacement level when compared with referral mix split tensile strength. The studies shows that the post-heat laterite soil shows slight decrease in compressive strength when compared with not-heated laterite soil concrete specimen.**

***Keywords*—Compressive strength, Split tensile strength, Laterite soil, Workability, Aggregates.**

I. INTRODUCTION

Concrete is the second largest materials consumed around globe after the water. The concrete exhibit various properties in hardened states such as strength, durability and fire resistance. Nowadays due to rapid development in the country, the construction industries are facing scarcity of natural resources such as river sand and coarse aggregate, also the burden on the raw materials used in the manufacturing of cement.

In [1] this research study, the authors concluded that the compressive strength, flexural strength and split tensile strength increases at 20% replacement of natural sand with laterite soil. It is observed that [2] by introduction of laterite content into the concrete matrix is found to reduce the workability of the mix. This is due to finesse of laterite which ultimately increases the total surface area of concrete and consequently, more water is required to wet the surface of aggregate. From the observation [3], the compressive strengths of laterite-cement mix increased with increase in percentage of cement content up to 20% but decreased at cement contents above 20%.

II. SCOPE OF RESEARCH

These experimental research work has taken up to investigate the strength properties of concrete by partially replacement of cement with laterite soil and compare the results with referral mix.

The objective of the research work is:

1. To study the fresh properties of concrete with various percentage of laterite soil.
2. To study the mechanical properties such as compressive strength and split tensile strength with various percentage of laterite soil (With and without heat of laterite soil).

III. EXPERIMENTAL PROGRAM

The properties of constituent's materials of concrete (M20) are discussed in this section:

A. Cement

The cement is the main ingredient of concrete is used as a binder material, setting starts when cement contacts with water. The cement plays vital role in concrete material to attain required strength and durability. The Ordinary Portland Cement (OPC) is used and it conforms to IS: 12269-1987.

TABLE I
PHYSICAL PROPERTIES OF ORDINARY PORTLAND CEMENT (OPC 53 GRADE)

Sl.No.	Characteristics	Unit	Test results	Requirement as per IS: 12269–1987
1	Setting time			
	Initial Set	Minute	90.00	Min 30.00
	Final Set	Minute	250.00	Max 600.00
2	Compressive Strength			
	3days	MPa	35.00	Min 27.00
	7days	MPa	51.00	Min 37.00
	28days	MPa	63.50	Min 43.00
3	Standard	%	35.00	-
4	Specific	-	3.15	-

B. Coarse aggregate

The crushed stone aggregates of 20 mm size obtained from local quarry site were used for the present research work. The

specific gravity of the coarse aggregates were found to be 2.7. The water absorption values obtained for the aggregates is 0.5%.

C. Natural sand

The natural sand was locally procured and conformed to grading zone III as per IS: 383-1970. The table 2 shows the properties of natural sand.

TABLE II
PROPERTIES OF NATURAL SAND

Sl. No.	Characteristics	Value
1	Type	Natural
2	Specific gravity	2.6
3	Water absorption	2.%
4	Grading zone	Zone III

D. Laterite soil

The laterite soil sample is collected from a quarry and sieved using 150 micron sieve. The fine laterite soil dust size less than 150 microns is used in the concrete. The chemical composition of laterite soil varies widely based on genesis, climatic conditions and age of laterization. Some lateritic soil contain more than 60% Fe_2O_3 and little of Al_2O_3 and where as some contain more than 60% SiO2 and little of Al_2O_3 and Fe_2O.

TABLE III
CHEMICAL PROPERTIES OF LATERITE SOIL

Sl. No.	Parameters	% by mass
1	Silicon dioxide	19.21
2	Calcium oxide	0.28
3	Magnesium oxide	0.6
4	Alumina	23.35
5	Ferric oxide	36.25
6	Sulphuric anhydride	0.069
7	Loss on ignition	14.36
8	Sodium	0.12
9	Potassium	0.43
10	Chloride	0.018

E. Water

Water is the most important constituent of a concrete mass which enables bonding between cementatious materials and the aggregates and also helps in the hydration of cement which is the most important phenomenon in gaining strength. Potable water which is free from salts and impurities is used for mixing and also curing purposes.

F. Mix design

The concrete mix is designed based on IS: 10262-2009. The mix proportions of M20 grade of concrete is 1:1.3:2.4 with water to cement ratio of 0.45. The Ordinary Portland Cement is partially replaced with lateritic soil at 5%, 10% and 15%.

IV. METHODOLOGY AND DISCUSSION

The calculated amount of concrete ingredients were weighed and mixed thoroughly in concrete mixer till the homogeneous mix is achieved. The cubes of 150 mm size, cylinder of 150 mm. diameter and 300 mm length were casted and cured for 7days and 28days. Total eighteen cubes and eighteen cylinders with varying percentage of cement by lateritic soil were tested at room temperature.

G. Compressive strength test

The compressive strength test was carried out on universal testing machine of 200 MT capacity as shown in fig. 1. After curing periods, the hardened concrete specimens were tested for 7 days and 28 days. The results of concrete specimen with various percentage of lateritic soil is compared with referral mix.

Fig. 1 Compressive Strength Test

H. Split tensile strength

The cylinder specimen were tested for split tensile strength after curing periods of 7days and 28days on universal testing machine of 200MT capacity as shown in fig. 2.

Fig. 2 Split Tensile Strength Test

I. Observation

The following graphs shows the test results of the hardened concrete for 7days and 28days:

TABLE IV
MECHANICAL PROPERTIES OF REFERRAL MIX

Sl. No.	Compressive Strength in N/mm^2		Split Tensile Strength in N/mm^2	
	7 days	28 days	7 days	28 days
1	24.78	40.8	2.5	4.6

The Table 4 shows the compressive strength and split tensile strength of concrete without laterite soil. The compressive strength at 7 days and 28 days is 25.78 N/mm^2 and 40.8 N/mm^2. The split tensile strength at 7 days and 28 days is 2.5 N/mm^2 and 4.6N/mm^2.

TABLE V
COMPRESSIVE STRENGTH OF M20 GRADE CONCRETE WITH LATERITE SOIL (LATERITE SOIL WITHOUT HEAT)

Sl. No.	% Laterite Soil	Compressive Strength in N/mm^2	
		7 days	28 days
1	5%	20.8	45.76
2	10%	29.4	49.68
3	15%	23.5	46.7

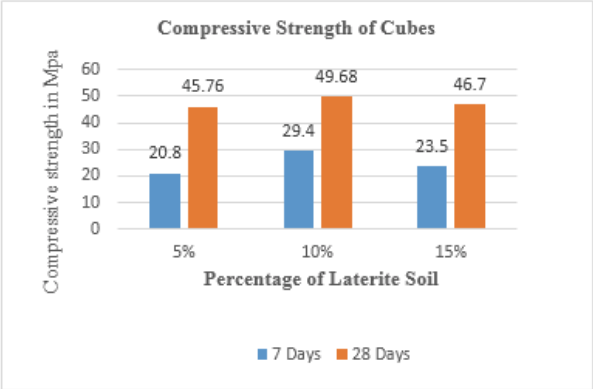


Fig. 3 Compressive strength of cubes at 7 days and 28 days with laterite soil

The Table 5 and Fig. 3 shows the variation in compressive strength of concrete specimens with various percentage of laterite soil (Laterite soil without heat). There is slight increase in compressive strength at 7 days and 28 days at 10% replacement of cement by laterite soil is 29.4 N/mm^2 and 49.68 N/mm^2. The compressive strength at 5% and 15% replacement for 7 days it shows 20.8 N/mm^2 and 23.5 N/mm^2 and for 28 days it shows 45.76N/mm^2 and 46.7 N/mm^2. There is slight decrease in compressive strength at 15% replacement when compared with 10% replacement.

TABLE VI
COMPRESSIVE STRENGTH OF M20 GRADE CONCRETE WITH LATERITIC SOIL (LATERITE SOIL HEATED UP TO 250^{0}C FOR 4HR)

Sl. No.	*% Laterite Soil*	*Compressive Strength in N/mm^2*	
		7 days	*28 days*
1	5%	25.5	41.96
2	10%	30.8	43.5
3	15%	27.6	42.1

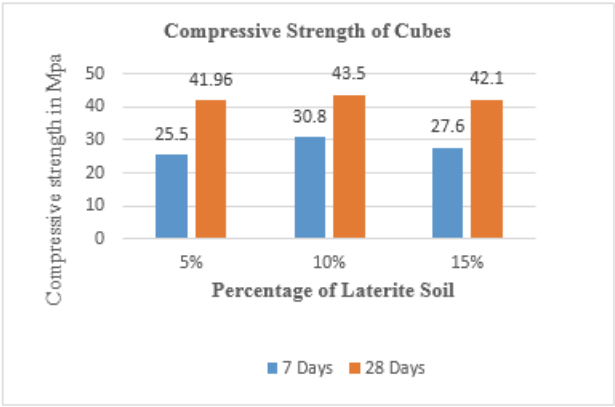


Fig. 4 Compressive strength of cubes at 7 days and 28days with laterite soil (Laterite soil heated up to 250^{0}C for 4hr)

The Table 6 and Fig. 4 shows the variation in compressive strength of concrete specimens with various percentage of laterite soil (Laterite soil with heated up to 250^{0}C for 4hours duration). There is slight increase in compressive strength at 7 days and 28 days at 10% replacement of cement by laterite soil is 30.8 N/mm^2 and 43.5 N/mm^2. The compressive strength at 5% and 15% replacement for 7 days it shows 25.5 N/mm^2 and 27.6 N/mm^2 and for 28 days it shows 41.96 N/mm^2 and 42.1 N/mm^2. There is slight increase in compressive strength at 15% replacement level when compared with 5% replacement level.

TABLE VII
SPLIT TENSILE STRENGTH OF M20 GRADE CONCRETE WITH LATERITE SOIL

Sl. No.	*% Laterite Soil*	*Split tensile Strength in N/mm^2*	
		7 days	*28 days*
1	5%	2.5	4.5
2	10%	2.54	4.7
3	15%	2.4	4.44

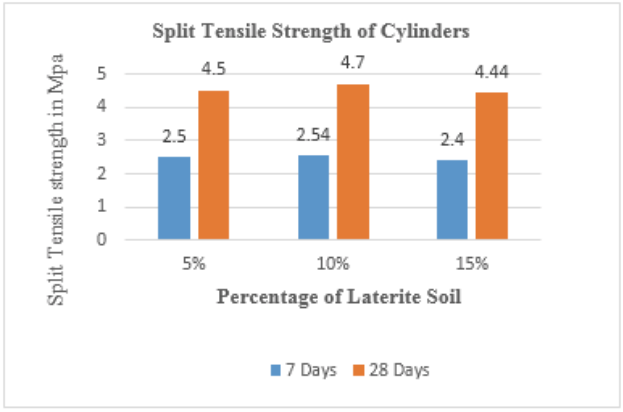


Fig. 5 Split tensile strength of cubes at 7 days and 28 days with laterite soil

The Table 7 and Fig.5 shows the variation in split tensile strength of concrete specimens with various

percentage of laterite soil (Laterite soil without heat). There is slight increase in split tensile strength at 7 days and 28 days at 10% replacement of cement by laterite soil is 2.54 N/mm^2 and 4.7 N/mm^2. The split tensile strength at 5% and 15% replacement for 7 days it shows 2.5 N/mm^2 and 2.4 N/mm^2 and for 28 days it shows 4.5 N/mm^2 and 4.44 N/mm^2. There is slight increase in split tensile strength at 10% replacement level when compared with 5% replacement level.

TABLE VIII
SPLIT TENSILE STRENGTH OF M20 GRADE CONCRETE WITH LATERITIC SOIL (LATERITE SOIL HEATED UP TO 250^{0}C FOR 4HR)

Sl. No.	% Laterite Soil	Compressive Strength in N/mm^2	
		7 days	28 days
1	5%	2.6	4.58
2	10%	2.68	4.9
3	15%	2.5	4.5

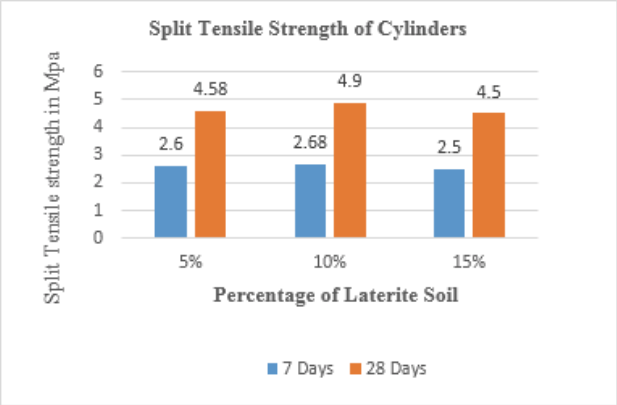


Fig. 6 Split tensile strength of cubes at 7 days and 28days with laterite soil (Laterite soil heated up to 250^{0}C for 4hr)

The Table 8 and Fig 6 shows the variation in split tensile strength of concrete specimens with various percentage of laterite soil (Laterite soil with heated up to 250^{0}C for 4hours duration). There is slight increase in split tensile strength at 7 days and 28 days at 10% replacement of cement by laterite soil is 2.68N/mm^2 and 4.9N/mm^2. The split tensile strength at 5% and 15% replacement for 7 days it shows 2.6N/mm^2 and 2.5N/mm^2 and for 28 days it shows 4.58N/mm^2 and 4.5N/mm^2. There is slight increase in split tensile strength at 10% replacement level when compared with 5% replacement level.

V. CONCLUSIONS

From the above observation, we can conclude that the compressive strength of concrete cubes specimen at all replacement level of cement with laterite soil shows slight increase in compressive strength when compared with referral mix. The cylinder specimen at 10% replacement level shows increasing in split tensile strength when compared with referral mix. The post-heat laterite soil in concrete shows slight decrease in compressive strength when compared with not-heated laterite soil in concrete and referral mix, but shows slight increase in split tensile strength when compared with not-heated laterite soil cylinder specimen. Further research work needs to be conducted to study the durability properties of concrete with laterite soil.

REFERENCES

[1] Biju Mathew, C. Freeda Christy, Soumya, Benny Joseph, "Study on Strength of Concrete by Partial Replacement of Fine Aggregate with M-Sand and Laterite with Super plasticizers," *International journal of Engineering Trends and Technology*, vol. 38, No. 8, pp. 413-416, 2016.

[2] Tanvir Asif Zerdi, Sayyad Saddan Hussain, Syed Zeeshan Ali, Qizari Ansari, "Suitability of Using Laterite as Partial Replacement of Fine Aggregate in Concrete", *Indian Journal of Applied Research,* Vol. 06, No.5, pp. 705-707, 2016.

[3] James Isiwu Aguwa, "Study of Compressive Strength of Laterite-Cement Mixes as a Building Material," *AU J.T.*, vol. 13, No.2, pp. 114-120, 2013.

[4] IS 383: Specification for coarse and fine aggregates from natural sources for concrete,1970.

[5] IS 10262: Concrete mix proportioning – guidelines, 2009.

Smart Surveillance System Using Wireless Sensor Networks: A Survey

Asthik Shet[#1], Akarsh V Kumar[#2], Deeksha S[#3], Deeksha S Kotian[#4], K. S. Shivaprakasha[#5]

[#]*Department of Electronics and communication Engineering,*
NMAMIT, Nitte, Karkala, Udupi, Karnataka - 574110, Affiliated to VTU, Belgaum.
shivaprakasha.ks@nitte.edu.in

***Abstract*—Wireless Sensor Networks (WSN) have become an emerging field in the modern communication system because of its ease of implementation. These networks comprise of hundreds of densely deployed sensor nodes which works through collaboration. In this paper we concentrate on the military applications of WSNs. Here we try to look into the different modules of a sensor node. We aim to present a qualitative analysis of the various systems proposed for military applications using WSN.**

***Keywords*—Nuclear, Biological, Chemical attack, CMOS Processor, transceiver, sensor unit.**

I. INTRODUCTION

Innovations in the field of sensor technology has evolved WSN as a promising solution to the modern communication problems. WSN poses many challenges. Resource constraint is one such problem. WSN finds applications in various fields including agriculture, military, biomedical, home automation, environmental and industrial applications. In this paper, we will be dealing with the military applications and surveillance system.

WSNs are used in battlefields for surveillance applications. They are deployed to monitor the critical areas where human interventions risk lives. Various sensors deployed in the field of interest collect the information about the enemy attack and the same can be conveyed to the central entity or the Base Station (BS). The sensor network thus deployed can be used to detect Nuclear, Biological and Chemical (NBC) attacks. Thus threats can be detected and an alert message can be sent to the military base. Another application of WSN in the field of battlefield is to track the military vehicles. The position and relative speed of the vehicle can be estimated using the sensors deployed.

WSNs operate on batteries. The concern here is that the battery technology should be improved enough to support the sensors. It must be long lasting and sustain harsh conditions. Coming to other modules such as sensors, transceivers and processors, it should match the military standards. Stability and durability will be the key factors which will decide the working of the system. Security too plays an important role. Confidential data should be exchanged without any third person intervention. Looking into all these aspects a sensor network is to be designed.

The paper is divided into following subparts: Section II gives an insight into different processors used in WSNs. Section III highlights various sensors used for the designs. Section IV gives an exhaustive list of transceivers used for communication. Section V details the energy sources used in WSN applications. Finally Section VI gives the concluding remarks.

II. PROCESSOR

Processing Unit is the heart of a sensor node. Every processor unit is associated with sensors, processor and a memory element. Processors manage the protocols to carry out the tasks of processing the sensing information that can be sent to the central entity in collaboration with the neighbouring nodes. The information sensed by the sensors will be in analog domain that have to be converted into a digital signal using ADC before feeding to the processor unit. The raw data thus received will be processed and the partially processed data will be then conveyed to the next hop. The processors embedded in the nodes of WSNs are generally less sophisticated and thus are unable to process complex cryptographic algorithms [1, 2].

Following are the processing units used in WSNs.

A. FPGA

Field Programmable Gate Arrays are Programmable Logic Devices. They have the advantage of being reprogrammable and reconfigured. They offer very low NRE (nonrecurring engineering) cost. But they consume more power and also not very compatible to the programming methodologies [1].

Ex: Cool Runner II

B. CMOS Processors

Limitations of cost and size in WSN lead us to the choice of CMOS technology for the processing. For every time the switch is on, CMOS transistor pair draws the power. Switching frequency, device capacitance and voltage swing are all proportional to switching power. This causes increase in the power consumption. One of the effective ways of lowering the power consumption is to reduce the supply voltage.

For data encoding and decoding we require an additional external circuitry [3].

C. Microcontrollers

Microcontroller is a computer that contains a processor, non-volatile memory, ADCs, UARTs, counters and timers. They are small in size compared to regular computers. There are many types of microcontrollers ranging from 4 to 32 bit. Given below is the classification of microcontrollers that can be used in Sensor Network design [4].

Atmel: This is one of the most important and popular microcontrollers used in WSNs. They support simpler OS. Mica Mote (Crossbow) is an example of WSN device with Atmel microcontrollers.

Cypress: The internal pins and components of this controller can be reconfigured. Free software packages are also provided for the developers which are useful when we are dealing with USB.

Microchip:They manufactures PIC microcontrollers that are relatively less expensive. These are mainly used in industrial development due to their low cost. They have serial programming capability. We can set the priority levels to the interrupts.
Ex: Hoarder Board, Pico Crickets

Panasonic: They too offer a variety of microcontrollers suitable for WSN applications. Examples: Panasonic WM64PNT

TI:It is one of the low power consuming processors available in the market. It is ideal for wireless applications and embedded systems. The MSP430 is a 16-bit RISC processor. It offers 27 core instructions and 7 addressing modes. There are six different power modes available. Wakeup time is 6 s with the use of a digital oscillator.

NXP: They are designed advanced microcontrollers. Their processors are of power architecture and ARM architecture.

III. SENSOR UNIT

WSNs use sensors to sense some physical entities from the environment. Sensors are hardware components that for a change in a physical condition produces a measurable change. They have certain specific characteristics such as accuracy, sensitivity etc. for measuring physical data of the parameters to be monitored. An analog-to-digital converter is used to digitalize the continuous analog signal produced by the sensor before sending it to the controller for further processing. Sensor nodes are generally small in size, consume less power, densely deployed, adaptive and can operate unattended.

Sensors are classified into three categories:

- Passive omni-directional sensors
- Passive narrow-beam sensors
- Active sensors.

In passive sensing, the data is sensed without active probing. Here the energy is needed just to amplify the signal.

On the contrary, in active sensing there is active probing of the environment. Thus they require power continuously from a source.

Narrow-beam sensors have a notion of the direction of measurement whereas omni-directional sensors have no notion of direction involved in their measurements.

Passive omni directional antennas are used in most of the WSN applications. For every sensor node there will be a certain area of coverage in which they can be reliable.

There are many parameters that consume power in sensor nodes. Sampling of signals, conversion of physical signals into an electrical quantity, signal conditioning, conversion from analog domain to digital domain are few such parameters.

Generally nodes are densely deployed in WSN with the spatial density may be as high as 20 nodes/ cubic meter.

Most of the sensors are passive devices, that is, they require external circuitry for biasing and amplifying the output signals. Based on the physical property measured, the sensors can be classified into

- Thermal
- Mechanical
- Magnetic
- Electrical
- Chemical and Bio-chemical
- Radiant

A. Mechanical Sensors

They detect mechanical properties and actions. These properties involves pressure, velocity, vibration and acceleration.

Pressure sensors:It is a type of the sensor where a corresponding electrical signal is generated depending upon the amount of pressure applied. There are many types of pressure sensors. However they are widely categorised as Piezoresistive pressure sensors [5], Capacitive pressure sensors and Optical pressure sensors.

Position and Motion Sensors: Position sensors are required in a large variety of WSN applications. They detect the position or movement of fixed or mobile object. There are many ways in estimating the position of an object. They can be either contact or contact free sensors. Position measurement can either be relative or absolute, linear or angular.

Accelerometers:These are a type of sensors that measures the acceleration of they are subjected to. There are many ways to accomplish the same. However the major set of accelerometers are based on resistive, capacitive and piezoelectric methods [6].

B. Temperature sensors

These are a set of sensors whose physical parameters like resistance or the output voltage is varied in accordance with the change in the temperature. They are classified as electronic, electro-mechanical and themo- resistive [7].

C. Humidity sensors

Humidity is defined as the water content in the air. The measurement of humidity of the air can be done in three ways namely: absolute humidity, relative or dew point.

Generally the humidity sensors are base on capacitive, resistive, and thermal conductivity measurement techniques [8].

D. Chemical sensors

Chemical sensors are used to determine the presence of the chemical elements or compounds in the area of interest. They generally contain a chemically sensitive film and a transducer. When a particular element comes in contact with the sensitive film, a chemical reaction occurs in or on the chemically sensitive film. This results in the generation of a corresponding signal from the transducer. They are generally used in medical, industry and military applications [9].

IV. TRANSRECEIVERS

A WSN node is designed to perform functions like sensing the physical entities, processing the raw information to extract data of interest and to store the extracted information before transmission [10, 11]. The data is communicated through the network and is then passed to the main station. Wireless communication is always handy as it reduces the wires in a system.

A transceiver is a device that helps in Wireless communication, between the sensor node and the BS. In this section we introduce different wireless devices used for communication between node and the BS.

A. Zigbee

Zigbee was conceived in the year 1998 and standardized in 2003. It is an IEEE 802.15.4 international standard based wireless technology designed to address the needs of device to device communication. It is cheap compared to Wi-Fi and Bluetooth. It has two interfaces, one is connected to the coordinator and the other to the host computer. Military security, environment monitoring and home automation are few places where this is used.

B. Bluetooth

Bluetooth is a short range communication technology that is less expensive and consumes small power. The use of Bluetooth helps to utilize many features of Bluetooth enabled devices for short range data transfer from fixed or mobile devices. Bluetooth can be deployed in WSNs. Bluetooth standard includes both link layer and application layer definitions for product developers [12, 13].

C. UWB (Ultra-Wide Band)

UWB is a short range wireless technology that is used to transmit large amount of data in digital domain over a wide frequency spectrum. It consumes less power. This is the earliest form of radio communication. It has been recognized as a feasible technology for WSN due to its very good time-domain resolution that allows precise location [14]. It adopts an extremely narrow pulse and extremely wide frequency spectrum.

D. Wi-Fi

It is a technology developed by Wi-Fi Alliance that allows devices to be connected to a wireless LAN. It is an IEEE 802.11 standard. The concern here is about the security. Wi-Fi can easily be hacked and misused. It can be protected using WPA2 encryption and other techniques. Access point of the user can be hidden by disabling SSID (Service Set Identifier) broadcast [12].

Table I gives a comparative study of various transmission technologies used in WSNs.

TABLE I
COMPARATIVE STUDY OF DIFFERENT WIRELESS COMMUNICATION TECHNOLOGIES

Standard	Bluetooth	UWB	ZigBee	Wifi
Range	10m	10m	70m-300m	100m
Complexity	Complex	Moderate	Simple	Very complex
Data Rate	1Mbps	480Mbps	250Kbps	11Mbps
No of RF channels	79	1-15	16	14
Channel Bandwidth	1MHz	500MHz-7.5GHz	0.3/0.6MHz, 2MHz	22MHz
Modulation type	GFSK	BPSK,QPSK	BPSK,OQPSK	CCK,QPSK
Encryption	EO stream cipher	AES block cipher	AES block cipher	RC4 stream cipher
Data protection	16-bit CRC	32-bit CRC	16-bit CRC	32-bit CRC

V. POWER UNIT

Energy or power unit is a crucial part of a WSN. Batteries continuous power supply can be used based on the location of the mote. In isolated places where human intervention is difficult, batteries that last long are used. They should be of optimal size and supply enough power to the sensors, so that there is no problem of replacing the batteries every now and then. Motes close to camps and stations can be supplied with continuous power supply. Criteria for a good battery are that it should last long and weigh less. It should be leak proof and sustain under harsh weather conditions.

A. Primary Energy Source

The predominant means of providing power to sensor nodes is through the electrochemical energy stored in the batteries. The battery should sufficiently provide energy to the sensor node when in use. The features that guide us on which battery can be selected are listed below [15].

A good battery should posses the following quality features to sustain:-
1) High energy density
2) Small cell potential
3) Active to packaging volume ratio should be high
4) Rechargeable
5) Life Cycle of the Battery

A battery has few parameters that describes its characteristics. Few of the mainly considered parameters for a purpose are as shown in Table II.

TABLE II
PARAMETERS OF A BATTERY [16]

Voltage	Potential of the Cell (Battery)
Capacity	The amount of electrical charge that can be stored.
Specific Energy	It is the volume content measured in energy/weight.
Internal resistance	Opposition offered by the internal components of the battery.
Self-discharge	The internal leakage or unwanted draining.
Charging procedure	Type of charging circuit required.

B. Energy from Other sources

These energy sources play an important role in power supply but all of these constitute only for a fraction of the energy consumed by the sensor nodes. Sensing, aggregating and storing the information requires high energy efficiency. Thus the energy harvesting circuit must be active at all times. It should provide the output in accordance with the application requirement. The power consumed by the harvester shall be minimal. Usage of capacitors may lead to lower the battery impedance.

Common energy ambient sources for energy harvesting are as shown in Table III.

TABLE III
DIFFERENT ENERGY SOURCES

Energy type	Source
Mechanical energy	Vibration, stress and strain
Thermal energy	Furnaces, heat sources
Solar energy	Sun
Electromagnetic energy	Inductors, coils and transformers
Wind energy	Wind, Air
Chemical energy	Radioactive substances

C. Batteries

Batteries in [17] are classified into two categories namely micro and macro scaled.

Macro scaled
It is further classified as Primary and Secondary. Primary- These batteries have high energy density but their lifetime is very short. Used in circuits where a constant, relatively high power is required. Ex: Zinc-air batteries

Secondary- They are Rechargeable batteries. To charge these another primary source is required. Solar energy is one such kind which can be used to harvest energy and store it in these secondary batteries.

Micro scaled
Achieving the battery compactness is not as efficient as that of electronic circuits. The battery technology is an issue where a lot of developments and changes can be bought indeed to optimize the size and power rating of the batteries. Power output because of the surface area limitations is the major obstacle in reducing the battery size. Surface area of the electrodes affects the maximum current output of the battery. As the micro-batteries are small in size, so as the surface area of the electrodes. Thus the maximum current output would be small. Many batteries are available in the market which offer varied combination of specifications.

A comparison of few widely used batteries and their features are presented in the Table IV.

TABLE IV
DIFFERENT BATTERIES AND THEIR PARAMETERS [16]

Type	Voltage	Capacity	Specific energy	Self-discharge
Lead acid	2.0 V	500Ah-1500Ah	30-40 Wh/kg	3-20%/ month
Nickel Cadmium	1.2V	400Ah-1200Ah	30-80 Wh/kg	15-20%/ month
Lithium Ion	3.6V	1200Ah	160 Wh/kg	5%/ month
Lithium polymer	3.7V	1200Ah-4000Ah	130-200 Wh/kg	1-2%/ month

D. Energy Efficient sensor management

The best possible way is to record data with a given sampling frequency [18].

The major approaches used for achieving minimal energy consumption in a sensor node are as follows:
1. Duty cycling – It is a technique in which the sensor nodes are active only when it has the data to sense. Soon after sensing, it is turned off and thus saving energy. Here the sampling rate should be accurate. Oversampling leads to waste of energy and under sampling leads to loss of data.
2. Adaptive sensing strategy – In this method the activity of the node is adjusted in accordance with the real time situations. However proper care should be taken in designing the software modules of the sensors.

Duty cycling and adaptive sensing approaches are complementary to one another. The system software has to provide a set of primitives to activate the sensor nodes as per the duty cycle requirement. Later the same primitives are used to acquire the data through adaptive sensing strategy.

E. Power Management

Generally sensor nodes operate in two modes viz: active mode where the sensor senses, processes and conveys the information and the idle mode in which the nodes would be inactive.

Obviously, active mode consumes more power. In idle state, the unused parts of the sensors can be switched off to avoid any power loss.

While designing, the energy problems are mainly classified at three tiers namely hardware, operating system and application. The techniques and approaches used to save power are:

a) Clock gating: It is one of the popular techniques which reduces dynamic power. Here static power is increased. In this method the clock is turned off to the inactive portions of the node. An appropriate control circuitry has to be devised for the same.

b) Power gating: In this technique, the power supply is shut down to the inactive portions of the sensor so as to conserve both static and dynamic power consumptions. However this technique requires more complex mechanism.

c) Voltage islands: If there are some slower blocks, they can be run at lower frequency and the supply voltage can be shut down till they meet the timing requirements.

d) Dynamic voltage frequency scaling: It is a combination of both power gating and voltage islands techniques.

e) Dynamic threshold voltage control: Here individual sets of transistors are dynamically controlled.

VI. CONCLUSIONS

From the above survey, it is clear that a variety of technologies and products are available for designing

sensor networks. Finally, the aim is to design an optimal one. Sensor networks have evolved highly in past few years and has the capability to grow in serving different fields. WSNs have many applications but we have concentrated over military applications. Precision and stability in the WSNs are key factors that determine the outcome of these networks. WSNs in the field of military applications need many more research activities to strengthen and build better networks since we are dealing with a sensitive and critical issue of security and safety.

REFERENCES

[1] Khemapech, Ittipong, Ishbel Duncan and Alan Miller. A survey of wireless sensor networks technology. *6th Annual Postgraduate Symposium on the Convergence of Telecommunications, Networking and Broadcasting*. Vol. 13. 2005.

[2] M. A. M Vieira., C. N. Coelho, D. C. Da Silva, , & J. M.Da Mata, Survey on wireless sensor network devices. In *Emerging Technologies and Factory Automation, 2003. Proceedings. ETFA'03. IEEE Conference,* Vol. 1, pp. 537-544, 2003.

[3] I. F. Akyildiz., Su, W., Y. Sankarasubramaniam, , E. Cayirci, Wireless sensor networks: a survey. *Computer networks*, Vol. 38*,* No.4, pp 393-422, 2002.

[4 Microcontrollers http://wsn.oversigma.com/wiki/index.php?title =Microcontrollers [Retrieved on 7th November 2016].

[5] M.Z. Shaikh, Dr. S.F. Kodad, Dr. B.C. Jinaga. A Comparative Performance Analysis of Capacitive and Piezoresistive MEMS for Pressure Measurement. In *International Journal of Computer Science and Applications* Vol.1, No.3, December 2008.

[6] Sensing Technologies used for Accelerometers. http://www.pcb.com/TestMeasurement/Accelerometers/Sensing_Technologies,[Retrieved on 16th November 2016].

[7] Common Temperature Measurement Sensors http://www.mstarlabs.com/sensors/temperature-sensors.html,[Retrieved on 16th November 2016].

[8] HumiditySensors http://www.engineersgarage.com/articles/humidity-sensor, [Retrieved on 16th November 2016].

[9] Zainab Yunusa, Mohd. Nizar Hamidon, Ahsanul Kaiser, Zaiki Awang. Gas Sensors: A Review. *In Sensors & Transducers*, Vol. 168, Issue 4, 2014.

[10] H. Karl and A. Willig, Protocols and Architectures for Wireless Sensor Networks, *John Wiley & Sons, New York*, 2005.

[11] A. Chandrakasan, R. Min, M. Bharadwaj, S-H. Cho and A. Wang, Power Aware Wireless Microsensor Systems, *European Solid-state Device Research Conference, Florence*, pp 24-26, 2002

[12] E. Ferro and F. Potorti, Bluetooth and Wi-fi wireless protocols: A survey and a comparison , *IEEE commun.*, Vol. 12, No.1, pp. 12-16, 2005.

[13] A. Rodzevski, , J. Forsberg, I. Kruzela, Wireless sensor network with Bluetooth. In *Smart Objects Conference (SOC'2003), Grenoble, France,* 2003.

[14] Weiwei, Wu, Wang Weidong, and Wei Guo. Wireless Sensor Network. *ZTE Communications, 2005*.

[15] F. Pistoia, Battery Operated Devices and Systems: From Portable Electronics to Industrial Products, *Elsevier, Amsterdam*, 2008.

[16] K. Stojcev Mile, and R. Mirko Kosanovi. Power management and energy harvesting techniques for wireless sensor nodes. *Telecommunication in Modern Satellite, Cable, and Broadcasting Services, 2009. TELSIKS'09. 9Th International Conference on*. IEEE, 2009.

[17] Roundy, Shad, Power sources for wireless sensor networks. *European workshop on wireless sensor networks*. Springer Berlin Heidelberg, 2004.

[18] Alippi, Cesare, Energy management in wireless sensor networks with energy-hungry sensors. *IEEE Instrumentation & Measurement Magazine,* Vol.12, No. 2, pp 16-23, 2009.

Influence of injector nozzle hole number and size on the performance of a supercharged direct injection diesel engine

Ravinarayana Bhat N.

Associate Professor, Department of Mechanical Engineering,

Srinivas Institute of Technology, Valachil, Mangaluru, Karnataka - 574143, Affiliated to VTU – Belgaum.

[1]ravinbhat74@gmail.com

***Abstract*—Diesel engine as a prime mover has witnessed tremendous growth in its application during the last century. Researchers across the globe have put lot of effort to increase the performance and improve the emission characteristics of it. It is well known that increasing the boost pressure of intake air or supercharging increases the power output of the internal combustion engines. In this paper, the performance of a direct injection diesel engine is discussed with different fuel injector nozzles having different number of holes of different nozzle orifice diameters under natural aspiration and supercharged conditions. It has been observed that the performance of the engine decreased with increased number of holes and larger nozzle holes under natural aspiration. However the performance of the engine has been found to be significantly improved under supercharged condition for all the injector nozzles. For 3 hole injectors at 80% load, the BTE has increased from 29.98% to 31.86% on supercharging, whereas for 4 hole and 5 hole injectors it increased from 11.48% to 19.24% and 20.49% to 27.16% respectively at the same load.**

***Keywords*—Diesel engine, fuel injector, nozzle hole, supercharging, performance**

I. INTRODUCTION

The rapid growth of automotive vehicle population and pressing need for increased mechanization of agricultural equipment due to the requirement of cost competitiveness along with ever-increasing shortage of labour force have resulted in exponential growth in the usage of Internal Combustion(IC) engines. The function of IC engine is to transform the chemical energy released by the combustion of fuel inside the engine cylinder into mechanical work. The German engineer Rudolf Diesel invented the diesel engine in which the combustion of the fuel is initiated by injecting the fuel into compressed air. These days diesel engines are the major source of energy in transport, stationary power plants and agricultural equipment [1, 2]. Diesel engines have proved to be superior to gasoline engines in terms of thermal efficiency, fuel consumption and throttling losses[3], that made the market share of diesel engines to exceeded 50% in some countries [2]. Furthermore, in terms of emissions also diesel engines are not inferior to the gasoline engines as far as carbon monoxide (CO) is concerned [3]. Today's engines require high power output, economy of operation with least pollutant emissions. Such specific demands have compelled the researchers to focus on improving the diesel engines in various aspects. Intake air pressure boosting or supercharging is a common way to improve the engine output power which is widely used in high performance Spark Ignition and Compression Ignition (CI) engine applications [4]. It is well known that supercharging improves the combustion process of Diesel engines [5]. Though the increase in intake air temperature due to supercharging reduces the unit air charge and also reduces the thermal efficiency moderately, the increase in the density due to the supercharging pressure compensates for the loss, and intercooling is not necessary except for highly supercharged engines[6]. Supercharging the reciprocating piston internal combustion engine is as old as the engine itself. Early on, it was used to improve the high-altitude performance of aircraft engines and later to increase the short term peak performance in sporty or very expensive automobiles. Later on it reached economic importance in the form of the efficiency improving exhaust gas turbocharging of slow and medium speed diesel engines. Today many demands are placed on automobile engines: on the one hand, consumers insist on extreme efficiency, and on the other hand laws establish strict standards for, e.g., noise and exhaust gas emissions. It would be extremely difficult for an internal combustion engine to meet these demands without the advantages afforded by supercharging [7].

The fuel injection system in a diesel engine, being responsible for supplying the metered quantity of fuel to the combustion chamber, is one of the most important systems. It meters the fuel delivery according to engine requirements, it generates the high injection pressure required for fuel atomization, for air-fuel mixing and for combustion and it contributes to the fuel distribution in the combustion system, hence it significantly affects engine performance emissions and noise [8]. The performance and emissions of diesel engine are greatly affected by the fuel atomization and spray processes, which in turn are strongly influenced by injector nozzle geometry [9, 10]. The number of holes in the fuel injector nozzle directly influences the spray parameters like

droplet size and penetration length and thus the combustion process [11]. The penetration length increases with increase the in line fuel pressure and it decreases with decrease in nozzle hole diameter [12]. Smaller injector nozzle orifices are believed to give smaller droplet size, even with reduced injection pressure, which leads to better fuel atomization, faster evaporation and better mixing [13]. Diesel nozzle geometry is considered a major issue in order to fulfil new stringent emissions regulations while maintaining or improving the efficiency of the engine [10].

Wang et al. [14] studied the influence of injector nozzle hole size on flame structure and soot formation of a diesel engine. They have carried out experiments in a high pressure, high temperature constant volume combustion vessel. High injection pressures of 100 MPa, 200 MPa and 300 MPa, and two injector nozzles with diameters of 0.16 mm and 0.08 mm were used. They have reported that with the conventional injector nozzle (0.16 mm), ultra-high injection pressure generated appreciably lower soot formation. With the micro-hole nozzle (0.08 mm), impinging spray flame showed much smaller size and lower soot formation at the injection pressure of 100 MPa. The soot formation was too weak to be detected with the micro-hole nozzle at injection pressures of 200 MPa and 300 MPa. Moon S. et al. [15] used the propagation based X-ray phase contrast imaging technique to visualize and compare the transient needle motion and near nozzle flow characteristics of the single and multi hole(3-hole and 6-hole) diesel injectors in various injection stages during the entire injection event. Yao et al.[10] used five kinds of single-hole cylindrical injectors which have different orifice diameters (0.13–0.23 mm) and lengths (0.7–1.0 mm) to investigate the effects of the nozzle geometry on spray droplet size distribution and corresponding combustion characteristics. The spray droplet size spatial distribution was measured with the Phase Doppler Particle Analyzer. They have reported that the Sauter Mean Diameter (SMD) reduces with the increase of the distance from injector tip and the SMD of the central axis was bigger than that of the periphery. With the increase of the injection pressure (40–120 MPa), the spray SMD decreased significantly. Results showed that different orifice diameters and lengths greatly affect the spray atomization, and then change the combustion and emissions characteristics. Montgomery et al. [16] investigated the effects of number and size of injector nozzle hole on the emissions of a direct injection diesel engine. They used four different injector nozzle hole size and number combinations and reported that the best emissions and second best brake specific fuel consumption were obtained with the nozzle with the maximum number of holes. Sayin et al. [11] have investigated the effects of fuel injector nozzle hole number and size on the performance and exhaust emissions of a diesel engine with biodiesel diesel blends as fuel. They have concluded that the best engine performance and exhaust emissions were obtained with highest injector nozzle hole number for the biodiesel fuel. Varghese et al. [17] have conducted experimental study to find out the effect of fuel injector nozzle hole diameter on diesel engine performance using Karanja oil- diesel blends. They have used injectors having three holes of different diameters and observed that the exhaust gas temperature and brake specific fuel consumption have increased with increase in nozzle hole size. Basavarajappa et al. [18] conducted experimental investigation on diesel engine operated on Uppage oil methyl ester with different combustion chamber shapes and fuel injectors with different number of holes as well as with varying orifice sizes. They used injectors with number of holes varied from 3 to 6 and the size of nozzle orifice varied from 0.18 to 0.3 mm and reported that the increased number of injector holes with reduced hole size resulted in overall improved performance with reduced emission levels.

With this background in the present work an attempt is made to find the effect of fuel injector nozzle hole size and number of holes in the injector nozzle on the performance of a single cylinder, four-stroke, stationary, direct injection diesel engine at different load conditions, under natural aspiration as well as supercharged conditions. Three fuel injectors with different number of holes and different nozzle hole sizes are considered for the experimental study.

II. EXPERIMENTAL SETUP AND PROCEDURE

The experiments are conducted on TV-1 model diesel engine manufactured by Kirloskar Oil Engine Ltd., India. It is a commercial four-stroke, constant speed, single cylinder, water-cooled, direct-injection diesel engine. It has a rated power of 5.2 kW at the rated speed of 1500 rpm and a compression ratio of 17.5. Its normal operating conditions are, fuel injection at 23^0 crank angle before Top Dead Centre (bTDC) and 190 bar fuel injection pressure. The engine has the cylinder bore diameter of 87.5 mm, stroke length of 110 mm, swept volume of 661.45 cm^3 and clearance volume of 41.09 cm^3. The engine is loaded by means of an eddy current dynamometer. A continuous circulation of cooling water is maintained through the engine jacket and dynamometer by means of a water pump. The cylinder gas pressure and fuel line pressure are measured using piezo sensors (Make: PCB Piezotronics, Model HSM111A22). The exhaust gas temperature is measured with the help of K-type Chromel-Alumel thermocouple with a range and resolution of $0\text{-}1000^0$C and 0.01^0C respectively. The air flow is measured using an orifice meter, connected to water manometer and the fuel flow is measured using a manometer and DP transmitter. A data acquisition system is connected to the engine for recording and processing of experimental data. The data sampling and recording are done using ICEngineSoft software. For the experiments under supercharged condition, two centrifugal air compressors (C1 and C2) are used, specifications of which are shown in Table 1. The output from the two compressors is fed to an air tank of 35 litre capacity, which is equipped with a pressure regulator to control the supercharging pressure. The general scheme of engine test bench and the experimental apparatus used is shown in Fig.1.

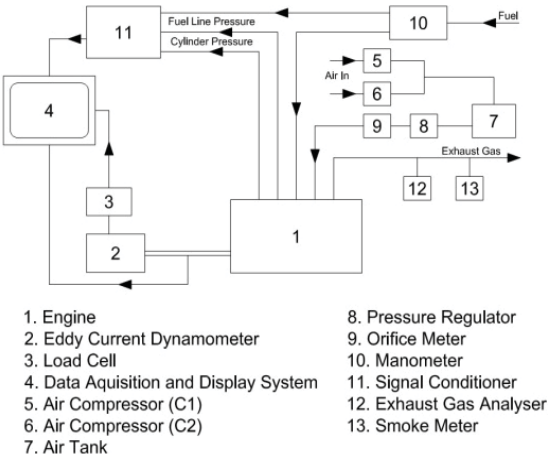


Fig. 1 Schematic diagram of experimental set up

The properties of diesel fuel are determined. The density was measured using Hydrometer as 827 kg/m^3, kinematic viscosity at 40^{0}C using viscometer (Cannon-Fenske) as 2.74 cst, caloric value using Bomb calorimeter (Make: Aditya) as 42,000 kJ/kg and flash point using Cleveland open cup tester (Make: Aditya) as 71^{0}C. The experiments were conducted with the normal conditions of 190 bar fuel injection pressure with fuel injection at 23^0 bTDC. All these experiments were conducted at the natural aspiration as well as supercharging conditions at 20%, 40%, 60%, 80% and 100% (full) load on the engine. An air inlet pressure of 100 kPa (gauge pressure) was maintained for supercharging condition. The parameters such as fuel consumption, air flow rate, cylinder gas pressure and temperature, exhaust gas temperature were recorded at different load conditions. Three different fuel injectors with 3, 4 and 5 holes of orifice diameters of 0.25 mm, 0.31 mm and 0.26 mm respectively have been chosen for the experiments. The total area of injector nozzle holes (orifice) with the 3, 4 and 5 hole fuel injectors are 0.1473 mm^2, 0.3019 mm^2 and 0.2655 mm^2 respectively.

TABLE I
SPECIFICATIONS OF THE COMPRESSORS USED

Specification	**Compressor C1**	**Compressor C2**
Make	ELGI	CEC
Power (HP)	2	3
Displacement Volume (lpm)	249	310
No. of cylinders	1	2
Speed (rpm)	2880	950
Tank Capacity (Litre)	100	200
Max. Working Pressure (kgf/cm^2)	10	12

III. RESULTS AND DISCUSSION

A. Brake thermal efficiency (BTE)

BTE is a measure of efficiency with which the energy in the fuel is converted into mechanical work output. The variation of BTE with load on the engine for different fuel injectors is presented in Fig. 2 for both the natural aspiration and supercharged conditions. Here 3HN, 4HN and 5HN represent 3, 4 and 5 hole injectors respectively, at natural aspiration, whereas 3HS, 4HS and 5HS represent 3, 4 and 5 hole injectors respectively, at supercharged condition. It is evident from the figure that higher BTE was obtained for 3 hole injector for all the loads, followed by 5 hole injector and 4 hole injector, in the increasing order of their total nozzle orifice areas. This reduced BTE is attributed to the larger quantity of fuel injected with 4 hole and 5 hole injectors due to their relatively larger total nozzle orifice areas, resulting in insufficient oxygen and thus incomplete combustion. It is observed that, with 4 hole and 5 hole injectors under natural aspiration, the BTE has gradually increased up to 40% and 60% load respectively and then decreased, while with 3 hole injectors under natural aspiration, highest BTE (29.98%) was obtained at 80% load and it has slightly decreased (28.3%) at full load. This decrease in the BTE at higher loads is a clear indication of lack of oxygen with increased quantity of fuel injection. As seen in the figure BTE has increased on supercharging for all the injectors and also, it has increased with load, and the maximum BTE was obtained at 100% load for 3 hole and 5 hole injectors. This is due to the higher availability of oxygen due to supercharging and better utilization of the available oxygen at higher loads. It can be noted that for 3 hole injectors at 80% load, the BTE has increased from 29.98% to 31.86% on supercharging, whereas for 4 hole and 5 hole injectors it has increased from 11.48% to 19.24% and 20.49% to 27.16% respectively at the same load. Also, it was noted during experimentation that the engine could not run at full load with 4 hole injector under natural aspiration due to the oxygen availability falling below the flammability limit for the fuel. However, on supercharging the engine could run event at full load due to increased availability of oxygen.

B. Specific fuel consumption (BSFC)

BSFC indicates the mass of fuel consumed per unit of brake power developed. The variation of BSFC with load for different fuel injectors is shown in Fig. 3. The general trend of declining BSFC with load is observed in most cases, especially at lower loads. As seen in the figure, the least BSFC is recorded for 3 hole injector at full load under supercharged condition and the maximum for 4 hole injector under natural aspiration. The mean droplet size of the fuel increases with increase in nozzle hole diameter [5]. For the 4 hole injector, the nozzle hole diameter being the largest, the droplet size is expected to be largest, resulting in slower evaporation and mixing with air and thus incomplete combustion. This may be the reason for the higher BSFC for 4 hole injector at all loads,

both under natural aspiration as well as supercharged conditions.

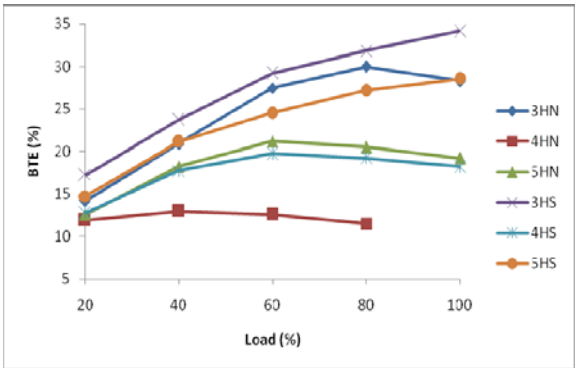


Fig. 2 Variation of BTE with load for different fuel injectors

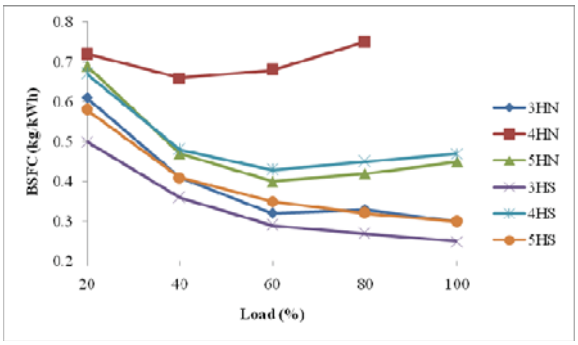


Fig. 3 Variation of BSFC with load for different fuel injectors

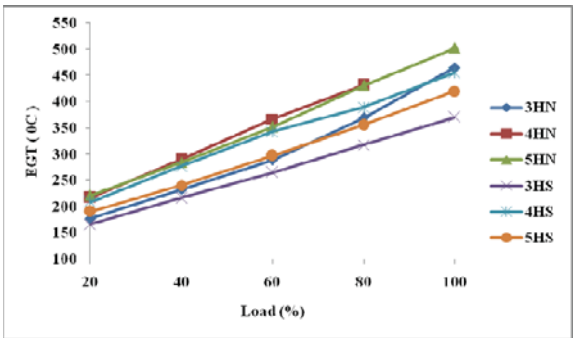


Fig. 4 Variation of EGT with load for different fuel injectors

C. Exhaust gas temperature (EGT)

The EGT at different loads on the engine for different injectors under natural aspiration as well as supercharged conditions are shown in Fig. 4. It is observed that EGT increases with load for all the nozzles. This is attributed to larger quantity of fuel burnt at higher loads. As seen in the figure, EGT is the minimum for 3 hole injector under supercharged condition at all the loads. This is attributed to smaller injector nozzle orifice of three hole injector, resulting in smaller droplet size and faster evaporation assisted by the denser air due to supercharging leading to combustion taking place at early part of expansion stroke. Also the EGT is highest for 4 and 5 hole injectors under natural aspiration, which may be due to larger droplet size because of larger nozzle hole size and lesser oxygen availability for the larger quantity of fuel injected, resulting in delayed combustion.

IV. CONCLUSIONS

The present study was focused on the performance evaluation of a direct injection diesel engine with different fuel injectors having different number of nozzle holes and nozzle hole sizes at natural aspiration as well as with supercharging at 100 kPa gauge pressure. Based on the analysis of experimental results, the following conclusions are drawn:

- Increasing the number of injector holes and nozzle sizes at natural aspiration condition decreases BTE, increases BSFC and EGT.
- Supercharging increases the power output and BTE, decreases BSFC and EGT at all the loads for all the fuel injectors.
- Under natural aspiration, the BTE was maximum at lesser than full load for all injectors, but on supercharging at 100 kPa, the maximum BTE was obtained at 100% load. Therefore further increase in supercharging pressure may result in increased power output and better performance of the engine. In that aspect the 4 hole and 5 hole injectors with larger total injector nozzle hole areas can be used effectively to obtain large increase in the power output by further increasing the supercharging pressure. However, the limit of supercharging pressure for an existing engine may be imposed by the maximum permissible pressure, temperature and thermal stresses in the engine cylinder.

REFERENCES

[1] A, Murugesan, C. Umarani, R. Subramanian, N. Nedunchezhian "Bio-diesel as an alternative fuel for diesel engines — a review," *Renewable and Sustainable Energy Reviews*, vol. 13, pp. 653-662, 2009.

[2] Helmut Eichlseder, Andreas Wimmer. "Potential of IC-engines as minimum emission propulsion system," *Atmospheric Environment,* vol. 37, 2003, pp. 5227-5236, 2003.

[3] T.M.Yunuskhan, Irfan Anjum Badruddin, Ahmad Badarudin, N.R.Banapurmath, N.J. Salman Ahmed, G.A.Quadir, Abdullah. A. Rashed, H.M.T.Khaleed , Sarfaraz Kamangar. "Effects of engine variables and heat transfer on the performance of biodiesel fuelled IC engines," *Renewable and Sustainable Energy Reviews*, vol.44, pp. 682–691, 2015.

[4] Mustafa Canakci. "An experimental study for the effects of boost pressure on the performance and exhaust emissions of a DI-HCCI gasoline engine," *Fuel*, vol.87, pp.1503–1514, 2008.

[5] J.B. Heywood, *Internal combustion engine fundamentals.* McGraw-Hill, 1988.

[6] G. Amba Prasad Rao, P. Rama Mohan. "Effect of supercharging on the performance of a DI Diesel engine with cotton seed oil," *Energy Conversion and Management*, vol. 44, pp. 937–944, 2003.

[7] Hermann Hiereth, Peter Prenninger. *Charging the Internal Combustion Engine*. Springer Wien NewYork, 2003.

[8] H. M. Patel, V. H. Chaudhari, S.A.Shah. "Design and Optimization of Fuel Injection System in Diesel Engine Using Biodiesel – A Review," *International Journal of Innovations in Engineering and Technology*, vol. 2, pp. 70-77, 2013.

[9] Sibendu Soma, I. Anita, Ramirez, E. Douglas, Longma, Suresh K. Aggarwal. "Effect of nozzle orifice geometry on spray, combustion, and emission characteristics under diesel engine conditions," *Fuel* , vol. 90, pp. 1267–1276, 2011

[10] Chunde Yao, Peilin Geng, Zenghui Yin, Jiangtao Hu, Dalu Chen, Yusheng Ju. "Impacts of nozzle geometry on spray combustion of high pressure common rail injectors in a constant volume combustion chamber," *Fuel*, vol. 179 , pp. 235–245, 2016.

[11] Cenk Sayin, Metin Gumus, Mustafa Canakci. "Influence of injector hole number on the performance and emissions of a DI diesel engine fueled with biodiesele diesel fuel blends," *Applied Thermal Engineering*, vol.61, pp.121-128, 2013.

[12] Subhash Lahane, K.A. Subramanian. "Impact of nozzle holes configuration on fuel spray, wall impingement and NOx emission of a diesel engine for biodiesel diesel blend (B20)," *Applied Thermal Engineering* , vol.64, pp. 307-314, 2014.

[13] Rohit Sharma, Rana Ranjit Singh, Shailendra Kumar Vishwakarma. "Experimental study of the Effect of Fuel Injector nozzle holes on Direct Injection Diesel Engine," *IOSR Journal of Mechanical and Civil Engineering*, vol. 7, pp. 67-74, 2013.

[14] X. Wang, Z. Huang, W. Zhang, O.A. Kuti, K. Nishida. "Effects of ultra-high injection pressure and micro-hole nozzle on flame structure and soot formation of impinging diesel spray," *Applied Energy,* vol. 88, pp. 1620-1628, 2011.

[15] Seoksu Moona, Yuan Gao, Suhan Park, Jin Wang, Naoki Kurimoto, Yoshiaki Nishijima. "Effect of the number and position of nozzle holes on in- and near-nozzle dynamic characteristics of diesel injection," *Fuel,* vol. 150, pp. 112–122, 2015.

[16] D. Montgomery, M. Chan, C. Chang, P. Farrell, R.D. Reitz. Effect of injector nozzle hole size and number on spray characteristics and the performance of a heavy duty D.I. diesel engine. SAE Paper 962002, 1996, doi:10.4271/962002.

[17] Lijo P Varghese, Rajiv Saxena, R.R. Lal. "Analysis of the effect of nozzle hole diameter on CI engine performance using Karanja oil-diesel blends," *International Journal of Mechanical Engineering and Technology*, vol. 4, pp. 79-88, 2013.

[18] D.N. Basavarajappa, N. R. Banapurmath, S.V. Khandal, G. Manavendra. "Effect of Combustion Chamber Shapes & Injection Strategies on the Performance of Uppage Biodiesel Operated Diesel Engines," Universal *Journal of Renewable Energy*, vol.2, pp. 67-98, 2014.

Piezo-actuator based workpiece feeding system using Maxwell inverse hysteresis model

Prasad Prabhu[#1], Muralidhara[#2]

[#]*Department of Mechanical Engineering,*

NMAMIT, Nitte, Karkala, Udupi, Karnataka - 574110, Affiliated to VTU, Belgaum.

[1]prasadrh91@gmail.com

[2]drmuralidhara@nitte.edu.in

***Abstract*— In recent years there are plenty of advancement in the piezo-actuator based micro-positioning and Nano-positioning system used for precise and smooth machining operations. This research paper consists of design, fabrication, and testing of piezo-actuator based workpiece feeding system which can be used for micro-milling. The workpiece feeding system was designed in such way that motion of the workpiece is restricted along 2 translational and 3 rotational degrees of freedom. The workpiece is free to move along only one translational degree of freedom. A Flexurally Amplified Piezo actuator(FAP) was designed and fabricated to give feed motion to the workpiece. But the piezo-actuator exhibits hysteresis between the applied voltage and displacement. Therefore, to reduce the hysteresis a mathematical model was developed using Maxwell slip hysteresis equation. Simulation and experiments were conducted on this workpiece feeding system for two different types of input waveform.**

***Keywords*—Piezo-actuator, Flexurally Amplified Piezo-actuator(FAP), Linear guideways, Micro-milling.**

I. INTRODUCTION

Piezoelectricity is a phenomenon by which some materials convert electrical energy into mechanical energy, reverse is also true. Piezoelectricity is the electric charge which accumulates in some of the solid materials like in crystals, ceramics, in reply to applied mechanical stress. The word piezoelectricity means electricity exhibits from pressure. Piezo actuators are classified into two groups, stripe and stack actuators. The name express stripe actuator is in the design of thin strips. Stack actuators are compound structures done by stacking individually finished piezoelectric materials. Since the displacement produced by the piezo-actuators are very small, but this displacement can be amplified suitably with help of Amplified piezo-actuators.

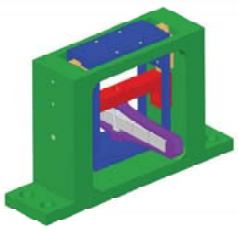


Fig. 1 Isometric view of assembled Piezo-actuator based workpiece feeding system.

II. DESIGN OF WORKPIECE FEEDING SYSTEM.

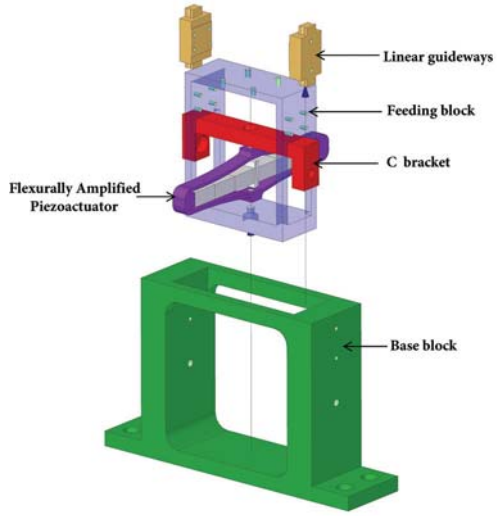


Fig. 2 Exploded view of Piezo actuator based workpiece feeding system

Piezo actuator based workpiece feeding system for micro-milling is as shown in the Fig. 1. Here the base block which is rigid and holds the entire setup. C bracket is fixed inside the base block at centre position. The feeding block consist of linear guideways with rails. When the voltage is applied to FAP, it produces displacement by contraction. Since top end of the FAP is fixed to base block with help of C bracket, only bottom end of the FAP will move upwards. Since the bottom end of FAP is connected to feeding block, the linear guideways which are connected to feeding block will guide the feed motion to be occurred in upward direction. The exploded view of workpiece feeding system is shown in Fig. 2.

III. DESIGN OF FLEXURAL AMPLIFIER

The dimension of flexural amplifier is of 35 mm in height and 145mm in width. By considering the cross section of the piezoelectric stack thickness is kept as 10 mm. The material selected is spring steel. The properties of spring steel are shown in the Table 1.

TABLE I
MATERIAL PROPERTIES

Property	Value
Young's Modulus (GPa)	210
Density(Kg/m^3)	7500
Poisson's ratio	0.3

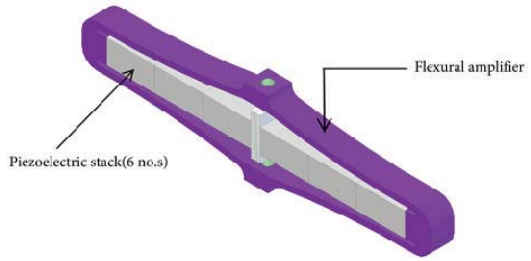


Fig.3 Isometric view of Flexurally Amplified Piezoactuator.

A Piezoelectric actuator converts an electric signal into a precisely controlled physical displacement. FAP consist of 6 piezoelectric stack actuators each of dimension 10*10*20 mm. The isometric view of FAP is shown in the Fig. 3.

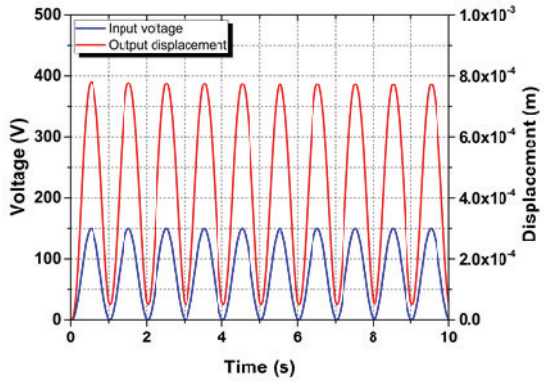


Fig. 4 Voltage and displacement plot for FAP

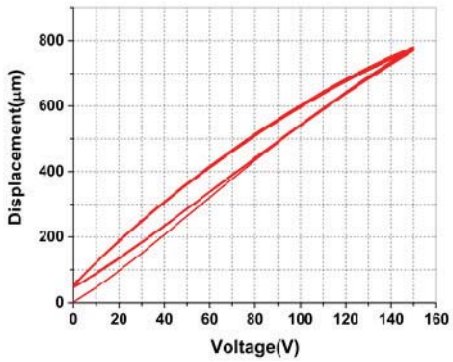


Fig. 5 Hysteresis curve between applied voltage and output displacement of piezo actuator.

Fig 4 shows the graph of voltage and displacement. A maximum voltage of 150 V is applied to the piezo actuator. From the graph, it is observed that FAP is producing a displacement of 780 μm. Fig. 5 shows the hysteresis curve obtained between input voltage and output displacement of piezo-actuator. From the graph a hysteresis of 50μm is observed. This effect of hysteresis can be reduced by using Maxwell slip hysteresis equation, discussed in chapter 4.

IV. HYSTERESIS MODELLING USING MAXWELL SLIP HYSTERESIS EQUATION.

Maxwell's slip model for modelling hysteresis is energy based method and hence it can be adopted for various energy levels. In most of the physical systems the hysteresis is mainly due to energy storage. Mechanically, this kind of behaviour could be modelled by using the combination of an ideal spring element and an ideal coulomb friction element.

A. Electro-mechanical Model

The electromechanical model for piezo actuator including hysteresis behaviour and the effect of flexural amplifier can be represented as shown in Fig 6.

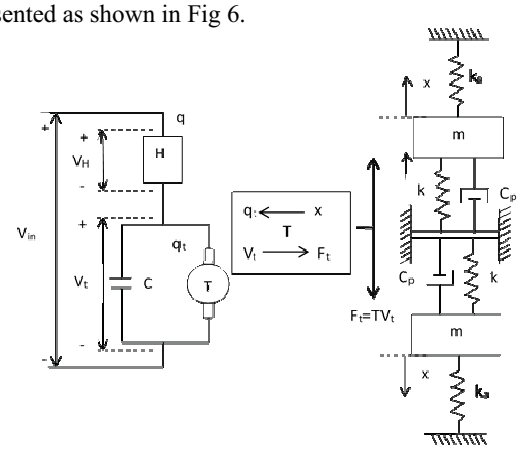


Fig. 6 Electromechanical model of piezo actuator

Hysteresis behaviour between electrical charge and the voltage is presented by block H, which resides in the electrical domain. The piezo stacks in the piezo actuator modelled as spring mass damper systems. Flexural amplifier can be modelled as a spring and force generated by spring element. This spring force considered to oppose the displacement of piezo actuator. The piezoelectric effect is represented by the piezoelectric transducer with transformer ratio T. The generalized Maxwell resistive capacitance, which is represented by the MRC element, resides in the electrical domain and therefore relates the element's electrical voltage to charge. The PZT model has two ports of interaction, a voltage-current port on the electrical side and a force-velocity port on the mechanical side. The following equation can be derived for electromechanical model.

$$q = Tx + C_pV_t \quad (1)$$

$$V_i = V_H + V_t \quad (2)$$

$V_H=H(q)$ (3)

$F_t=TV_t$ (4)

$m\ddot{x} + b\dot{x} + kx = F_t - F_a$ (5)

where:

'q' is the total charge in the ceramic

'T' is the electromechanical transformer ratio

'x' is the stack endpoint displacement

'C_p' is the linear capacitance in parallel with the transformer

'V_t' is the back-emf from the mechanical side

'V_i' is the actuator input voltage

'V_H' is the voltage across the Maxwell capacitor

'F_t' is the transduced force from the electrical domain

'F_a' is the force applied from flexural arm of an actuator

m, b and k are the mass, damping, and stiffness of the ceramic.

The applied voltage V_i is divided into hysteresis voltage (V_H) and voltage for the electromechanical transduction (V_t). Hysteresis model takes charge q as input and gives hysteresis voltage V_H as output. The piezoelectric transducer converts voltage V_t to force F_t. The flexural displacement amplifier of actuator considered as spring of stiffness k_a which exerts a force of Fa in opposite direction that of F_t. The difference between force Ft and Fa results in actuator displacement x by considering piezo stack material as a spring mass damper system. The displacement amplification provided by the flexural amplifier, which is represented by D_a. Since piezo actuator takes voltage as the input to produce displacement, we need to apply specified voltage corresponding displacement. This is done by Inverse model. Inverse model takes displacement as input and produces a voltage for particular input displacement, which in turn applied to actuator.

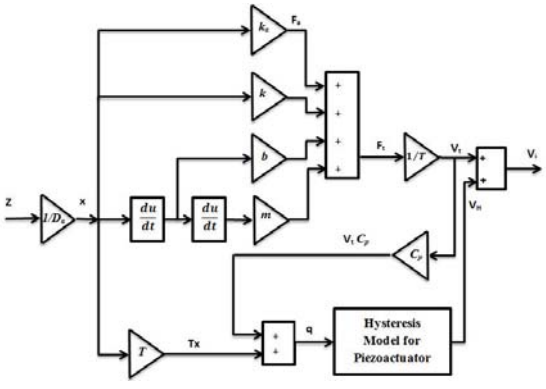


Fig. 7 Block diagram of the electro mechanical inverse model.

V. SIMULATION OF WORKPIECE FEEDING SYSTEM.

Based on Electro-mechanical model of piezo a ctuator using Maxwell slip hysteresis equation, it is possible to simulate the piezo actuator based workpiece feeding system using MATLAB software. Maxwell hysteresis model is used for simulation with displacement as the input and voltage as the output.

Fig.8 shows the block diagram for simulation of workpiece feeding system. The block diagram contains 10 Maxwell slip Hysteresis equation in parallel, to reduce the hysteresis between the voltage and displacement. Input to the block diagram is displacement and output obtained is the voltage. The simulation of workpiece feeding system can be performed for different types of input displacement waveform, like sine, triangular, step, ramp etc. The output obtained is voltage in the corresponding waveform.

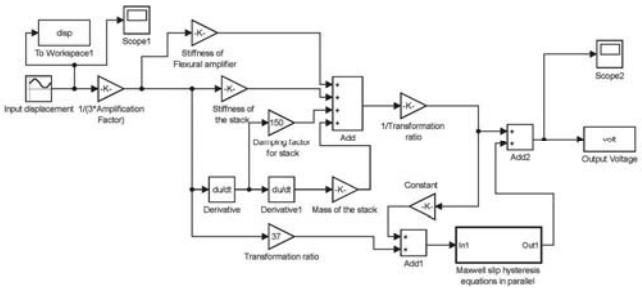


Fig. 8 Block diagram for simulation workpiece feeding system

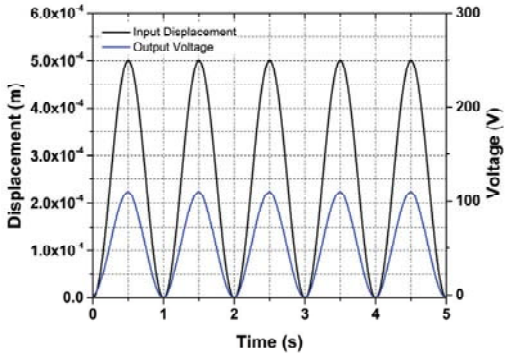


Fig. 9 Simulation result obtained for workpiece feeding system with sine waveform

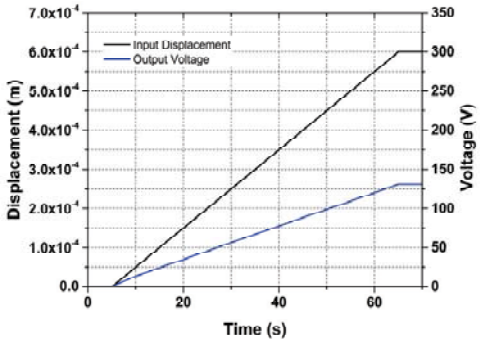


Fig. 10 Simulation result obtained for workpiece feeding system with ramp waveform

Fig. 9 shows the simulation result obtained for workpiece feeding system with displacement as input in sine wave form.

From figure, it is understood that to get a displacement of 500µm for workpiece feeding system, it is required to apply a voltage of 120V.

Fig. 10 shows the simulation result obtained for workpiece feeding system with displacement as input in ramp wave form. The slope of the ramp wave form was 20 µm/s. From the figure to get a displacement of 600µm for workpiece feeding system it is required to apply a voltage of 135V.

VI. EXPERIMENTS ON WORKPIECE FEEDING SYSTEM.

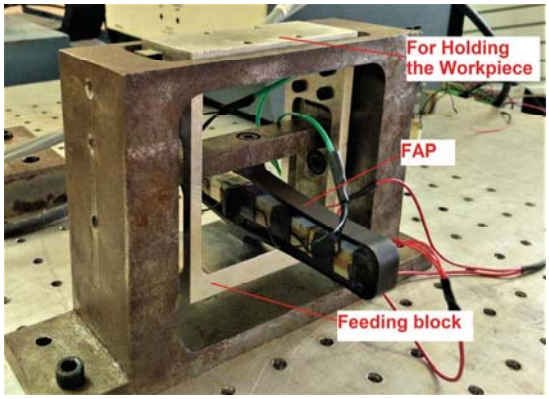


Fig. 11 Assembled view of Workpiece feeding system

Fig.11 shows the assembled view of workpiece feeding system, the base part rigidly fixed on an aluminium board. For micro-milling operation workpiece, can be held on the top of workpiece feeding system. Flexurally Amplified Actuator is used for controlling the feed rate of the workpiece against the milling tool.

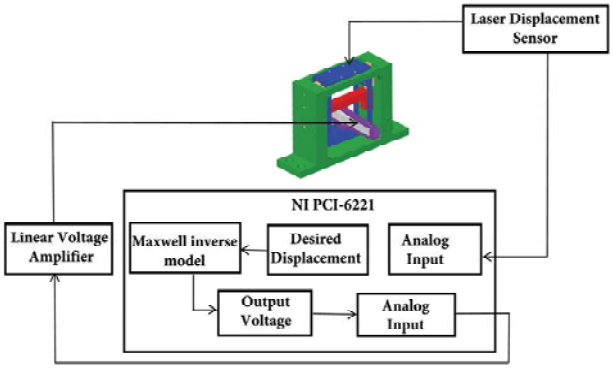


Fig. 12 Block diagram for experiment on workpiece feeding system

Fig.12 shows the block diagram for experiment on workpiece feeding system. Desired displacement is given as input to the Maxwell hysteresis model, which gives back voltage signal as output. The experiment requires NI-PCI 6221 Data acquisition system with LabVIEW software. Laser displacement sensor is also required for measuring the displacement produced by the workpiece feeding system for a given input signal. Desired displacement is given as input signal to Inverse Maxwell model, to get voltage as output signal. This output signal is sent to NI-PCI 6221 data acquisition system. DAQ will generate voltage according to the signal received from the Inverse Maxwell Model. The Voltage from DAQ is sent to Linear Voltage amplifier, where the voltage is multiplied or amplified 20 times. This amplified voltage is applied to FAP to control the feed rate of workpiece feeding system. Laser Displacement sensor ILD 2220 with 20µm range is used to measure the displacement produce by the workpiece feeding system. Fig. 13 shows the Experimental setup for the workpiece feeding system.

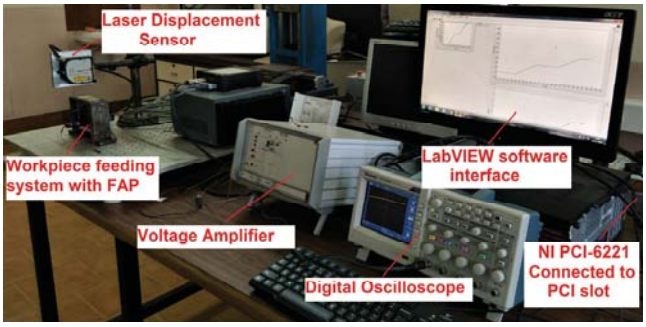


Fig. 13 Experimental setup for the workpiece feeding system.

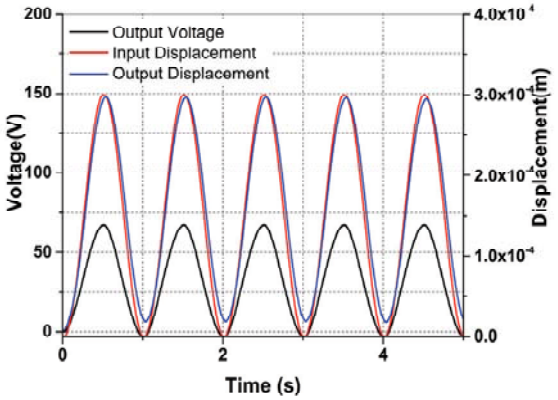


Fig. 14 Experimental results obtained for workpiece feeding system for reference input displacement of 300µm

Fig.14 shows the experimental results obtained for workpiece feeding for reference input displacement of 300µm to with sine waveform. Here the Output Displacement is the actual displacement of the workpiece feeding system measured using Laser displacement sensor ILD 2220-20.

Table II shows the experimental results obtained for workpiece feeding system for sinusoidal waveforms. Experiments from reference displacement of 300µm to 600µm were carried out. From the table, it is observed that the percentage error between the reference displacement and the

actual displacement of the workpiece feeding system is less than 2 percent.

TABLE II
EXPERIMENTAL RESULT OBTAINED FOR WORKPIECE FEEDING SYSTEM FOR SINE WAVEFORM.

Reference Displacement (m)	Output Displacement (m)	Error %
$300x10^{-6}$	$294.2x10^{-6}$	1.93
$400x10^{-6}$	$395.5x10^{-6}$	1.12
$500x10^{-6}$	$495.7x10^{-6}$	0.86
$600x10^{-6}$	$596.5x10^{-6}$	0.58

Fig.15 shows the experimental results obtained for workpiece feeding for reference input displacement of 500µm for ramp waveform with 20 µm/s slope. Here the Output Displacement is the actual displacement of the workpiece feeding system measured using Laser displacement sensor ILD 2220-20 and the Output voltage is the voltage applied to FAP.

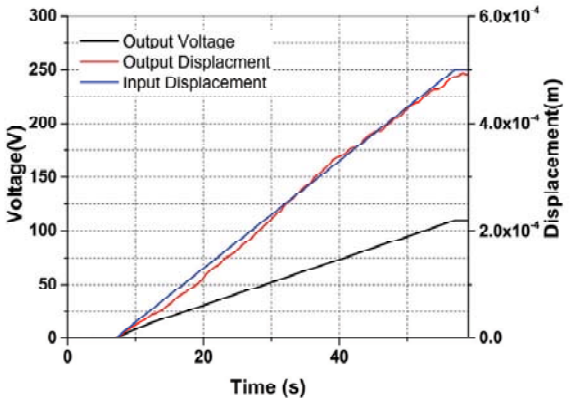


Fig. 15 Experimental results obtained for workpiece feeding system for reference input displacement of 500µm

Table 3 shows the experimental results obtained for workpiece feeding system for ramped waveforms. Experiments from reference displacement of 300 µm to 600µm were carried out. From the table, it is observed that the percentage error between the reference displacement and the actual displacement of the workpiece feeding system is less than 6 percent.

TABLE III
EXPERIMENTAL RESULT OBTAINED FOR WORKPIECE FEEDING SYSTEM FOR RAMP WAVEFORM.

Reference Displacement (m)	Output Displacement (m)	Error %
$300x10^{-6}$	$283.5x10^{-6}$	5.5
$400x10^{-6}$	$385.1x10^{-6}$	3.725
$500x10^{-6}$	$488.2x10^{-6}$	2.36
$600x10^{-6}$	$592.5x10^{-6}$	1.25

VII CONCLUSIONS

Piezo actuator based workpiece feeding system was designed, fabricated and tested to be used for micro milling machine. The design of workpiece feeding system allows the workpiece to move in only upward direction, all other degrees of freedom are constrained. Flexurally Amplified Piezo actuator plays an important role in feeding the workpiece. Since the piezo actuator exhibits hysteresis, Maxwell slip hysteresis equation was used to reduce the hysteresis behaviour between the applied voltage and displacement. Simulink block diagram of workpiece feeding system was designed with 10 Maxwell slip hysteresis equations in parallel. Simulation was carried out in MATLAB software using two different types of waveform. Experiments on workpiece feeding system are conducted using NI PCI 6221 Data Acquisition System along with LabVIEW software. Different types of waveforms are used for experiment like sinusoidal and ramp wave form as the reference input displacement. For the sinusoidal waveform, the percentage error between the reference displacement and output displacement of the workpiece feeding system was less than 2 percent and for ramp waveform it is less than 6 percent as shown in Table 2 and Table 3.

REFERENCES

[1] Xiuzhuo Fu, Qinhe Zhang, Liying Gao, Qingyu Liu, Kan Wang,Yu-Wei Zhang "A novel micro-EDM—piezoelectric self-adaptive micro-EDM" International Journal of Advance Manufacturing Technology pp 1-8. 2015.

[2] Yong Li, Min Guo, Zhaoying Zhou, Min Hu "Micro electro discharge machine with an inchworm type of micro-feed mechanism" *Journal of the International Societies for Precision Engineering and Nanotechnology* 26 pp 7–14. 2002.

[3] Ali Ozgedik, Can Cogun "An experimental investigation of tool wear in electric discharge machining" *International Journal of Advance Manufacturing Technology* 27 pp 488-500. 2006.

[4] Z.Y. Yu, K. P. Rajurkar and H. Shen "High Aspect Ratio and Complex Shaped Blind Micro Holes by Micro EDM"

[5] Eckart Uhlmann, Markus Roehner "Investigations on reduction of tool electrode wear in micro-EDM using novel electrode materials" *CIRP Journal of Manufacturing Science and Technology* 1 92–96. 2008.

[6] G. Karthikeyan J. Ramkumar. Dhamodaran "Block Edg: Issues and Applicability in Multiple Pass µED-Milling" Machining Science and Technology, 18:120–136.

[7] Michael Goldfarb, Nikola Celanovic "Modeling Piezoelectric Stack Actuators for Control of Micromanipulation" IEEE Control Systems, 0272-1708/9 7/1997.

[8] Yanfang Liu, Jinjun Shan, Ulrich Gabbert and Naiming Qi "Hysteresis and creep modeling and compensation for a piezoelectric actuator using a fractional-order Maxwell resistive capacitor approach" Smart Materials And Structures, Smart Mater. Struct. 22 115020 pp 12. 2013.

[9] D.T. Pham, S.S. Dimov, S. Bigot, A. Ivanov, K. Popov "Micro-EDM-recent developments and research issues" *Journal of Materials Processing Technology* 149 50–57. 2004.

[10] Eckart Uhlmann, Sascha Piltz, Ulrich Doll "Machining of micro/miniature dies and moulds by electrical discharge Machining-Recent development" *Journal of Materials Processing Technology* 167 488–493. 2005.

[11] U. Maradiaa, M. Boccadorob, J. Stirnimannc, I. Beltramib, F. Kustera, K. Wegenera "Die-sink EDM in meso-micro machining" Procedia CIRP 00000–000. 2011.

[12] Muralidhara, NileshJ.Vasa, Singaperumal Makaram "Investigations on a directly coupled piezoactuated tool feed system for micro-electro-discharge machine" *International Journal of Machine Tools & Manufacture.*

[13] Veeresha R.K, Muralidhara and Rathnamala Rao "Development of Tool Based Micromilling/Microdrilling Machine with Piezoactuated Workpiece Feeding System" Applied Mechanics and Materials Vols. 592-594. 2014.

[14] Vahid Hassani, Tegoeh Tjahjowidodo and Thanh Nho Do "A Survey on hysteresis modelling, Identification and control" Elsevier 2014.

Matching Governance Systems with Performance Frameworks in Higher Education

K. Sankaran

Director, Justice K. S. Hegde Institute of Management

Nitte, Karkala, Udupi, Karnataka - 574-110, Affiliated to VTU, Belgaum.

sankaran@nitte.edu.in

***Abstract*— This paper argues for seeking a possible match between higher education (HE) governance systems for the country and the demands on the performance of the governed. This paper argues that a match between the two have to be sought for achieving high performance of HE sector.**

***Keywords*— Higher Education Governance, Outcome-based Education.**

I. Introduction

This paper argues for seeking a possible match between Higher Education (HE) governance systems that a country could follow and the demands on the performance of the governed. Conversely a mismatch would lead to less that "optimal" performance. In this article we first identity a framework for defining a) Alternative Governance Systems and b) Performance. Then the paper suggests the kind of governance that would fit with the performance matrix expected today from the HE sector.

A. Governance Frameworks

A framework for Alternative governance frameworks for HE is provided by [1]. They suggest that there are five different governance models that are found today, viz. Institutional, Resource Dependence, Agency, Stewardship and Stakeholder models. Table 1 below lists these models and provides description of the underlying assumptions and approaches that underlie them. The Institutional Model is based on the notion that the regulator, by bureaucratic oversight, can achieve the objective of proper control and change management. It is assumed that the top of the pyramid (say, ministry of education, educational departments and central and state levels etc.) knows when and how to make changes. It is assumed that governance of institutions in HE can be controlled through standard operating procedures (SOPs) and rules of conduct. It further assumes that the "reverse" communication would occur in reporting of best practices that can be popularized by the top of the pyramid where some of the innovative "subjects" or constituents (universities and colleges) may do something different that can be replicated through the "approval" . This is a "rational" model with limited scope for local variations that can be exercised by the constituents. The next one, Resource Dependence Model, is very similar to Institutional model except that the resources (read financial) that are allocated, and the control that comes with such allocation, will provide as an instrument for exercising control over the constituents that receive the financial fund allocations.

TABLE I

CHARACTERISTICS OF GOVERNANCE MODELS

	Governance Models				
	1	**2**	**3**	**4**	**5**
Key Characteristics of Governance models	**Institutional Model**	**Resource Dependence Model**	**Agency Model**	**Stewardship Model**	**Stakeholder Model**
Key assumption about change drivers	Top of the pyramid knows what and how of change	Top of the pyramid knows what and how of change	Principal's interest should drive change, but principal - agent conflict exists	Players work towards welfare of constituents whose care is vested in them.	Stakeholders will exert pressure for change
Key assumption about how change can be affected	Change can be top-down driven rationally	Change can be top-down driven rationally	Change can be affected through handling conflictual relationship with agent	Change happens through self - order created by actions of samaritans	Stakeholder engagement
How is governance achieved?	Employment & standardization mandated from the top	Mainly through allocative power of finance	External oversight through structures or simply through rules	Through a hands-off processual orientation and self regulation	Multiple demands will gradually reach "optimization" on different interest dimensions
How does change come about?	Through a bureaucratic process	Through resource allocation priorities	Through constant vigil to prevent "violations"	Aligning of aspirations of players with constituents' welfare	Satisficing multiple demands in creative ways

The third approach, namely, Agency Model, assumes that the government that legitimizes the "academy" (and provides the sustenance through funds) will be in a conflict-laden relationship with the latter. This idea comes from the corporate governance literature [4]. By appropriate mechanisms such as rules of engagement and a system of checks and balances (including structural and processual means), it is assumed that, it is possible to "discipline" those that violate the "covenant". While in the previous two models it was assumed that the agent would be "benign", here the agent, having asymmetric knowledge via-a-vis the sponsor, is assumed to work towards selfish instrumental goals unless there are systems and structures in place to prevent this from happening. By this reckoning, the HE institutions, are merely driven by self-interest. This necessarily warrants strict control by the sponsor (state or government) on the agent (HE institutions).

The next model puts the onus for responsible action on the idea of stewardship. Here the educational institutions are assumed to act responsibly through their own internally-generated positive motivations. Here it is assumed that order comes about in the network of institutions through emergent action [6] and self order. Finally, the Stakeholder Model assumes that there are external forces that push the educational institutions to accommodate the interests of various stakeholders [3], such as students, parents, etc., the interplay of which directs the institution onto appropriate governance trajectories. The stakeholder model assumes that the market, consisting of consumers as a group, is a legitimate stakeholder.

The next question, for the purpose of this paper, is whether we can combine the last two models and create a stakeholder-mediated stewardship model as suggested by Balakrishnan, Malhotra and Falkenberg (2015). In the

next section we classify performance frameworks in terms of a) output-based systems and b) outcome-based systems. Further we show that the stakeholder-mediated stewardship model would correspond best with outcome-based performance systems.

B. Performance Frameworks

Here we adopt two broad methods of defining performance of education institutions; Viz., Output-based versus Outcome based. Table 2, adopted from Sankaran (2015), contrasts the two.

Providing feedback to students, via grades or marks, in individual *courses* requires and output orientation. Here the performance of the students in specific courses is the output. Performance is objectively evaluated and communicated to the students. Output measurements have evolved over time through different means such as examinations, tests, quizzes, assignments (and variations within them such as whether through open-book or closed book, surprise or pre-announced) etc.

In addition to this, there is call to take into account *outcomes* [5] while evaluating the performance of the *programs* themselves. Programs need to be evaluated from both inside (mainly peer faculty) and outside (by employers, students themselves after a few years of working, parents, society etc.). The means to measure of outcomes and the matrices to be used are still emerging. A more detailed discussion in outcomes is therefore relevant here. As indicated in the Table, outcomes are meant primarily for the non-student constituents of the system (faculty, educational institution, regulators, accrediting agencies etc.) Outcomes measurement may be formative or summative in nature.

An outcome-based system goes beyond individual faculty members and individual courses. The key criterion would be whether the institutional vision is being fulfilled and whether the expectations of various constituents are fulfilled. The faculty members have to come together and reflect and act upon the institutional goals. Narrow disciplinary boundaries have to be broken down and overall coherence sought. This would also entail new communication among the students, faculty, staff and management for collective performance. There will have to be much intra-institutional dialogue on how results can be achieved. To achieve system-wide results in a knowledge environment (that marks HE institutions) and create systems thinking and learning organizations [9], hierarchical systems and traditional means of influencing behavior of organizational members will have to be challenged. Here peer-to-peer oriented accreditation agencies can play a positive role.

C.Match between Governance and Performance Frameworks

The assessment system(whether internal or external to the educational institution) can promote open and flexible process standards that encourage innovation and diversity and do not prescribe too narrowly what ought to be done or what the output should be. Role of assessment agencies (such as accreditation agencies) would be significant here. They ought to provide enough room for continuous improvement to take hold. This will necessarily require experimentation and term-by-term fine-tuning. Care should be taken if institutions are modeled on the basis of leading best practices and bench-marking [8]. Often, the idea of best practices may militate against experimentation and homegrown innovations. In a post-industrial environment where past institutional practices are being constantly challenged what is required is not one inflexible benchmark but creation of communities of practice [5]. This is precisely what can be achieved through peer-to-peer sharing of good practices. Governance by process requires a different mindset for the regulatory and the accreditation agencies as well as the institutions that are being assessed. A departure from the past for both may not be easy. End-based governance will have to be replaced by process-based governance. Table 3 below shows the differences between the two.

TABLE II

DIFFERENCES BETWEEN OUTPUT BASED SYSTEMS AND OUTCOME BASED SYSTEMS

Aspect	**Output Based**	**Outcome Based**
Basis to check whether intended achievement has been made	Course Objectives (as decided by the university/ faculty members)	Institutional vision and program objectives
Time Span	Course Duration	Program Duration
The criteria as to whether the objective has been achieved is obtained and who is this information communicated to	Achievement of the students, communicated to the students	Outcomes, communicated to fellow faculty/ accreditation agency etc. In those courses that have one right convergent answers course output and course outcomes could be measured by the same means.
Measurement orientation	Unbiased objectivity and communication of the same to the students	Self-reflective (in the institutional sense) and being truthful to the process. May or may not be communicated with the students
Coherence between measurement parameters	Not an issue since course objectives are all generally known to peer/ faculty fraternity	Based on each institution's mission

TABLE III

CONTRASTING END-BASED AND PROCESS-BASED GOVERNANCE SYSTEMS

Basic Questions that underlie the Assessment Process	**End-based**	**Process-based**
What is the fundamental question answered?	Has the institution met specified threshold levels of quality?	What is the exalted purpose of the institution being assessed? What is being done to demonstrate that the purpose is being achieved on a time scale?
What constitutes quality?	Things demonstrated to be achievable by top institutions in the same category	Defining a purpose and working authentically towards it with measurable landmarks
What is ultimately being measured?	How close is the institution to the threshold or benchmark organization or leader-in-class?	How is the institution moving towards achieving the stated purpose?
What is the relationship between the accreditor and	Inspector-inspected	Largely peer-peer

the accredited		
What kind of change orientation can be expected?	Top down. The leaders-in-class has to demonstrate change which trickles down over a period of time.	Scope for internal forces to change autonomously and be locally creative. Room for multiple voices.
What will such a system generate in the long run?	Standardized, compliant behavior of institutions.	Pluralism and opportunity for multiple models to thrive at the same time.
What will the relationship between the accreditor and the accredited?	Hierarchical	Collegial
What are the likely challenges?	One-size-fits-all syndrome, Compliance orientation, and tendency towards bureaucratization.	Lack of accountability to stakeholders "outside" the system. This can be overcome by not being just stewardship oriented but also being stakeholder oriented

It may be pointed out that process-based systems would allow greater buy-in of the participants for continuously tracking performance (outcomes) and be able to constantly tweak the means to get to the outcomes desired, reminiscent of the Japanese Kaizen philosophy or continuous improvement [10].

II. Conclusions

This paper argued that the fundamental basis for HE governance need to be carefully considered before choosing the particular form of governance mechanism. This particularly applies to countries such as India which are in a "hurry" to catch up with the western nations such as the United States. It is often tempting to put in regulatory mechanism without taking into account the consequences that such regulatory mechanisms may bring about. Inter-institutional systems do not exactly behave in pre-determined ways. One can expect unintended consequences from governance systems (such as rigidities that militate against knowledge generation or undervaluing the role of incremental improvements that emerge from flexibilities available at grass-roots level). When this is the case, while designing or redesigning governance systems, it is important to dwell deeper into various forms of governance theories to explore their paradigmatic underpinnings and their consequences. This paper also considered output and outcome-based systems of HE and suggested that there has to be fit between the form of governance system adopted and the results expected. We suggested that a stakeholder-mediated stewardship model as congruent with outcome-based performance expectations.

References

[1] I. Austin, A. J. Jones, *Governance of Higher Education: Global Perspectives, Theories, and Practices,* New York, USA: Routledge, 2016.

[2] J. Balakrishnan, A. Malhotra, L. J.Falkenberg, Multi-Level Corporate Responsibility: A Comparison of Gandhi's Trusteeship with Stakeholder and Stewardship Frameworks. *Journal of Business Ethics*. doi:10.1007/s10551-015-2687-0, 2015.

[3] W. M. Evan, R. E. Freeman, *A stakeholder theory of the modern corporation: Kantian capitalism.* In T. L. Beauchamp & N. Bowie (Eds.), *Ethical Theory and Business* (3rd ed.). Englewood Cliffs, NJ, USA: Prentice Hall.1988.

[4] E. F.Fama, M. C. Jensen, Separation of Ownership and Control . *Journal of Law & Economics,* 26(2), 301–325. 1983.

[5] P. FHildreth, C. Kimble, *Knowledge Networks: Innovation Through Communities of Practice*. London, U.K.: Idea Group Inc (IGI). 2004.

[6] J. Jeston, , J. Nelis, Management by Process: *A Roadmap to Sustainable Business Process Management.* Butterworth Heinemann Amsterdam 2008.

[7] K. Sankaran, Generating the Right Institutional Environment for Ethical Behavior in University-Affiliated Institutions in India" at the conference *"Professional Ethics for Higher Education Faculties: Roles and Responsibilities of Teachers"* held by at the Indian Institute of Technology Madras, Chennai, India. 29th Aug. 2015.

[8] V. Schray,, (2012). *Assuring Quality in Higher Education: Recommendations for improving Accreditation. Fourteenth in a series of Issue Papers released at the request of Chairman Charles Miller to inform the work of the Commission*. Washington, DC, USA.

[9] P. Senge, (1994). *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York, USA: Currency Doubleday.

[10] D. N Thalner,., (2005). *The Practice of Continuous Improvement in Higher Education.* PhD Dissertation, Western Michigan University, Kalamazoo, Michigan, USA.

Gut microbiota, short-chain fatty acids and host gene regulation

Prasanna K. Santhekadur

McGuire Research Institute, McGuire Veterans Affairs Medical Center, Research BC-101. Richmond, VA 23249, USA.

Prasanna.Santhekadur@vcuhealth.org

***Abstract*— Recent advance in microbiological and medical research have explored very important role of gut microbiota in maintenance of human health. Diet plays significant role in determining health and disease state of each and every organism including human beings. Recently, gut microflora has emerged as major regulators of metabolic syndrome, inflammation, and cancer. Fibrous food intake helps in getting major energy source for these gut microbes through anaerobic fermentation by which they produce short-chain fatty acids (SCFAs) such as acetate, butyrate, and propionate. These SCFAs act as signal transducing ligands via their specific G-protein coupled receptors and through unknown nuclear receptors. SCFAs are involved in activation/suppression of various transcription factors and regulates genetic and epigenetic gene expression. They are also known for their histone deacetylase (HDAC) inhibitory function. Recent studies on gut microbiota have suggested that gut microbial-derived SCFAs exert multiple and major beneficial effects on the host energy metabolism and they function not only by improving the intestinal gut microbial habitat, but also by directly affecting various host peripheral organs, tissues, and cells. In this review, it is summarized that the various physiological functions of these SCFAs in the host energy regulation in metabolic syndrome and various cancers and helps in current understanding of their molecular mechanism of action.**

***Keywords*— SCFAs, gut microbiota, metabolic syndrome, HDAC**

I. INTRODUCTION

The digestive tract or gut starts with the mouth and proceeds to the end point anus in almost all organisms including human beings. This gut is known for harboring trillions of microorganisms which constitutively forms gut microbiota. Until recently, human beings are not familiar with the beneficial effects as well as harmful effects of these microbes in the gut. Recent elegant studies have explored major beneficial effects of these gut microbiota via which they opened new and interesting area of research in basic and medical sciences. These microbiota mainly depend on the food we eat for their growth, development, and colony formation. There exists a strong competition between each species and genus of bacteria for their survival. Some time they may grow symbiotically and many a times commensalism is associated with them and they also produce antibiotics to inhibit growth of other bacterial species. Due to recent changes in the life style and also due to westernization, food habit of people have changed. Food helps in nourishment of all the organisms by providing micro and macro nutrients. Nutrients are

very essential for harmonious growth of every organism including microbes and human beings. Any change in food habit and daily nutrient acquisition leads to dysregulation of energy homeostasis. Also, excess intake of high calorie food or western diet leads to obesity, fatty liver, type2 diabetes and cardiovascular diseases which are collectively called as "metabolic syndrome". Metabolic syndrome is currently one of the major serious public health challenge globally, including Asian countries such as India, China, and Japan. The progress of metabolic syndrome is caused by a long-term imbalance between energy intake (excessive high calorie food intake) and expenditure, physical activity, exercise, genetic and epigenetic factors and also on gut microbiota which in turn influences on multiple complex pathways involving carbohydrates, proteins, lipids, nucleic acids, vitamins and hormones. However, microbiota are known for their harmful effect but most important beneficial effects of the gut microbiota are due to catabolized dietary fibers (present in fruits, vegetables, and grains) that are not completely hydrolyzed by the host enzymes during digestion. The complex carbohydrates present in dietary fibers undergo fermentation by intestinal anaerobic bacteria and produces short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate (Fig. 1). These short chain fatty acids have many useful effects for both the host and the gut bacteria. This association between host and bacteria is symbiotic, where host gets SCFAs which can be used for de novo synthesis of lipids, glucose, and other biomolecules and gut bacteria use them as energy source and also they use glucose, amino acids and fatty acids for their growth and habitat for colony formation.

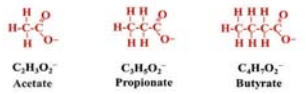


Fig.1 Structural formula of short chain fatty acids.

A. Gut microbial flora and disease

Human gut consists of trillions of bacterial cells and numerous different species of bacterial colonies. Many a times these inter species of bacteria compete with each other for food, shelter and for colonization. They also compete with each other by producing harmful secondary metabolites which are toxic and also for host human beings. There are many diseases that are associated with gut microbiota which includes gastric cancer by *Helicobacter Pylori*, irritable bowel syndrome (IBD), type 2 diabetes, obesity, colon cancer and LPS-induced liver cancer. Due to the anaerobic nature of these microbes, identification and functional analysis has been very difficult. In Recent times, advent of metagenomics and bioinformatics tools have helped and it has been revealed that gut microbes play a pivotal role in host immune response, immunological diseases and also adipogenesis associated obesity.

Helicobacter pylori is known to induce gastric ulcer and gastric cancer and two well-known scientists, Barry Marshall and Robin Warren showed that the bacterium *Helicobacter pylori* is the cause for most peptic ulcers. It was thought that ulcers were caused by stress, spicy foods and too much acidic condition but reversing decades of medical doctrine of false notion, this discovery has allowed for a major breakthrough in understanding a

causative link between *Helicobacter pylori* infection and stomach cancer. For this major landmark discovery, prestigious Nobel Prize was awarded to both of them.

Irritable bowel syndrome (IBS) is characterized by severe abdominal pain or discomfort and altered bowel habits due to change in normal gut microbiota and low-grade intestinal inflammation. Chronic Irritable bowel syndrome may lead to colon cancer and this IBS is associated with the increase number of bacterial species such as *Dorea, Firmicutes, Clostridium,* and *Ruminococcus* in addition to a marked reduction in *Faecalibacterium* and *Bifidobacterium* species.

Inflammatory bowel disease (IBD) is also characterized by a chronic and relapsing inflammation of the gastrointestinal tract and it encompasses both ulcerative colitis and Crohn's disease and it is also one of the emerging worldwide epidemics. The incidences of IBD is directly associate with socio-economic development and environmental factors persistently detected in different parts of the world. The interaction of various microbes with mucosal immune compartments in the gut seems to have a major role which progresses from IBD to colon cancer. This was supported by direct evidences from clinical studies which shows that patients with inflammatory bowel disease (IBD) are at maximum risk for developing colon cancer.

Colon cancer is associated with many causing factors and recent studies have established that gut microorganisms play a major role in this cancer initiation, development, and progression. The imbalance in the gut microbiota have been linked to alteration in immunological signaling which leads to IBD, colorectal adenomas and cancer.

Among trillions of gut bacteria only *Fusobacterium* has been identified as a main risk factor for these tumors and many studies have confirmed it. Recent studies also showed the role of *Porphyromonas* species in polymicrobial disease trigger in colon. In addition to these bacteria, studies have also identified some additional genera which are involved in colon cancer such as *Campylobacter*, *Peptostreptococcus*, *Leptotrichia*, *Prevotella*, *Parvimonas*, and *Gemella*. Scientific analysis of 16S rRNA gene signatures from the stool samples of healthy and cancer patients revealed that the feces of people with cancer tend to have a maximally altered gut microflora with excess population of common mouth microbes *Fusobacterium* or *Porphyromonas*.

Hepatocellular Carcinoma is also associated with various factors such as viruses, chemical carcinogens, obesity, fatty liver diseases and high consumption of alcohol etc. However, recently there are reports which shows that gut microbiota also causes HCC. There is a study which demonstrates that LPS-induced local and systemic inflammation is associated with hepatic cirrhosis further, which predicts progression to end-stage hepatocellular carcinoma in patients with HBV or HCV infection. Also, a connection exists between gut microbiota and nonalcoholic fatty liver diseases (NAFLD). Increased or altered microbial populations and bacterial overgrowth with increased concentration of harmful secondary metabolites and toxins such LPS leads to activation of toll like receptors (TLR) and mediates inflammatory response and activation of oncogenic pathways resulting in hepatocellular

carcinoma. LPS acts mainly through its receptor TLR4 and mediates inflammation associated liver cancer.

B. Beneficial effects of gut microbial flora

Recent advance in transcriptomics, proteomics and metabolomics have helped in identifying novel microbial signatures which are associated with the disease phenotypes. These microbiome signatures include circulating secondary metabolites and endotoxins (LPS) which can be exploited for the therapeutic purposes and also can be developed into diagnostics and therapeutics. There are many studies which shows the use of prebiotics, probiotics and symbiotics could be used to prevent over growth of gut microflora so that they prevent and decreases the pathogenic gut microbiota and their endotoxemia. These probiotics are also involved in stimulation of immune response against colonizing pathogenic bacteria and these strains are safer and less expensive in comparison to pharmaceutical drugs. The probiotics are living microorganisms and they can be orally administered as a diet in adequate amount and they maintain balance between useful and harmful gut microbiota by producing some metabolites. They are also known for stimulating natural digestive juices and enzymes that keep our digestive organs in good function. Some of the very popular probiotics are Yogurt (*Lactobacillus bulgaricus*), Kefir (fermented cow or goat's milk and Kefir grains- a symbiotic culture of bacteria and yeasts).
Sauerkraut is also a form of probiotics and it is made from fermented vegetables mainly cabbage. Sauerkraut is known for its extreme rich source of healthy live cultures (rich in vitamins B, A, E, and C) and is also known to reduce allergy symptoms. Dark chocolates are also associated with probiotics and these probiotics are used in the ratio four times more than in other forms of dairy products. Thus, dark chocolates have more health benefits compared to other high calorie chocolates. Recently, microalgae such as spirulina, chlorella and blue-green algae are also referred as probiotics and these algae based foods have been shown to increase the amount of both beneficial *Lactobacillus* and *Bifidobacteria* in the human digestive tract. Some of the other useful probiotics are Miso soup, Pickles, Tempeh (it is a probiotic-rich grain made from soy beans), Kimchi and Kombucha Tea etc.

Prebiotics are a kind of nondigestible complex carbohydrates (oligosaccharide substances, such as lactulose) food ingredient that promotes the growth of beneficial microorganisms in the human gut and inhibits harmful pathogenic microorganisms. Symbiotics is the mutually beneficial relationship between probiotics and prebiotics such as certain nutrients (prebiotics) and the probiotics (bacteria) that populate our bodies or supplemented from external diet source. When this symbiotics are well balanced they optimally enable and trigger immune system and maintains proper and good digestive health.

These gut microbiota produces various short chain fatty acids and exerts their beneficial effects by preventing from numerous inflammation associated diseases and metabolic syndrome and also from cancers.

C. Short chain fatty acids and their mode of action

Short chain fatty acids (SCFAs) are small biomolecules which are produced by gut microbiota in the gastrointestinal tract, mainly during anaerobic

fermentation of insoluble complex dietary fibers or roughage from dietary plant source which includes, fruits, leaves, vegetables, grains, and cereals etc. These fibers are complex carbohydrates which undergo fermentation by anaerobic gut bacteria and produces SCFAs such as acetate, propionate, and butyrate.

The molecular mechanisms behind these SCFAs production and their beneficial action are the subject of intensive scientific research and this involves complex interaction between diet, gut microbiota, and host energy metabolism, gene regulation and expression . The exponential increase in the subjects of metabolic syndrome (obesity, loss of glycemic control, dyslipidemia, and hypertension) due to decrease in physical exercise and increase in energy intake and lack of physical activity leads to disturbed microbiota population in the gut which leads to various maladies. Recently, dietary fibers have raised much interest due to their beneficial effects on metabolic syndrome and cancers. Also, many epidemiological studies showed a strong association between high fiber intake with reduced risk of IBS, IBD, colon cancer and metabolic syndrome.

The amount of different SCFAs produced in the gut lumen is approximately 100 mM and it is about 400 μM and 100 μM in the portal circulation and peripheral circulation respectively. Hence, the action of SCFAs exhibit organ and tissue specific physiological function which is also dependent on the concentration of each fatty acids. Butyrate is a very well-studied SCFA and it enhances the expression of peroxisome proliferator-activated receptor-gamma coactivator-1α (PGC-1α) which leads to increased fatty acid oxidation and thermogenesis in muscle and liver tissue and also activates the phosphorylation of adenosine-monophosphate-activated kinase (AMPK) and mitochondrial uncoupling protein-1 (UCP-1) in brown adipose tissues . It is also very well known for its anti-cancerous effects on colon cancer and few other cancers. The anti-angiogenic effect of butyrate is also well established. Propionate is also derived from the action of gut microbiota and reduces cancer cell proliferation in the liver via the G-protein coupled receptor- GPR43. Propionate and butyrate both downregulate ERK phosphorylation in HT29 colon carcinoma cells.

The gut derived SCFA- acetate is also involved in the reduction of appetite via a central homeostatic mechanism by changing the expression profiles of appetite regulatory neuropeptides (neuropeptide Y) in the hypothalamus of the brain through activation of tricarboxylic acid (TCA) cycle. Acetate also mediates a microbiome-brain-pancreas axis to promote gut microbiota-induced metabolic syndrome. All these three SCFAs (propionate, butyrate and acetate) activates their receptor proteins and one such main receptor is GPR43 (also known as FFAR2) which is activated by acetate and propionate followed by butyrate. These SCFAs activates FFAR2 and releases PYY and GLP-1 from intestinal endocrine L-cells.

Another receptor FFAR3 has also been identified as a receptor for SCFAs and is mainly activated by both propionate and butyrate. The propionate and butyrate activated FFAR3 is also involved in the expression of neuropeptides such as PYY- and GLP-1, indicating its role and involvement in energy homeostasis in similar fashion that of FFAR2. GPR109A and olfactory

receptor 78 (OLFR78) are other two receptors which are associated with beneficial effects of SCFAs.

D. Genetic and epigenetic regulation by SCFAs

The SCFAs plays a major role in both genetic and epigenetic regulation of genes. Here, one of the important role of butyrate in transcriptional regulation is the induction of protein phosphatase enzyme. This enzyme is very well known in the transcriptional regulation of various genes. Butyrate also transcriptionally activates the WAF1/Cip1 gene promoter through Sp1 transcription factor in p53-negative human colon cancer cell line (Fig. 2) Further, it inhibits VEGF gene expression by inactivating Sp1 transcription factor. It is also involved in counter-regulatory effect on tumor necrosis factor-alpha -induced complement C3 and factor B biosynthesis in human intestinal epithelial cells. Butyrate, a well-known histone deacetylase inhibitor has beneficial effect on diabetes mellitus and inhibits beta-cell proliferation, function, and glucose homeostasis through modulation of p38/ERK MAPK and apoptotic signaling pathways in juvenile diabetic rat. Butyrate also improves myocardial function and prevents cardiac remodeling in diabetic mice and ameliorates eNOS, iNOS and TGF-β1-induced fibrogenesis and induces apoptosis and DNA damage in the kidney of juvenile diabetic rats. Both SCFAs (butyrate and propionate) protect against diet-induced obesity and regulate gut hormones via FFAR-3-independent mechanisms and butyrate also alleviates adipocyte inflammation by inhibiting NLRP3 pathway. The epigenetic effects of butyrate have potential therapeutic implications in the treatment of various diseases.

Propionate helps in appetite regulation, body weight maintenance and adiposity in overweight adults through colon absorption and increases hepatic pyruvate cycling and is also involved in the regulation mitochondrial metabolism. Propionate also inhibits *salmonella* invasion through the post-translational regulation of HilD protein and stimulates pyruvate oxidation in the presence of acetate. Further, propionate stimulates GLP-1 and PYY secretion via FFAR2 in rodent gut and reduces Akt2 knockout-mediated dysfunction in myocardial contractile ability and reduces cancer cell proliferation in the liver.

The SCFA, acetate functions as an epigenetic metabolite to promote lipid synthesis under hypoxic condition and reduces appetite via a central homeostatic mechanism. Acetate is also a bioenergetic substrate for human glioblastoma growth and development which also helps in brain metastasis. Acetate further modulates inflammatory cytokines through mitogen-activated protein kinases in primary astrocytes. It alters expression of genes involved in adipogenesis in obese mice and might represent a potential therapeutic agent and useful target to combat obesity. Recent studies also suggest that some tumors also depend on acetate for their metabolic energy source and acetate is also known to induce apoptosis in colorectal cancer cells which involves lysosomal membrane permeabilization and cathepsin D release.

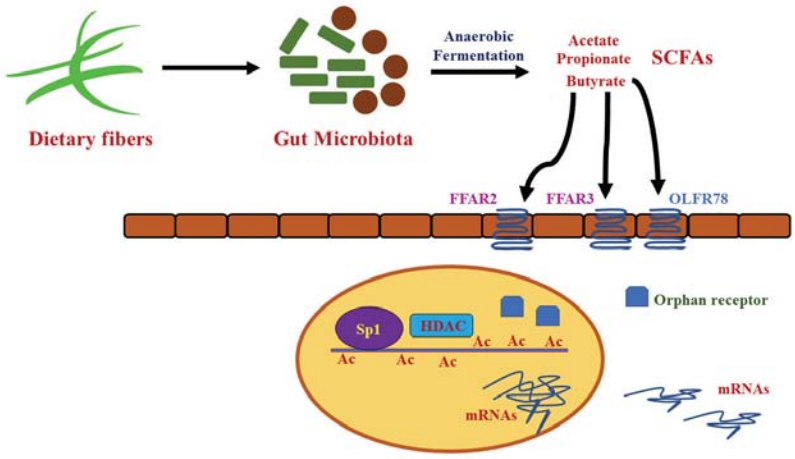


Fig.2 Schematic representation of gut microbiota mediated short chain fatty acids synthesis and mechanism of SCFA-induced gene regulation.

II. CONCLUSIONS

Recent elegant studies have established strong direct link between diet, gut microbiota and various disease including metabolic syndrome and cancers. These gut bacteria are also involved in activating and suppressing various immune response pathways. Many studies have also shown with strong evidences that SCFAs are beneficial compounds which helps in maintenance of good health. Thus probiotics, prebiotics and symbiotics which are the sources for the production of SCFAs are used as diet and therapeutic drugs to cure IBD, colon cancer and metabolic syndrome. The molecular mechanism behind butyrate, propionate and acetate actions at cellular level are still elusive and it is tempting to speculate that these SCFAs have all the properties of future therapeutic drugs for various diseases. By considering all these studies and beneficial effects of SCFAs, this mini review is a small effort to shed light on recent advances in the research on gut microbiota and SCFA.

REFERENCES

[1] E.Nagy, R.M. Rodriguiz, W.C.Wetsel, N.J MacIver, L.P Hale. "Reproduction and Growth in a Murine Model of Early Life-Onset Inflammatory Bowel Disease". *PLoS One*. 5; 11(4): April. 2016.

[2] C.M Guinane, P.D Cotter. "Role of the gut microbiota in health and chronic gastrointestinal disease: understanding a hidden metabolic organ". *Therap Adv Gastroenterol*. 6(4): pp. 295-308, July. 2013.

[3] B.J Marshall, J.R Warren. "Unidentified curved bacilli in the stomach of patients with gastritis and peptic ulceration". *Lancet*. 16;1 (8390): pp.1311-5. June. 1984.

[4] B Sánchez, S Delgado, A Blanco-Míguez, A Lourenço, M Gueimonde, A Margolles. "Probiotics, gut microbiota, and their

influence on host health and disease". *Mol Nutr Food Res.* 61(1). January. 2017.

[5] G.P1 Donaldson, S.M1 Lee, S.K1 Mazmanian. "Gut biogeography of the bacterial microbiota". *Nat Rev Microbiol.* 14(1): pp.20-32. January. 2016

[6] G.O Canny, B.A McCormick. "Bacteria in the intestine, helpful residents or enemies from within?". *Infect Immun.* 76(8): pp. 3360-73. August. 2008.

[7] J. Chow, S.M Lee, Y. Shen, A. Khosravi, S.K Mazmanian. "Host-bacterial symbiosis in health and disease". *Adv Immunol*; 107: pp. 243-274. 2010.

[8] Segata N. Gut Microbiome: Westernization and the Disappearance of Intestinal Diversity. Curr Biol. 20; 25(14): R611-3. July. 2015.

[9] R.W Warne. "The micro and macro of nutrients across biological scales". *Integr Comp Biol.* 54(5): pp. 864-72. November. 2014.

[10] A.R Weseler, A .Bast. "Masquelier's grape seed extract: from basic flavonoid research to a well-characterized food supplement with health benefits". *Nutr J.* 19; 16(1):5. January. 2017

GUIDELINES FOR AUTHORS

The contributors are expected to highlight their research work with sufficient details & discussion of results.

The original research paper should be limited to 6 and short communication to 3 printed pages of the journal in double column standard IEEE format. Please refer to IEEE website for the standard format.

Manuscripts must be submitted online to nmamit.arj@gmail.com in .docx format.

Enough precaution should be taken to make the manuscript error free.

The papers that are not in the standard format may be rejected

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out.

Authors of the selected papers have to send the final camera ready paper (both in MS Word &PDF) for final print

After the review process, the selected papers will be published in the Journal.

Article structure

Subdivision - numbered sections

Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Material and methods

Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

Theory/calculation

A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a calculation section represents a practical development from a theoretical basis.

Results

Results should be clear and concise.

Discussion

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusion

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Appendices

If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.s1, etc.

NMAM INSTITUTE OF TECHNOLOGY, NITTE – 574110

NMAM Institute of Technology was started in the year 1986, as a part of Nitte Education Trust, Mangalore and celebrated its Silver Jubilee in 2011. The Institute is named in fond memory of Nitte Mahalinga Adyanthaya, a distinguished engineer of the district. It is affiliated to the Visvesvaraya Technological University, Belgaum, enjoying academic autonomy and is recognized by the All India Council for Technical Education, New Delhi. It is accredited by the National Board for Accreditation and is certified to the ISO 9001 – 2008 standards for quality education by KEMA, Netherlands. The Institute has been recognized as Lead Institute under TEQIP- I Project of World Bank.

The Institute offers B.E, M.Tech and Ph.D pragrammes in various Engineering and Technology disciplines. The graduate programs comprise of 7 branches of Engineering – Electronics & Communication Engineering, Computer Science & Engineeing, Civil Engineering, Electrical & Electronics Engineering, Information Science & Engineering, Bio-Technology and Mechanical Engineering. The Institute's postgraduate programs include, Master of Technology in 13 disciplines, Master of Computer Applications and Master of Business Administration. The Visvesvaraya Technological University has opened a postgraduate extension centre at NMAMIT, offering M.Tech in Micro-electronics & Control Systems. Besides these, students also pursue their M.Sc(Eng.) and Doctoral Programs at the Institute. The Institute got academic autonomy in the year 2007, bringing in the much needed flexibility to innovate in terms of curriculum, education delivery and evaluation. Institute entered into collaboration with Penn State University, Harrisburg, USA and started offering 2+2 twinning program in Engineering since 2011.