Prediction of Surface Hardness based on Experimentation of Single Roller Burnishing Operation

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Abstract

In the Present study, effortsare taken to develop an artificial neural network model for predicting surface hardness of single roller burnishing operation. Single roller burnishing operation is designed based on Taguchi orthogonal design matrix. An ANN model was developed based on burnishing process parameters like speed, feed, force and number of passes for prediction using Matlab. It is observed that developed ANN model with accuracy of around 98%

Keywords: Artificial neural network, Burnishing process, surface hardness, Taguchi method, predicted hardness

1. Introduction

Now a days, the post-machining operationsare considered to be very important, like laser pinning process, shot blasting, shut pinning and burnishing. This will result ingood surface finish, geometrical tolerance and closed dimensional accuracy.Another process which is follows as Roller burnishing. This is work hardening process. Practically in this pressure is applied throughhard and smooth roller on surface of work material. This will deform the material permanently [1,2]. To improve the surface roughness the burnishing process is used. Out of all these above processes the RollerBurnishing process is considered asa most economical, very simple and time saving process. The major advantages of this process is improvement in mechanical propertiesof the machined surface of workpiece [4], maximum residual stresses in compression[10] and fatigue.Burnishing force, speed, feed rate, workpeice material, roller material, number of passes and lubrication [1-10] are the parameters which are significantly affecting the mechanical properties of the material.

S No	Paper	Statistical methos used for optimization and prediction of quality characteristics
1	Klocke, F., Bäcker, [3]	Response surface methodology (RSM)
2	Bounouara, A., Hamadache [12]	Desirability function analysis
3	Sagbas, A., [8]	Fuzzy logic
4	Hassan, A. M [5]	Artificial neural network
5	Kumar, P. S., Babu, B. S [2]	Grey relational analysis
6	Esme, U [14]	Taguchi method
	Basak and Goktas [11]	optimized the burnishing parameters using fuzzy logic.
	Kurkute and Chavan [19]	modeled and optimized the surface roughness and microhardness roller burnished aluminum alloy using RSM.
	Kumar et al. [2]	used Taguchi technique and fuzzy logic model in roller burnishing process for estimation of surface roughness and hardness of AA 2014 and AA 6063 aluminum alloy. It compared models to obtain minimum surface roughness and maximum hardness.
	El-Taweel and El-Axir [4]	analyzed and optimized the ball burnishing process on surface roughness and micro-hardness of brass using Taguchi technique.
	Sarhan and El-Tayeb [17]	performed the estimation of surface roughness in burnishing of brass C3605. The approach used the fuzzy rule-based approach. The results, which acquired from the fuzzy model, are immensely coherent with the experiments.
	Esme et al. [10]	focused on the surface roughness and microhardness of AA 7075 aluminum alloy using grey-based fuzzy algorithm.
	Kahraman [15]	developed an empirical model for the prediction surface hardness of AA 7075 aluminum alloy using RSM with central composite design.
	Sagbas and Kahraman [1]	studied optimal burnishing parameters for surface hardness of AA 7178 aluminum alloy using Taguchi method.
	Dweiri et al. [16]	optimized the surface roughness roller burnished nonferrous component using fuzzy model.

In this paper, the surface hardness was estimated as a function of four factors namely,

1. burnishing speed,
2. feed rate,
3. burnishing force and
4. number of passes.

ANOVA method is primarily used by the researchers to analyze the effect of control factors of any experiments on the outcome of the experiment. In this experiment the outcome is the surface hardness. So the co-relation between the control factor and hardness need to be evaluated by using ANOVA methodology. A detailed study and comparison is made and compared the results from the methods as, Taguchi method, regression analysis and fuzzy logic model for surface hardness.

Experimental Details

In this experimental study, the Aluminium_6061 is used. The Chemical composition of which can be seen in the following table.

Mg	Si	Cu	Zn	Mn	Cr	Fe	Ti
0.2	0.4- 0.8	0.15-0.4	0.25	0.15	0.04- 0.35	0.7	0.1

Particular	Specifications
Work piece Test work piece A roller burnishing tool (Bright Burnishing PVT. Ltd, Coimbatore)	Bar of 32 mm rod of 30 mm diameter and 100 mm length diameter 30 mm
Lathe Machine Specifications / settings / type	
General purpose type all geared lathe machine (Mac Power)	5Hp spindle motor
	step-less spindle speeds ranging from 76 – 7 RPM
The distance between the centres	800 mm
Swing over bed	300 mm
Swing over cross slide Chuck size Longitudinal feed	190 mm 148 mm diameter 0.4 – 0.9 mm/rev
Cross feed	0.05 – 0.52 mm/rev
Initially the turning operation is being performed using carbide tool and then burnishi operation carried out.	
The work piece is clamped with the help of the tailstock centre and three jaw chuck machine	
No need of coolant during burnishing process.	

Fig. 1.A roller burnishing tool

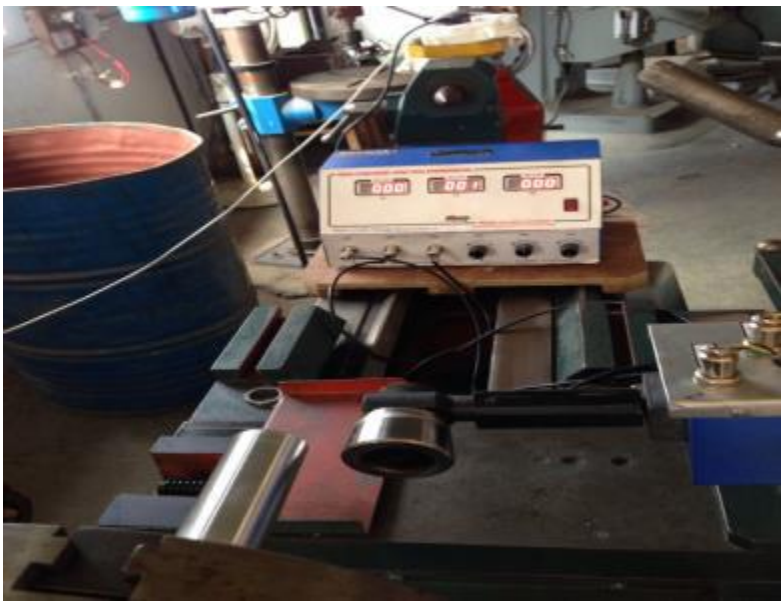


Fig.2 Burnishing setup

Fig. 3workspace after burnishing

Artificial Neural Network

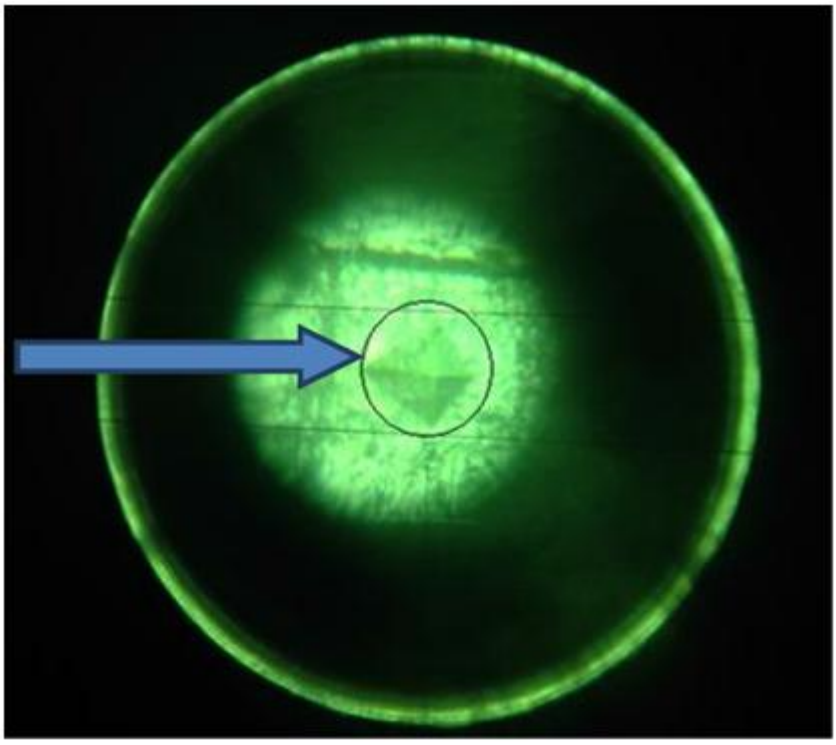
ANN implemented in Matlab technology. Based on input and output parameter values, an ANN creates multi layers neural networks. Input layer match input columns in the grid, and output layers layer match output columns in the grid .Hidden layers are connect input and output layers. The training of the ANN model is done on the training data set partially selected on random basis from the original dataset. The same datacan be usedfor validation. After completion of the training the generated model is further tested. The training data is then inputted by separate files are used for different queries [6].

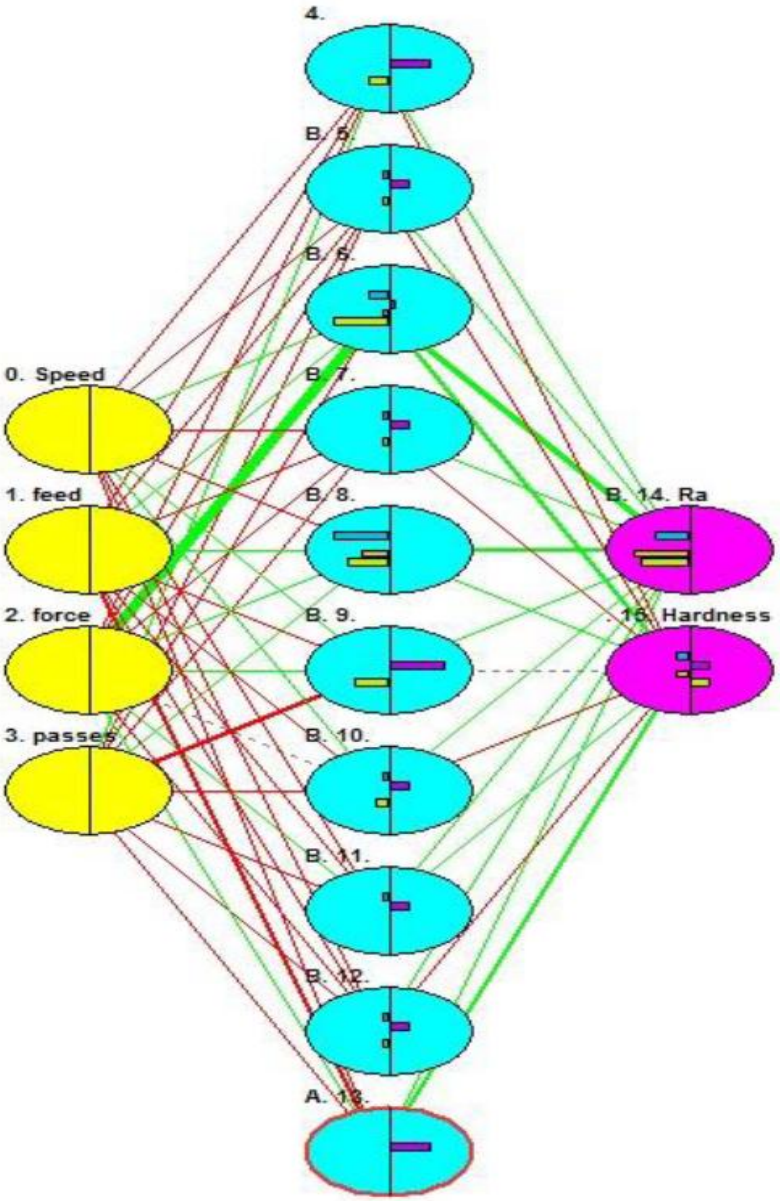
4. RESULT AND DISCUSSION

Taguchi analysis is done with L25 orthogonal array. The different factors and their different levels of the experiment is as shown below.

Level	Speed	Feed	Force	No. Of Pass
i.	79	0.3	4	1
ii.	107	0.4	5	2
iii.	287	0.5	6	3
iv.	459	0.6	7	4
v	730	0.7	8	5

Sr. No.	Speed	Feed	Force	No. Of Pass	Micro Hardness	Predicted Micro Hardness
1	76	0.3	4	1	125	123
2	76	0.4	5	2	127	126
3	76	0.5	6	3	129	125
4	76	0.6	7	4	126	125
5	76	0.7	8	5	132	130
6	105	0.3	5	3	125	124
7	105	0.4	6	4	127	125
8	105	0.5	7	5	128	124
9	105	0.6	8	1	133	132
10	105	0.7	4	2	124	120
11	280	0.3	6	5	126	125
12	280	0.4	7	1	129	124
13	280	0.5	8	2	133	131
14	280	0.6	4	3	124	122
15	280	0.7	5	4	126	125
16	460	0.3	7	2	129	128
17	460	0.4	8	3	132	131
18	460	0.5	4	4	123	122
19	460	0.6	5	5	127	125
20	460	0.7	6	1	129	128
21	720	0.3	8	4	132	130
22	720	0.4	4	5	123	121
23	720	0.5	5	1	127	125
24	720	0.6	6	2	129	125
25	720	0.7	7	3	130	129



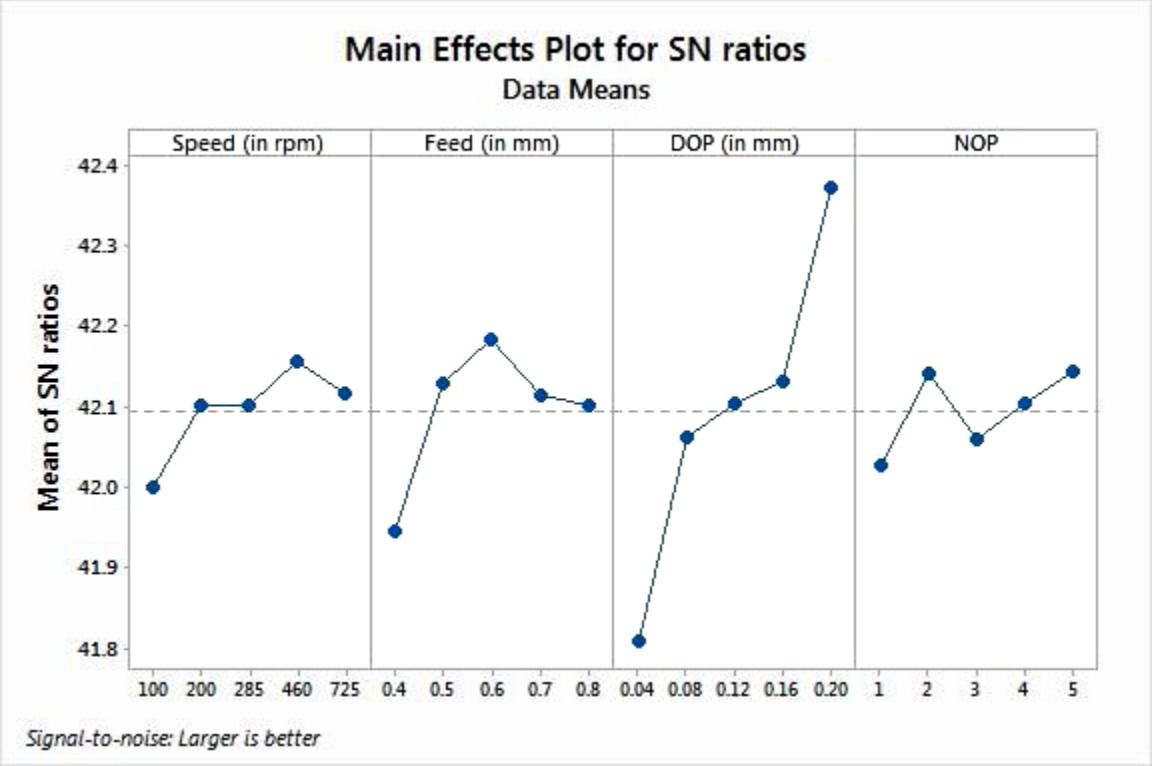


The F – Ratio is calculated the surface roughness.

Factors	DoF	SS	%SS	MS	F
Speed	4	9.65	0.96	3.280	0.6
Feed	4	9.65	0.96	8.050	1.49
*Force**	*4*	*888.63*	*96.01*	*42.550*	*7.89*
No. Of Pass	4	6.61	0.67	2.560	0.47
Error	8	13.52	1.4		
Total	24	928.06			

Table :The result of ANOVA for surface roughness

The Force* value 7.89 which is greater than $F_{0.025, 4, 8}$ is 5.053. So, the burnishing force is the most significant factor for surface micro hardness.



CONCLUSIONS :

The experimental results demonstrate the uniqueness of using the ANNOVA methos in evaluating the important and causal parameters of the experiments. The evaluations of the i. four burnishing variables, ii. no. of passes, iii. speed burnishing force and iv. feed rate were investigated using DOE and ANN. DOE with ANN was employed to evaluate the effects of burnishing parameters on the surface hardness on aluminium alloy. The significant factor on the surface hardness is determined as burnishing force.

The effect of individual parameter on surface hardness is as follows:

i. Burnishing Speed - As Speed increases, surface hardness increases reaches to maximum value and again decreases
ii. Burnishing Feed - As Feed increases, surface hardness increases reaches to maximum value and again decreases
iii. Burnishing Force - As Force increases, surface hardness is continuously increases reaches to maximum.
iv. Number of passes:- As Number of Passes inc., surface hardness inc. then dec. and inc.

REFERENCES

[1] Sagbas, A., Kahraman, F., (2009) Determination of optimal ball burnishing parameters for surface hardness", *Materiali in tehnologije*,

[2] Kumar, P. S., Babu, B. S., Sugumaran, V., (2018) Comparative Modeling on Surface Roughness for Roller Burnishing Process, using Fuzzy Logic, *International Journal of Mechanical and Production Engineering Research and Development*.

[3] Klocke, F., Bäcker, V., Wegner, H., Zimmermann, M., (2011) Finite element analysis of the roller burnishing process for fatigue resistance increase of engine components, *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture.*

[4] El-Taweel, T. A., El-Axir, M. H., (2009) Analysis and optimization of the ball burnishing process through the Taguchi technique, *The International Journal of Advanced Manufacturing Technology*.

[5] Hassan, A. M., Al-Dhifi, S. Z., (1999) Improvement in the wear resistance of brass components by the ball burnishing process, *Journal of Materials Processing Technology*.

[6] Yen, Y. C., Sartkulvanich, P., Altan, T., (2005) Finite element modeling of roller burnishing process, *CIRP Annals-Manufacturing Technology*.

[7] Esme, U., Kulekci, M. K., Ustun, D., Kahraman, F., Kazancoglu, Y., (2015) Grey-based fuzzy algorithm for the optimization of the ball burnishing process", *Materials Testing.*

[8] Sagbas, A., (2011) Analysis and optimization of surface roughness in the ball burnishing process using response surface methodology and desirabilty function, *Advances in Engineering Software.*

[9] El-Tayeb, N. S. M., Low, K. O., Brevern, P. V., (2007) Influence of roller burnishing contact width and burnishing orientation on surface quality and tribologicalbehaviour of Aluminium 6061, *Journal of materials processing technology.*

[10] Esme, U., Sagbas, A., Kahraman, F., Kulekci, M.K., (2008) Use of artificial neural networks in ball burnishing process for the prediction of surface roughness of AA 7075 aluminum alloy, *Materiali in tehnologije*.

[11] Basak, H., Goktas, H. H., (2009) Burnishing process on al-alloy and optimization of surface roughness and surface hardness by fuzzy logic, *Materials & Design.*

[12] Bounouara, A., Hamadache, H., Amirat, A., (2018) Investigation on the effect of ball burnishing on fracture toughness in spiral API X70 pipeline steel, *The International Journal of Advanced Manufacturing Technology*.

[13] Pałka, K., Weroński, A., Zalewski, K., (2006) Mechanical properties and corrosion resistance of burnished X5CrNi18-9 stainless steel, *Journal of Achievements in Materials and Manufacturing Engineering.*

[14] Esme, U., (2010) Use of Grey based Taguchi method in ball burnishing process for the optimization of surface roughness and microhardness of AA 7075 aluminum alloy, *Materiali in Tehnologije.*

[15] Kahraman, F., (2015) Application of the response surface methodology in the ball burnishing process for the prediction and analysis of surface hardness of the aluminum alloy AA 7075, *Materials Testing*.

[16] Dweiri, F., Hassan, A. M., Hader, A., Al-Wedyan, H., (2003) Surface finish optimization of roller burnished nonferrous components by fuzzy modeling, *Materials and Manufacturing Processes*.

[17] Sarhan, A. A., El-Tayeb, N. S. M., (2014) Investigating the surface quality of the burnished brass C3605—fuzzy rule-based approach, *The International Journal of Advanced Manufacturing Technology*.

[18] Kurkute, V., Chavan, S. T., (2018) Modeling and Optimization of surface roughness and microhardness for roller burnishing process using response surface methodology for Aluminum 63400 alloy, *Procedia Manufacturing.*

[19] Kurkute, V., Chavan, S. T., (2018) Modeling and Optimization of surface roughness and microhardness for roller burnishing process using response surface methodology for Aluminum 63400 alloy, *Procedia Manufacturing.*

[20] Mulani, Altaf O., and P. B. Mane. "Watermarking and cryptography based image authentication on reconfigurable platform." Bulletin of Electrical Engineering and Informatics 6.2 (2017): 181-187.

[21] Jadhav, Makrand M. "Machine Learning based Autonomous Fire Combat Turret." Turkish Journal of Computer and Mathematics Education (TURCOMAT) 12.2 (2021): 2372-2381.

[22] Swami, Shweta S., and Altaf O. Mulani. "An efficient FPGA implementation of discrete wavelet transform for image compression." 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS). IEEE, 2017.

[23] Shinde, Ganesh, and AltaafMulani. "A robust digital image watermarking using DWT-PCA." International Journal of Innovations in Engineering Research and Technology 6.4 (2019): 1-7.

[24] Kulkarni, Priyanka R., Altaaf O. Mulani, and P. B. Mane. "Robust invisible watermarking for image authentication." Emerging Trends in Electrical, Communications and Information Technologies. Springer, Singapore, 2017. 193-200.

[25] BhanudasGadade and AltafMulani, "Automatic System for Car Health Monitoring", International Journal of Innovations in Engineering Research and Technology, 57–62, 2022

[26] PratimaAmolKalyankar, Altaf O. Mulani, Sampada P. Thigale, PranaliGajananChavhan and Makarand M. Jadhav, "Scalable face image retrieval using AESC technique", Journal Of Algebraic Statistics Volume 13, No. 3, p. 173 – 176, 2022

[27] A. O. Mulani and G. N. Shinde, "An approach for robust digital image watermarking using DWT- PCA", Journal of Science and Technology, Vol.6, Special Issue 1, 2021

DOI: https://doi.org/10.46243/jst.2021.v6.i04.pp59- 62

[28] U. P. Nagane and A. O. Mulani, "Moving Object Detection and Tracking Using Matlab", Journal of Science and Technology, Vol.6, Special Issue 1, 2021 DOI: https://doi.org/10.46243/jst.2021.v6.i04.pp63- 66

[29] Priyanka Kulkarni and A. O. Mulani, "Robust Invisible Digital Image Watermarking using Discrete Wavelet Transform", International Journal of Engineering Research & Technology (IJERT), Vol. 4 Issue01, pp.139- 141, Jan.2015

[30] Mulani, Altaf O., and Pradeep B. Mane. "High-Speed Area-Efficient Implementation of AES Algorithm on Reconfigurable Platform." Computer and Network Security (2019): 119.

[31] Deshpande, Hrushikesh S., Kailash J. Karande, and Altaaf O. Mulani. "Area optimized implementation of AES algorithm on FPGA." 2015 International Conference on Communications and Signal Processing (ICCSP). IEEE, 2015.

[32] Godse, A. P., and A. O. Mulani. Embedded systems. Technical Publications, 2009.
[33] Mulani, Altaf O., and P. Mane. "Secure and area efficient implementation of digital image watermarking on reconfigurable platform." Int. J. Innov. Technol. Explor. Eng.(IJITEE) 8.2 (2018): 1.
[34] Rahul G. Ghodake and A. O. Mulani, "Microcontroller Based Drip Irrigation System", Techno-societal 2016, International conference on advanced technologies for societal applications, pp. 109–115.
[35] AmrutaMandwale and A. O. Mulani, "Different Approaches For Implementation of Viterbi decoder", IEEE International Conference on Pervasive Computing (ICPC), Jan. 2015.
[36] AmrutaMandwale and A. O. Mulani, "Implementation of Convolutional Encoder & Different Approaches for Viterbi Decoder", IEEE International Conference on Communications, Signal Processing Computing and Information technologies, Dec. 2014.
[37] AmrutaMandwale and A. O. Mulani, "Implementation of High Speed Viterbi Decoder using FPGA", International Journal of Engineering Research & Technology (IJERT), Feb. 2016
[38] D. M. Korake and A. O. Mulani, "Design of Computer/Laptop Independent Data transfer system from one USB flash drive to another using ARM11 processor", International Journal of Science, Engineering and Technology Research, 2016.
[39] Rahul G. Ghodake and A. O. Mulani, "Sensor Based Automatic Drip Irrigation System", Journal for Research, 53-56, 2016.
[40] Rahul Shinde and A. O. Mulani, "Analysis of Biomedical Image", International Journal on Recent & Innovative trend in technology (IJRITT), July 2015
[41] Rahul Shinde and A. O. Mulani, "Analysis of Biomedical Image using Wavelet Transform", International Journal of Innovations in Engineering Research and Technology (IJIERT), July 2015
[42] A. O. Mulani and P. B. Mane, "Area optimization of cryptographic algorithm on less dense reconfigurable platform,"2014 International Conference on Smart Structures and Systems (ICSSS), Chennai, 2014, pp. 86- 89
[43] A.O.Mulani, M. M. Jadhav and Mahesh Seth, "Painless Non- invasive blood glucose concentration level estimation using PCA and machine learning" in the CRC Book entitled Artificial Intelligence, Internet of Things (IoT) and Smart Materials for Energy Applications, 2022.
[44] Kamble, Akshata, and A. O. Mulani. "Google Assistant based Device Control." Int. J. of Aquatic Science 13.1 (2022): 550-555.
[45] Pathan, Atik N., et al. "Hand Gesture Controlled Robotic System." Int. J. of Aquatic Science 13.1 (2022): 487-493.
[46] Kolekar, Supriya D., et al. "Password Based Door Lock System." Int. J. of Aquatic Science 13.1 (2022): 494-501.
[47] SwapnilTakale, Dr. AltaafMulani, "Video Watermarking System", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 10, Issue III, Mar-2022.
[48] J. P. Patale et al. "Python Algorithm to Estimate Range of Electrical Vehicle", Telematique,

Volume 21, No. 1, 2022.

[49] Jayshri Prakash Patale, A. B. Jagadale, A. O. Mulani, and Anjali Pise. "A Systematic Survey on Estimation of Electrical Vehicle". Journal of Electronics,Computer Networking and Applied Mathematics(JECNAM) ISSN : 2799-1156, vol. 3, no. 01, Dec. 2022, pp. 1-6, doi:10.55529/jecnam.31.1.6.

[50] Kashid, M.M., Karande, K.J., Mulani, A.O. (2022). IoT-Based Environmental Parameter Monitoring Using Machine Learning Approach. In: Kumar, A., Ghinea, G., Merugu, S., Hashimoto, T. (eds) Proceedings of the International Conference on Cognitive and Intelligent Computing. Cognitive Science and Technology. Springer, Singapore. https://doi.org/10.1007/978-981-19-2350-0_5

[51] SwapnilTakale, and Dr. AltaafMulani. "DWT-PCA Based Video Watermarking". Journal of Electronics,Computer Networking and Applied Mathematics(JECNAM) ISSN : 2799-1156, vol. 2, no. 06, Nov. 2022, pp. 1-7, doi:10.55529/jecnam.26.1.7.

[52] A. O. Mulani and Dr. P. B. Mane, "High throughput area efficient FPGA implementation of AES Algorithm", in the Intech Open Access Book entitled Computer and Network Security, Feb. 2019.

[53] Hemlata M. Jadhav, AltafMulani and Makarand M. Jadhav, "Design and Development of Chatbot based on Reinforcement Learning", in the Wiley-IEEE book entitled Natural Language Processing using Machine and Deep Learning, 2022

[54] V. B. Utpat, Dr. K. J. Karande, Dr. A. O. Mulani, "Grading of Pomegranate Using Quality Analysis", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 10 Issue II Feb 2022.