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This is to certify that Dr./Mr/Mrs. Satish Patil and Rachayya R Arakerimath ***has Participated/Attended/Presented/paper*** *entitled* "Analysis of Heterogeneous Catalyzed Castor oil Biodiesel" ***in International E- Conference on Intelligent Mechanical Systems for Industry 4.0- (ICIMSI-2021) during 26th - 27th February, 2021 at Department of Mechanical Engineering, GHRCEM, Wagholi, Pune.***

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Chapter 12

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ANN Validation of Biodiesel Synthesis Optimization using Heterogeneous Catalyst (SiO_2)

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ABSTRACT

Biodiesel is a renewable, ecofriendly fuel that can provide comparable engine performance. Karanja oil is made in this experiment using a transesterification process with SiO_2 as a heterogeneous catalyst. It is investigated utilising five separate parameters and their respective levels. The orthogonal arrays are fixed using Minitab, and the Taguchi method is utilised to study the interaction impact for the transesterification reaction. Molar ratio, catalyst concentration, reaction temperature, reaction time, and stirring speed are the five variables that affect biodiesel yield. The impact of these variables has been investigated on a limited scale. Experimentally biodiesel yield obtained is 77% at optimum conditions are 20% molar ratio, 3% SiO_2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed. Minitab results are compared here with ANN results using script by analytically as well as graphically.

Keywords: Transesterification; biodiesel; SiO_2; Heterogeneous catalyst.

1. INTRODUCTION

Diesel fuels are utilized in various zones and contribute to the economies of the countries. Alternative fuels are required due to a rise in environmental consciousness and dwindling petroleum reserves [1]. The ongoing requirements for fuel in meeting the ever-growing demand in commercial sector have pushed researchers in finding and optimizing the production of biofuels from cheap sources, enabling for a sustainable production [1]. The properties like non-toxic, degradability, less carbon monoxide emission, particulate matter and unburned hydrocarbons, the biodiesel has gained an international focus as an alternative to diesel fuel [2]. The conventional compression engine does not require any modification to use the biodiesel as fuel [3]. Improvisation of the biodiesel production by employing heterogeneous catalyst and its optimization is the best way to mitigate the growing concern with the traditional feedstocks and their prices [4].

The yields of Karanja oil biodiesel were obtained by 25 different sets of different experimental conditions and noted. All experiments were performed as per array obtained by Taguchi method under the different experimental conditions as mentioned here.

The analysis of the results has done by Taguchi method using Minitab for optimization of input parameters. The graphs namely main effect plots, interaction plots, regression plot, and mathematical model have obtained during the analysis [5]. The ANN script has written for obtaining results. The yield values obtained by Taguchi array experimentation and obtained by ANN are compared. The graphical and analytical comparative analysis has done. The results obtained by Minitab experimentation are validated by ANN.

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2. OPERATING CONDITIONS

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During the Transesterification process for biodiesel production from Karanja oil using heterogeneous catalyst the effect of different input parameters is studied as follows [4].

1) Variation of Molar Ratio. (MR)
2) Effect of Percentage of catalyst.(CP)
3) Effect of Temperature of Process/reaction.(PT)
4) Effect of Stirring Speed of reaction.(SS)
5) Effect of Reaction Time of reaction. (RT)

The range of operating conditions for each parameter has as follows.

Table 1. Optimizing parameter conditions

A:MR		B: CP	C: PT	D: RT		E:SS	
%		%	ºC	min		rpm	
A1	= 5	B1 = 1.5	C1=55	D1	= 60	E1	=300
A2	= 10	B2 = 2.0	C2=60	D2	= 90	E2	= 400
A3	= 15	B3 = 2.5	C3=65	D3	= 120	E3	= 500
A4	= 20	B4 = 3.0	C4=67	D4	= 150	E4	= 600
A5	= 25	B5 = 3.5	C5=70	D5	= 180	E5	= 700

3. EXPERIMENTAL RESULTS WITH SiO_2 AS A CATALYST

Initially the esterification process is done, the color of Karanja oil after esterification changed from deep brown to reddish yellow. The transesterification process produces methyl ester (Karanja oil biodiesel) and glycerol form upper and lower layers respectively. Due to more density of glycerin, it was settled at bottom. The catalysts and unused methanol were in the lower glycerol layer. The results shown that, using SiO_2 catalyst the biodiesel production has a considerable potential.

Twenty-five numbers of experiments for transesterification process were conducted using Karanja oil with methanol under different conditions of reactions to produce biodiesel. Input parameters and % of yields were noted. The sample readings are given below [4,5].

Design details
Array obtained by Taguchi Method L25 (5^5)
Factors: Five numbers
Runs: Twenty five
Columns of L25 (5^6) array: 1 2 3 4 5

Table 2. Sample reading of Yield obtained and SNRs

MR	CP	PT	RT	SS	Yield %	SNRA1	SRES
5	1.5	55	60	300	50	33.9794	-0.06531
5	2	60	90	400	52	34.3201	-1.24764
10	3.5	55	90	500	72	37.1466	1.83866
15	3	55	120	700	68	36.6502	-0.5516
15	3.5	60	150	300	73	37.2665	0.16741
20	2.5	55	150	400	67	36.5215	-0.94569
20	3	60	180	500	77	37.7298	1.62962
20	3.5	65	60	600	74	37.3846	-0.4575
25	1.5	70	150	500	68	36.6502	0.85144

The above table gives the optimal values of input parameters for maximum biodiesel yield because of high value of SN ratio. The biodiesel yield obtained experimentally at optimum conditions are 20% molar ratio, 3% SiO_2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed is 77%.

4 TAGUCHI ANALYSIS WITH SiO_2 CATALYST

Taguchi Analysis: yield % versus Molar Ratio %, Catalyst ... reaction Speed [5,6,7]

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Signal to Noise Ratios: Larger is better

Main Effects on yield by SN ratio for Individual Parameter: For examine differences between level for one or more factors the main effect plot is used. The graphs shows the response mean for each factor level [1].

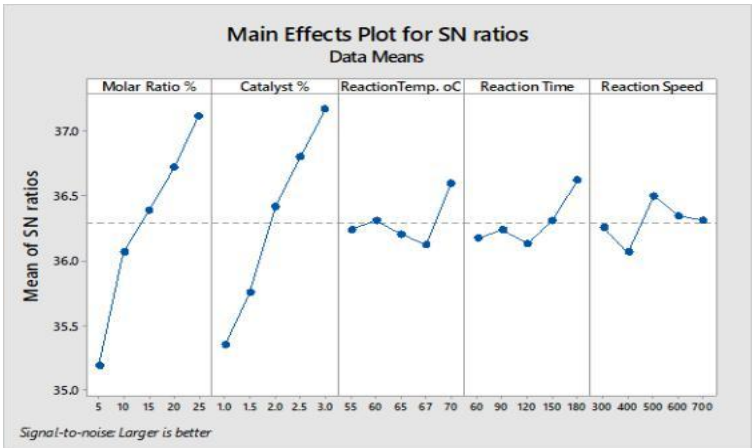

Fig. 1. Main effects Plot for SN ratios

This Fig. 1 shows that, the two graphs are steeper than others. First is the mean of S/N ratios vs molar ratio and second is the mean of S/N ratios vs. catalyst%. So, it is concluded that the two parameters affecting the yield mainly are the molar ratio and catalyst %. The effects of other three parameters can be neglected.

Interaction Plot for SN ratios: Main effects were generally focused by Taguchi method, but suspected interactions are important to test. To measure whether the effect of one factor on response characteristic depends on the level of other the interaction plot is used [1].

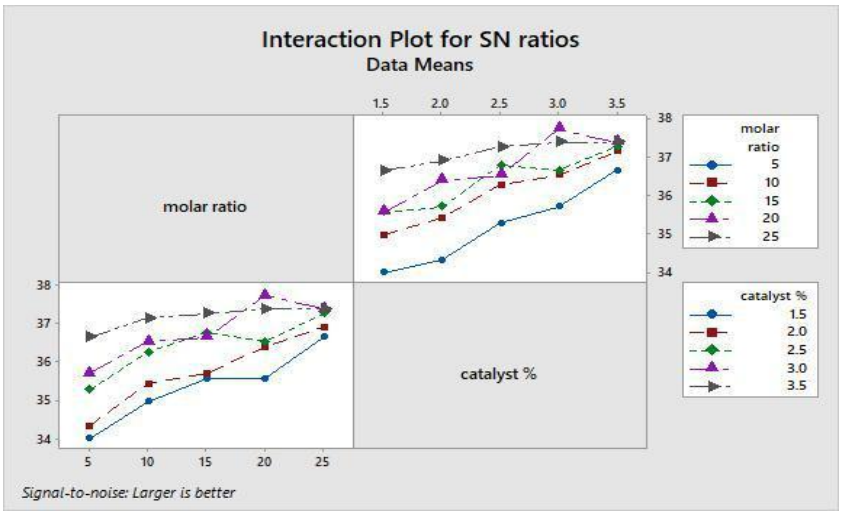

Fig. 2. Interaction Plot for parameter A and B (For molar ratio and Catalyst %)

Simultaneously the interaction plots shows, the variation of yield with effect of molar ratio and catalysts are as shown in Fig. 2. This shows that the yield has maximum value for 20 % molar ratio and catalyst 3%.

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5. REGRESSION ANALYSIS FOR SIO_2

Regression Analysis: yield % versus Molar Ratio %, ... , Reaction Speed Analysis of Variance [5,7].

Table 3. Analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	5	1165.96	233.191	42.00	0.000
Molar Ratio %	1	544.50	544.500	98.08	0.000
Catalyst %	1	598.58	598.580	107.82	0.000
Reaction Temp. ^{0}C	1	1.66	1.657	0.30	0.591
Reaction Time	1	19.22	19.220	3.46	0.078
Reaction Speed	1	2.00	2.000	0.36	0.555
Error	19	105.48	5.552		
Total	24	1271.44			

Model Summary: R square value in model summary provides the measure of, how perfect the model is fitting with the actual data. R square value 91.70% shows that the obtained model is fitted to actual data.

Table 4. Summary of Model

S	R-sq	R-sq (adj)	R-sq (pred)
2.35622	91.70%	89.52%	86.30%

Regression Equation: It is a statistical model that determine the specific relationship between the input and output parameters. It gives the outcome with a relatively small amount of error.

$$\text{Yield \%} = 35.39 + 0.6600\,A + 6.920\,B + 0.0484\,C + 0.0207\,D + 0.00200\,E$$

6. VALIDATION OF EXPERIMENTAL RESULTS

Table 5. Sample Readings of Comparison of Yield by Experimentation and ANN for SiO_2

MR	CP %	PT	RT	SS	Yield %	ANN	Error	Error %
5	1.5	55	60	300	50	49.97	0.03	0%
5	2.5	65	120	500	58	58.64	-0.64	-1%
5	3.5	70	180	700	68	68.00	0.00	0%
10	1.5	60	120	600	56	54.17	1.83	3%
10	2	65	150	700	59	58.47	0.53	1%
10	2.5	67	180	300	65	65.00	0.00	0%
15	2	67	60	500	61	61.32	-0.32	-1%
15	3.5	60	150	300	73	71.29	1.71	2%
20	1.5	67	90	700	60	61.15	-1.15	-2%
20	2	70	120	300	66	65.77	0.23	0%
25	1.5	70	150	500	68	67.65	0.35	1%
25	3	65	90	300	74	73.04	0.96	1%

Comparison of Yield obtained by Experimentation and ANN for SiO_2:

The graphical comparative study of yield obtained by experimentation and ANN is as follows:

The graphical comparison of yield obtained by experimentation and ANN is appearing in Fig. 3. The values of yield obtained by experimentation, by ANN, the difference in these values, and also the % errors are given in Table 5. There is a very small difference between these values and% errors are also very small. So, results obtained by Taguchi method are validated by ANN.

Regression Plots: The normal probability plot is a graphical tool for comparing a data set with the normal distribution. A straight line in this plot shows the data fit a normal probability distribution. There are very low residual values and all residuals obtained are almost along the line.

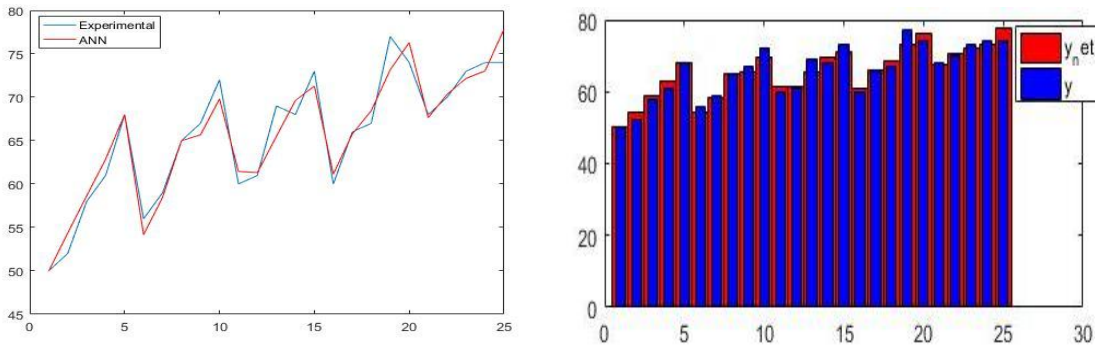

Fig. 3. Comparison of Yield by Experimentation and ANN for SiO_2

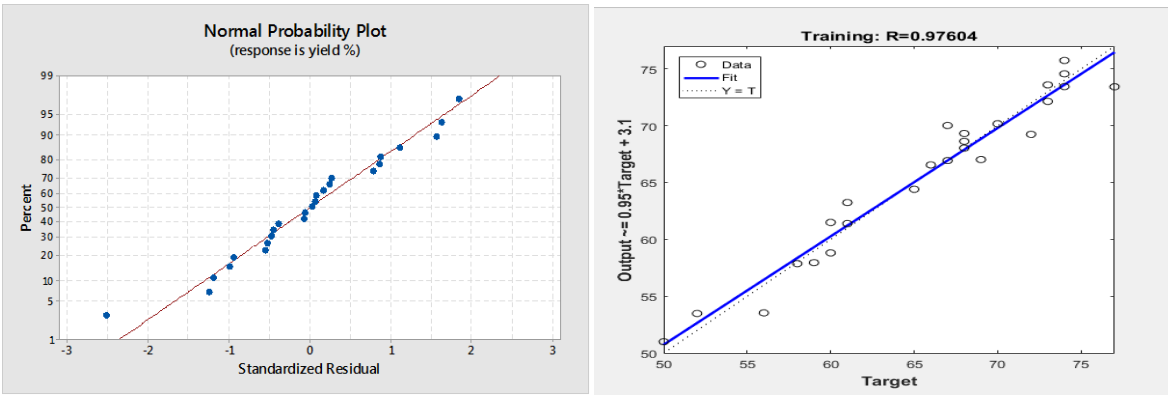

Fig. 4. Comparison of Regression plots by Minitab and by ANN for SiO_2

The R-square value for this regression is 91.70%. The regression plot obtained by ANN is compared with the Minitab regression plot. There are very low residual values and all residuals obtained are also along the line. There is a similarity in these plots, hence results are validated.

7. CONCLUSION

The analysis of optimizing the transesterification process has been carried out by Taguchi method for production of biodiesel from Karanja oil using SiO_2 as a heterogeneous catalyst. The results by experimentation through Minitab have validated by ANN (Artificial Neural Network), the conclusions are;

1) The biodiesel yield obtained experimentally is 77% at optimum conditions are 20% molar ratio, 3% SiO_2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed.
2) Main effective plot is concluded that the two parameters affecting the yield mainly are the molar ratio and catalyst %.
3) From interaction plot the yield has maximum value for 20 % molar ratio and catalyst 3%.
4) R square value 91.70% shows that the obtained model is fitted to actual data.
5) There are very small errors between the yields obtained by experimentation and by ANN.
6) The regression plot obtained by Minitab is similar to ANN regression plot.
7) In this way, various results obtained by Minitab have validated by ANN.

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COMPETING INTERESTS

3.3.4

Authors have declared that no competing interests exist.

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DISCLAIMER

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A Stereolithography System for 3D Low Cost Components

Criteria 3

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Keywords:
photo-polymer, stereolithography, rapid prototyping, ultra-violet light

ABSTRACT

The stereolithography (SL) process is one of the rapid prototyping technics and it is also known as additive layered manufacturing method. It is a chipless manufacturing method and the object is built layer by layer. A low cost stereolithography apparatus (SLA) is developed to produce highly precise, three-dimensional (3D) structures from broad selection of functional materials, especially photopolymer resin. The present SL systems available in the market are very expensive. The developed low cost SLA will be affordable to medium scale industries as well as customers. The developed SLA utilizes focused light beam of wavelength range of 300 nm – 700 nm from the DLP projector and passes through the objective lens over the surface of a photo-curable resin, which undergoes photo-polymerization and forms solid structures. The photopolymer used in this experimentation is polyethylene glycol di-acrylate and photo-initiator is Irgacure 784. The experiments are performed on objects with hexagonal cross-section and pyramid geometries and 0.1 mm curing depth along Z – axis. The trials are performed with different exposure and settling period. The 3D objects are successfully fabricated with high build speed and low cost. The pyramid object with maximum 120 numbers of layers with 12 mm dimension along Z-axis is built in 11.0 minutes. It is found that the optimum exposure time to cure a layer is two seconds. The maximum exposure area obtained in X-Y plane is 55 mm x 45 mm. The percentage dimensional error of the build objects is decreased as the curing time is reduced and the error is minimum for the two seconds curing period per layer. The obtained resolution of the build objects in X-Y plane is 23 microns and Z-stage resolution is 0.1 mm.

1. INTRODUCTION

There are a number of processes that can realize three-dimensional (3D) shapes such as those stored in the memory of a computer. An example is the use of holographic techniques [1], but these require many complex calculations to obtain the hologram and there is insufficient accuracy and clarity. A manual or a conventional mechanical process can also make a physical model, but such models require long fabricating times, high cost and excessive labour. To solve these kinds of problems, a new group of techniques called additive manufacturing (AM) technologies have been developed by a number of researchers group [2-5]. AM is a collection of processes in which physical objects are quickly created directly from computer generated models. The basic concept of rapid prototyping is where 3D structures are formed by laminating thin layers according to two-dimensional (2D) slice data, obtained from a 3D model created on a CAD/CAM system [2-5]. Stereolithography (SL) is one of the most popular AM process. It usually involves the curing or solidification of a liquid photosensitive polymer by focusing a light beam or laser beam of specific wavelength on the surface with liquid photopolymeric resin. The focused light beam supplies energy that induces a chemical reaction, bonding large number of small molecules and forming a highly cross-linked polymer [6]. Now a day, rapid prototypes of the different objects are required before their actual manufacturing because one can improve the design at the early stage of product development. The rapid prototyping or 3D printing field is very fast developing and this technology can applicable to all the fields i.e. engineering as well as non-engineering. The objective of this research work is to develop a low cost stereolithography apparatus (SLA) to produce highly precise, three-dimensional (3D) structures from broad selection of functional materials, especially photopolymer resin. The present SL systems available in the market are very expensive. The overall cost of the newly developed SLA is very low as compared to cost of SLA available in the market. The cost of photo-curable resin used is also low as compared to other available resins. Therefore, the developed low cost SLA will be affordable to medium scale industries and customers as the overall build cost of the objects is minimum.

A large number of researcher's groups have developed the SL systems out of which some of them are briefed in the following literature review.

Fujimasa [7] has been described the concepts of microplanes, microrobots, microcars and microsubmarines and MEMS which are systems that combine computers with

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tiny mechanical devices such as sensors, valves, gears, mirrors, and actuators embedded in semiconductor chips. Ventura et al. [8] developed a direct photo shaping process for the fabrication of functional ceramic components layer by layer and each layer is photo image or a digital light processing (DLP) projection system. Bertsch et al. [9] developed a micro stereolithography apparatus employing a pattern generator in which a UV laser and dynamic LCD pattern generator were used to generate the cross section of a 3D structure. While the substrate did not move in the x–y direction in the liquid photopolymer, an LCD pattern generation system was necessary and the resulting diffraction had to be considered. Maruo et al. [10] developed two-photon polymerization (TPP) which utilizes focused lasers to precisely polymerize small volumes resin and the volume is only polymerized if it is excited by two different photons within a very short time period. TPP is much slower than SL, but has successfully created components with 100 nm features. TPP is limited to polymers because it requires a clear resin to function; suspended particles would scatter the laser beams. Young et al. [11] have described a novel device for producing 3D objects that has been developed using an LCD as a programmable, dynamic mask and visible light to initiate photopolymerization. Ikuta et al. [12] introduced micro stereolithography technology and proposed a means of applying micro stereolithography in mass-production using an optical fiber array so that multiple microstructures could be fabricated in a single process. Monneret et al. [13] presented a new process of microstereolithography to manufacture freeform solid 3D micro-components with outer dimensions in the millimeter size range. Sun et al. [14] performed Monte Carlo simulations and experimental studies to understand the detailed microscale optical scattering, chemical reaction (polymerization), and their influence on critical fabrication parameters. It was found that due to the scattering, the fabricated line is wider in width and smaller in depth compared with polymeric fabrication at the same condition. The doping technique substantially reduced the light scattering, which in turn enhanced the fabrication precision and control. The experimental values of curing depth and radius agreed reasonably well with the theoretical modeling. Bertsch et al. [15] described new polymer/composite photosensitive resins that can be used in the microstereolithography process for manufacturing complex 3D components. Huang et al. [16] analyzed the shrinkage deformation of the mask type stereolithography process. Lee et al. [17] developed a micro stereolithography apparatus using a UV laser and a complex optical system. Jiang et al. [18] developed a Masked Photopolymerization Rapid Prototyping (MPRP) system using LCD panel as dynamic mask with an upper exposure skill. Dongkeon et al. [19] developed a liquid crystal display (LCD) based micro stereolithography process in order to fabricate microparts with superior mechanical properties (for e.g., micro gears) and investigates the fabrication process of micro bevel gears using photosensitive resins reinforced with ceramic nanoparticles. Deshmukh et al. [20] proposes and develops an offaxis lens scanning technique for MSL and carries out optical analysis to compare its performance with the existing techniques mentioned above. The comparison clearly demonstrates improved performance with the proposed offaxis lens scanning technique. Limaye [21] presented a more sophisticated process planning method to build a part with constraints on dimensions, surface finish and build time and formulated an adaptive slicing algorithm that slices a CAD model so as to obtain the required trade-off between build time and surface finish of up facing surfaces of the part. Hadipoespito et al. [22] developed DMD based UV micro – stereolithography system for fabricating 2D and 3D micro – parts. With the help of characterization experiments it was observed that the developed the DMD based imaging system irradiates an entire photopolymer layer at once, providing reasonable curing speed and good resolution at a low cost. Micro parts were also fabricated in nanocomposites, which were obtained by ultrasonic mixing of the transparent photopolymer and nano-sized ceramic particles. The micro models fabricated by this process could be used for micro scale investment casting, tooling, devices, and medical applications. In this method process optimization is needed to improve the quality of fabricated micro – parts. Singhal et al. [23] has presented a statistical surface roughness model for SLS prototypes as a key to slice the tessellated CAD model adaptively. The adaptive slicing system is implemented as Graphic User Interface in MATLAB-7.

Choi et al. [24] developed a more economical and simpler micro-stereolithography technology using a UV lamp as a light source and optical fiber as the light delivery system and photopolymer solidification experiments were conducted to examine the characteristics of the developed micro-stereolithography apparatus. Zhao et al. [25] developed a thick film mask projection stereolithography to fabricate films on fixed flat substrate and develop a column cure model in which a CAD model of part is discretized into vertical columns instead of being sliced into horizontal layers, and all columns get cured simultaneously till the desired heights. Vatani et al. [26] optimized the exiting slicing algorithms for reducing the size of the files and memory usage of computers to process them. In spite of type and extent of the errors in STL files, the tail-to-head searching method and analysis of the nearest distance between tails and heads techniques were used. As a result STL models sliced rapidly, and fully closed contours produced effectively and errorless. Deshmukh et al. [27] carried out analysis and experimental verification of optomechanical scanning systems for microstereolithography. Choi et al. [28] developed MSL system for tissue engineering using a Digital Micromirror Device (DMD) for dynamic pattern generation and an ultraviolet (UV) lamp filtered at 365 nm for crosslinking the photoreactive polymer solution. Gandhi et al. [29] proposes and analyses a 2D optomechanical-focused laser spot scanning system for microstereolithography which allows uniform intensity focused spot scanning with high speed and high resolution over a large range of scan. Higher speed and high resolution at the same time are achieved by use of two serial double parallelogram flexural mechanisms with mechatronics developed around them. Itoga et al. [30] developed maskless photolithography device by modifying Liquid Crystal Display (LCD) projector optics from magnified to reduced projection. The developed device produces a practical centimeter scale micro-pattern by dividing a large mask pattern and divisionally exposing it synchronized with an auto – XY stage, applying it to cell micro-pattern and microfluidic device production. But they arise problems in jagged pattern boundaries due to the liquid crystal panel structure and collapse pattern of the boundary divided on divisional exposure using the auto – XY stage. Zhou et al. [31] presented a novel AM process based on the mask video projection. For each layer, a set of mask images instead of a single image are planned based on the principle of optimized pixel blending. Experimental results show that the mask video

projection process can significantly improve the accuracy and resolution of built components. The disadvantage of this method is that it will require an additional linear stage with good accuracy and moving speed. In addition, the platform movement during the building process requires the designed hardware to ensure the repeatability between different layers which increases the overall cost of the system. Zabti [32] carried out Pareto based Multi-objective function based optimization of STL process which has three objective functions. The goal is to find the optimum exposure time value by minimizing the cure depth, surface roughness and maximizing the mechanical strength. Lehtinen [33] developed a DMD based projection stereolithography and a computer code is written to control the entire manufacturing process. Gandhi et al. [34] analyze various optical scanning schemes used for MSL systems along with the proposed scheme via optical simulations and experiments. The mechanical design of the scanning mechanism is carried out to meet requirements of high speed and resolution. The system integration and investigation in process parameters is carried out and fabrication of large micro-component with high resolution is demonstrated. Campaigne III [35] developed projection stereolithography and material characterization of nanocomposites photopolymers was carried out. Valentincic et al. [36] conclude that DLP based stereolithography is used to reduce the build time and to increase the manufacturing accuracy. Compared to fused deposition modeling (FDM) machines, machines for DLP stereolithography are expensive and thus not available to a broad range of users as it is the case with FDM 3D printers. Luo et al. [37] developed desktop manufacturing system which can produce RP parts with good machining efficiency, but the surface roughness should be further improved. Ibrahim et al. [38] investigate the influence of process parameters which are layer thickness and exposure time on physical and mechanical properties of DLP structure.

Thus, by going through the aforementioned literature on SL systems, it is observed that most of researchers develop microstereolithography systems. The developed SL systems are either LCD based or DMD based. The disadvantages of LCD based SL systems are low pixel filling ratio, print – through errors occurs due to light that penetrates into already cured layers, unnecessary wavelengths cause inaccurate dimensions in the cured part. The advantages of DMD based SL systems are availability of UV compatibility, high modulation efficiency, high light transmission, high optical fill factor, low pitch size and pixel size. Both the developed SL systems i.e. LCD as well as DMD based mentioned in above literature survey are very expensive, which are not affordable to common or medium sized industries or vendors who can build their prototypes with a cheaper cost. Therefore, development of a low cost SLA with better build speed is a goal of this research work.

The sub-section 2.1 of section 2 describes the developed low cost SLA in detail with specifications of the sub-systems, different softwares, photo-polymer and photo-initiator used in the apparatus. In sub-section 2.2 the absorbance spectrum of photo-curable resin and light beam spectrum of DLP projector are plotted. In sub-section 2.3 the slicing procedure of 3D CAD model into 2D slices is explained with the help of developed MATLAB code. The experimental results and discussions are given in section 3. Finally, the conclusions are drawn from experimental work in section 4.

2. EXPERIMENTAL SET UP

2.1 Stereolithography apparatus (SLA)

The stereolithography apparatus (SLA) is developed to produce highly precise, three-dimensional (3D) structures from broad selection of functional materials, especially photopolymer resin. The lay-out of the experimental set-up is shown in Figure 1 and the CAD model is shown in Figure 2. The developed stereolithography apparatus (SLA) utilizes focused light beam from DLP projector and then through the objective lens over the surface of a photo-curable resin, which undergoes photo-polymerization and forms solid structures. The lamp of the modified DLP projector works as light source and DMD chip in the DLP projector works as a dynamic pattern generator for this SLA. The colour wheel of the DLP projector is filtering most of the UV light out. But UV light is required for solidification of the photopolymer. Therefore, we had done changes in the colour wheel. The color wheel is a glass disc with several colored segments that spins while the projector is running to colorize the image. The projector actually requires it to run; when the color wheel is simply removed, the projector would not turn on the lamp. Therefore, only glass portion of the color wheel is removed so that maximum UV light should come out from the projector which is the requirement for solidification of liquid resin. After removing glass portion from the color wheel, the projector becomes black and white. Infocus make DLP projector with display resolution 1024×768 is used. The photograph of actual experimental set-up is shown in Figure 3.

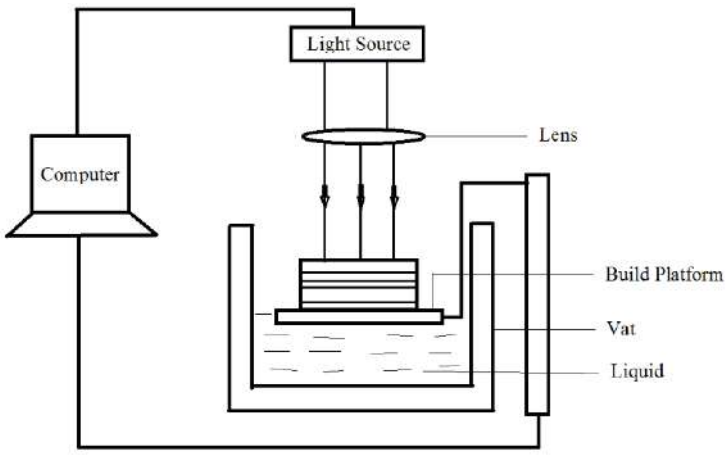
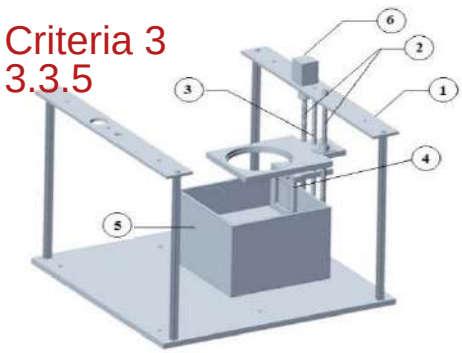


Figure 1. Lay-out of the experimental set –up

Criteria 3
3.3.5



1-Frame, 2-Ball Screw, 3-Guide rod, 4-Z stage, 5-Resin Tank, 6-Stepper motor

Figure 2. CAD model of experimental set-up without DLP projector

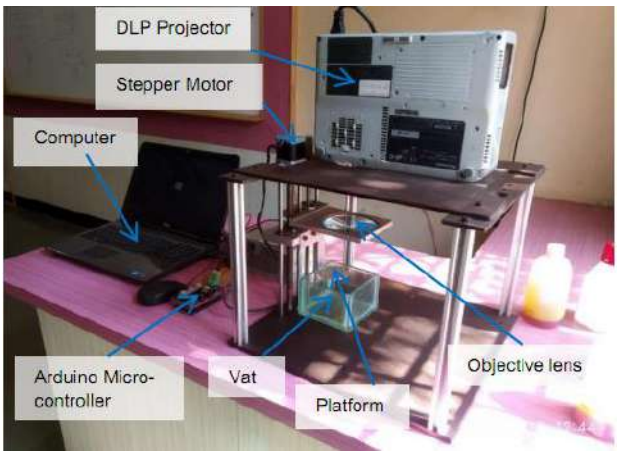


Figure 3. Experimental set-up

The photopolymer used in this experimentation is polyethylene glycol di-acrylate with 2% Irgacure 784 as photo-initiator. The absorbance spectrum of the photopolymer is plotted and the maximum absorbance observed is in the range of 315 nm to 480 nm. The peak absorbance of polyethylene glycol di-acrylate matches with the peak intensity of light beam of DLP projector which is in the range of 400 nm – 570 nm. Therefore, polyethylene glycol di-acrylate is selected as photo-curable resin and cost of the same resin is also low as compared to other resins. From this data it is concluded that maximum UV light is required for solidification of the photopolymer. The NEMA 17 bipolar stepper motor with 0.9˚ step angle, 5% step accuracy, 5 mm shaft diameter is used to rotate the ball screw. The ball screw with nominal diameter 12 mm, pitch 2.0 mm, core diameter 10.084 mm and lead angle 3.04˚ is used for up and down motion of the Z-stage. The maximum speed of the stepper motor is 2344 rpm and holding torque is 4.8 kg-cm. The Creo 3.0 software is used for modeling of 3D CAD model. The 3D CAD model and STL file format in Creo 3.0 software is more compatible with developed MATLAB code for slicing of 3D CAD model as compared to other modeling softwares. Therefore, Creo 3.0 software is selected for 3D CAD modeling. A special MATLAB code is developed for slicing of the 3D CAD model and this sliced 3D CAD model is imported into the Creation Workshop software version 1.0.0.75 which is used to control the focusing time period of sliced images through DLP projector and focusing lens. The make of focusing lens is Optics and Allied Engineering Private Limited, Bangalore with 100 mm diameter and 100 mm focal length.

The Creation Workshop software also controls the motion of the Z-stage through Arduino MEGA 2560 micro- controller and NEMA 17 bipolar stepper motor. It also controls input parameters, such as layer thickness, motor movement speed, exposure time and settling period. These parameters make the equipment versatile and suitable for a wide range of different tasks. Finally, the different shape objects are built by curing the aforementioned photo-curable resin. The photographs of the build components are taken by the Amp Cam digital microscope with optimum resolution 640×480 and 5X digital zoom. The FARO Edge 3D scanner with the specifications ±25µm accuracy, 25µm repeatability, 115 mm depth of field, 80 mm effective scan width for near field, 2,000 scanning points per line, 40µm minimum point spacing, 280 frames/second scan rate and Class 2M laser is used to measure the dimensions of the build objects. Thus, a low cost, high build speed SLA is developed to fabricate 3D components.

In the Z- Stage, we have to control the linear movement of the platform with the help of stepper motor and ball screw. The stepper motors rotational motion is transformed in to linear motion with help of ball screw coupled with motor shaft. Arduino microcontroller is used for precise and accurate control the movement of the motion stage. The rotational movement of the stepper motor is controlled with the help of special Arduino program. The program mainly consists of various commands and statements to control the various parameters such as speed, time delay etc. Figure 4 shows the window of Arduino software in which the uploaded program is shown. The Arduino Micro-controller with stepper motor is interfaced with Creation Workshop Software to obtain desired motion of Z-stage.

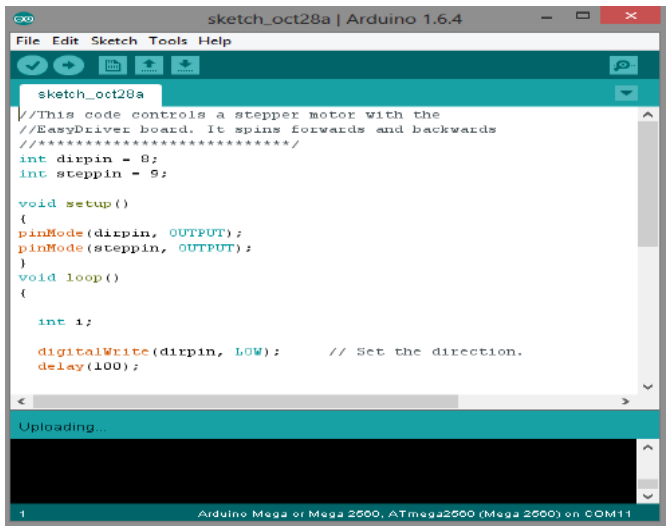


Figure 4. The program uploaded to the Arduino software

2.2 Spectrum study of photopolymer and DLP projector

The 3D object is built by focusing the light beam of DLP projector through objective lens on the z-stage platform. On the Z-stage platform a layer of liquid photopolymer of thickness equal to the slice thickness of CAD model is made available by lowering the platform with help of ball screw and stepper motor. Therefore, it is necessary to plot the absorbance spectrum of photopolymer from which we can conclude that what is value of wave length for peak absorbance. The Figure 5 shows the absorbance spectrum plot of photopolymer and it is observed that the peak absorbance is at wavelength 335 nm,

410 nm and 480 nm. Therefore, the focused light beam must have the peak wavelength in the range of 300 – 500 nm which is a UV light region.

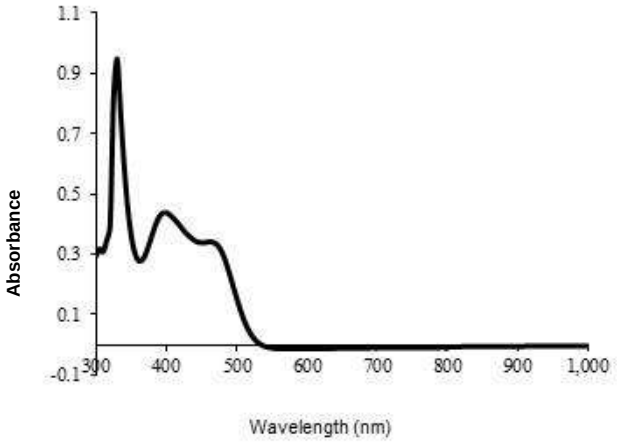


Figure 5. Absorbance spectrum of photopolymer

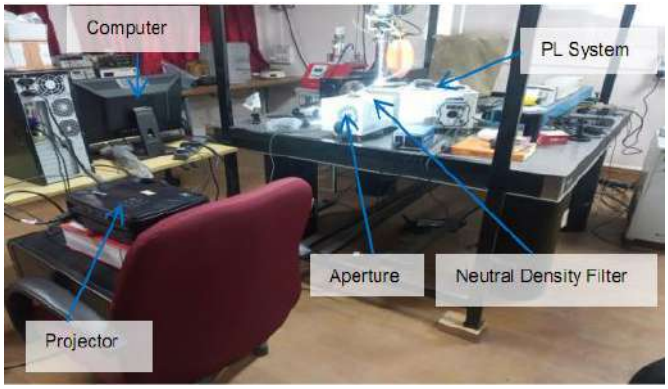


Figure 6. DLP projector light beam spectrum plotting set-up

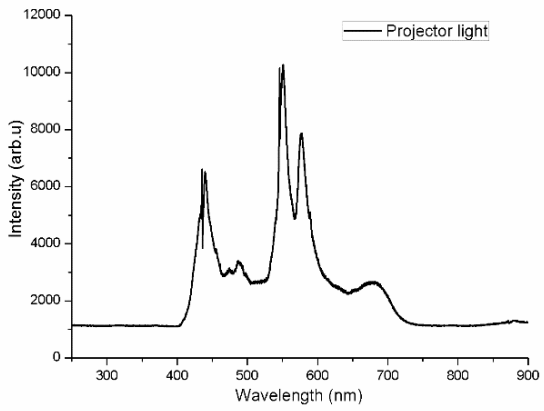


Figure 7. Light beam spectrum of DLP projector

The study of DLP light beam spectrum is done by using Horriba (model iHR320) light spectrometer. The Figure 6 shows the set-up for plotting the spectrum of DLP projector light beam. The light beam from the DLP projector is passes through the aperture then it passes through the neutral density filter. The neutral density filter removes the unwanted light rays. The spectrum is plotted for the light wavelength range of 250 – 900 nm. Finally, light beam passed into the photoluminescence (PL) system. The PL system consists of optical grating, mirror 1 and mirror 2 with CCD (closed circuit device) camera. The measured spectrum data by PL system is collected by the computer. The Figure 7 shows the light beam spectrum obtained by above mentioned spectrometer. From light beam spectrum it is observed that the peak values are in the wavelength range of 400 nm – 570 nm. Therefore, the light beam of DLP projector is useful to cure the selected photopolymer as peak wavelength range matches with each other.

2.3 Slicing of 3D CAD model

Basically, the stereolithography equipment consists of a DLP projector, focusing lens, resin vat, a linear translation stage with a platform and a computer. Before the manufacturing can begin, some preparations must be done. First, the CAD model is sliced into horizontal cross-section images. These black and white images will be projected one by one onto the platform with resin layer. As there are different methods available to slice a CAD model without tessellation but slicing a triangulated mesh model is still the commonly used method in 3D printing caused by its format (i.e. STL) is widely adopted in software and machine. These different methods of slicing a 3D CAD models are Contour, Voxelization and Ray tracing [39]. The contour method is the traditional slicing process that generates the cross-sectional information by intersecting the input model with a set of horizontal planes. As the input model is tessellated into faces (e.g. triangles defined in the STL), the slicing operation is actually a number of face-plane intersections, each of which is a segment. In a layer, the intersection between the model and a slicing plane is one or more polygons (contours), which are constituted by the segments. The voxelization method creates a 3D array of voxels that can cover the whole volume of the input model, and then decides whether each voxel is inside or outside the model. The in/out determination is challenging, because the mesh is just a set of faces in the 3D space without the information of inside or outside. In ray-tracing method, 2D image is used and in/out for every pixel in a slice is determined similar to point-in-polygon testing. In this method testing can be done by casting a ray from each pixel to intersect with the model, and finding out if the ray reaches the interior or exterior of the model at a particular height. Out of the above three slicing technologies, the ray-tracing method is the fastest in most cases and it needs a moderate amount of memory for computation. It maintains a good balance between computation time and memory space. It would be optimal if the intersection problem can be handled without creating other problems. Therefore, due to these advantages, the ray-tracing method is used for development of a special MATLAB code for slicing of 3D CAD model in this research work.

The STL file shown in Figure 8 was originally conceived by 3D Systems [40] and it opened the door for rapid prototyping and manufacturing market by allowing CAD data to be used in STL systems. The file consists of an unordered list of triangular facets that represent the outside skin of a part. The triangular facets are described by a unit normal vector and a set of X, Y, Z coordinates for each of the three vertices. The unit vectors indicate the outside of the part. Since the STL model consists of triangular facets, it is an approximate model of the accurate CAD data. Regardless of being an imprecise model, STL has become the standard used by most CAD and RP systems. STL is a simple solution for representing 3D CAD data and it provides small and accurate files for data transfer for specific shapes [41, 42]. There are two formats for STL file:

ASCI and Binary which are shown in Figure 9 and Figure 10 respectively. Binary files are smaller and more compact. Hence, they are more common. After generating the STL file of the 3D CAD model then it is necessary to slice the model into a number of horizontal cross-section images. The 3D CAD model of the object which is to be built by using stereolithography process is developed with the help of CREO 3.0 software. Then it is saved in STL file format using the same software. The Figure 11 shows the 3D CAD model in STL file format.

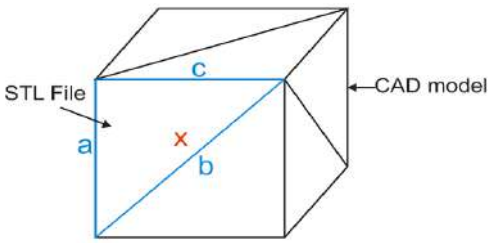


Figure 8. Standard Tessellation Language (STL) file and CAD model [42]

```
solid name

facet normal ni nj nk
    outer loop
        vertex v1x v1y v1z
        vertex v2x v2y v2z
        vertex v3x v3y v3z
    endloop
endfacet

endsolid name
```

Figure 9. ASCII STL file format [42]

```
UINT8[80] – Header
UINT32 – Number of triangles

foreach triangle
REAL32[3] – Normal vector
REAL32[3] – Vertex 1
REAL32[3] – Vertex 2
REAL32[3] – Vertex 3
UINT16 – Attribute byte count
end
```

Figure 10. Binary STL file format [42]

Figure 11. 3D CAD model in STL file format

Thus, a special MATLAB code is developed by using ray tracing method and by using this code, the 3D CAD model is sliced into a number of layers as shown in Figure 12. The Figure 13 (a) and (b) shows a single sliced layer in MATLAB software window. Then these sliced layers are imported in Creation Workshop software and focused one by one at required time interval with the help of DLP projector through objective lens on the Z- stage platform and finally the 3D object is built.

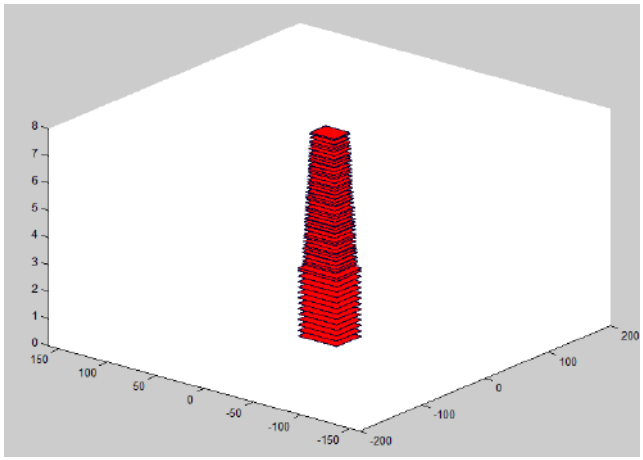
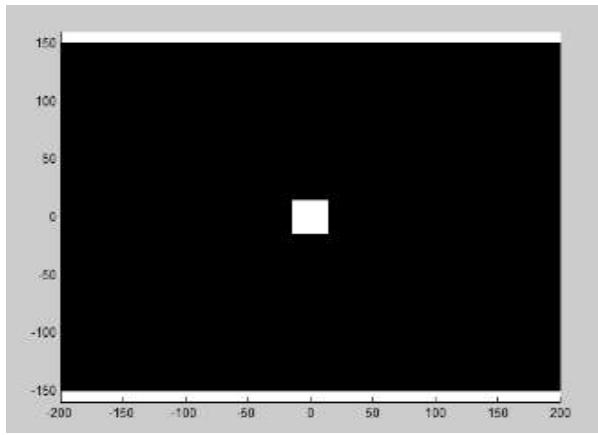
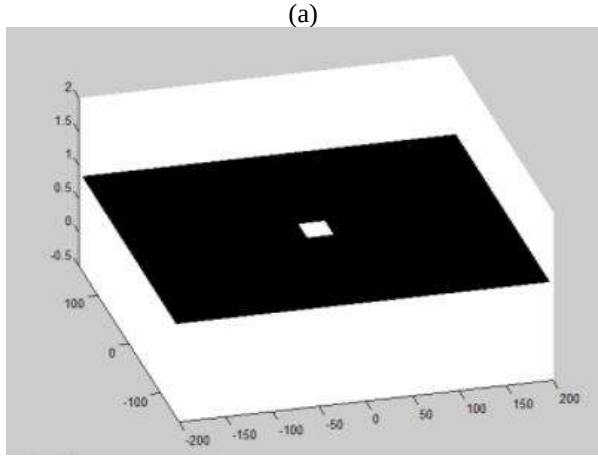


Figure 12. Sliced 3D CAD model



(a)



(b)

Figure 13. 2D Slices in MATLAB window

3. RESULTS AND DISCUSSIONS

The experiments are performed with hexagonal cross-

section and pyramid objects with 0.1 mm curing depth along Z – axis. The trials are performed with different exposure time and settling period. The exposure time is varied from 10 seconds to 1 second and it is observed that the objects are best cured for 2 seconds curing period. The experimental test data for hexagonal cross-section and pyramid objects are given in Table 1 and Table 2 respectively. The CAD model of the hexagonal prism is shown in Figure 14 and scanned image of build hexagonal prism by FARO Edge 3D scanner is shown in Figure 15. The built hexagonal prism is shown in Figure 16 (a) and (b). The Figure 17 shows the measurements of dimensions of hexagonal prism by FARO Edge 3D scanner. The Figure 18 shows the CAD model of pyramid and Figure 19 shows the built pyramid. The scanned image of built pyramid by FARO Edge 3D scanner is shown in Figure 20 and the measurement of dimensions of pyramid by FARO Edge 3D scanner are shown in Figures 21-23. The pyramid object with 120 numbers of layers with 12 mm dimension along Z-axis is built. The maximum area 18 mm x 16 mm of pyramid object along X-Y plane is cured. For commercial SLA machines resolution in Z-axis is in between 0.01 to 0.25 mm. The resolution along Z-axis of 0.25mm creates a fairly coarse surface for medium sized parts, but for larger models, the layer steps are not too noticeable due to the relative size of larger parts. A resolution of 0.1mm provides a more favorable surface finish for medium and small parts. Therefore, experiments are performed with 0.1 mm curing depth along Z-axis. The maximum exposure area obtained is 55mm x 45mm. It is observed that as the curing time decreases the percentage error between the 3D CAD model dimensions and built dimensions are also decreases. The maximum and minimum percentage errors for hexagonal cross-section object are 9.43 and 2.0 respectively. The maximum and minimum percentage errors for pyramid object are 4.44 and 0.93 respectively. The minimum percentage error is observed for 2 seconds curing period. The dimensions of the built components are measured by FARO Edge 3D scanner with ±25µm accuracy. Creation Workshop software Version 1.0.0.75 is used: (i) to control the Z-stage motion, (ii) to control the focusing time of sliced images and settling time. The resolution of the built components depends upon Software Imposed Parameters (SIP) and SL Process Parameters (PP). The Software Imposed Parameters (SIP) are line width compensation, .stl file resolution, layer thickness, z compensation, and stereolithography grid. The SL Process Parameters (PP) consists of light beam size and intensity, light beam focus depth, and layer thickness [43].

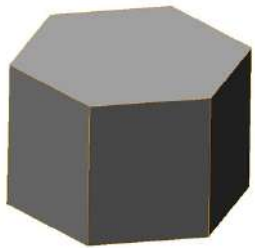
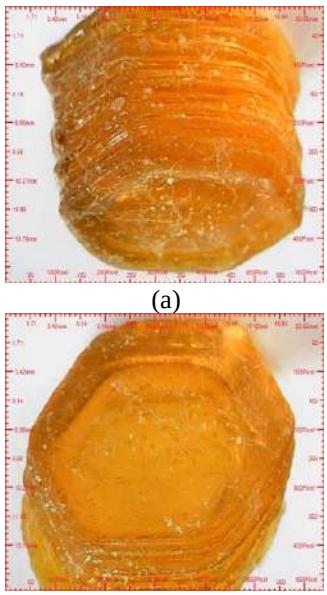


Figure 14. CAD model of hexagonal prism

Figure 15. Scanned image of build hexagonal prism



(a)

(b)

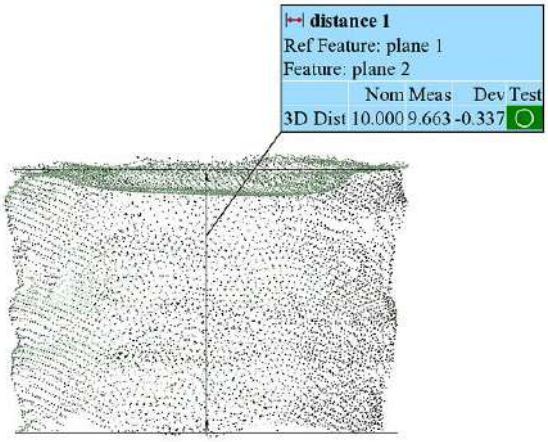
Figure 16. Built hexagonal prism

Table 1. Hexagonal prism experimentation data

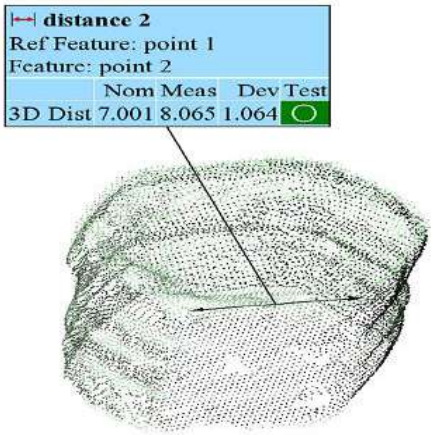
Object Cross-section	Measuring Scale	Dimensions (mm)			Layer thickness (mm)	No. of layers	Exposure time (sec.)	Settling Period (sec.)	Build time (sec.)
		x	y	z					
Hexagon (7 mm side)	CAD Model	14	14	10	0.1	100	2	3.5	546.5
	Built object	15.32	14.28	9.66					
	% Error	9.43	2.0	3.4					

Table 2. Pyramid experimentation data

Object Cross-section	Measuring Scale	Dimensions (mm)			Layer thickness (mm)	No. of layers	Exposure time (sec.)	Settling Period (sec.)	Build time (sec.)
		x	y	z					
Pyramid	CAD Model	18	16	12	0.1	120	2	3.5	656.5
	Built object	17.20	16.15	10.85					
	% Error	4.44	0.93	2.33					



(a)



(b)

Figure 17. Measurement of height and side of hexagonal prism

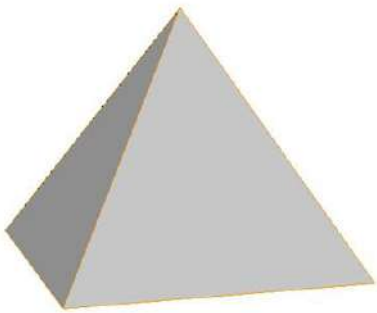


Figure 18. CAD Model of pyramid

Figure 19. Built pyramid

Figure 20. Scanned Image of build pyramid

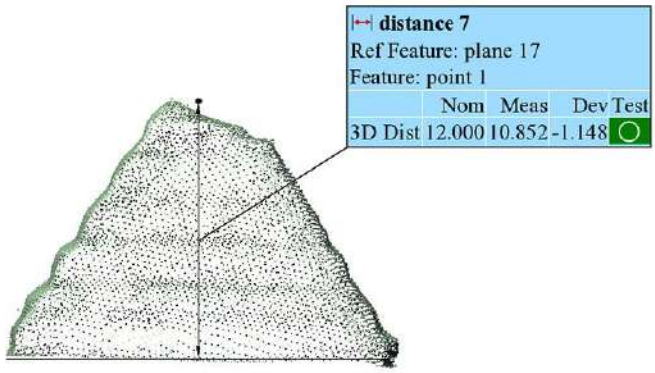


Figure 21. Height measurement of build pyramid

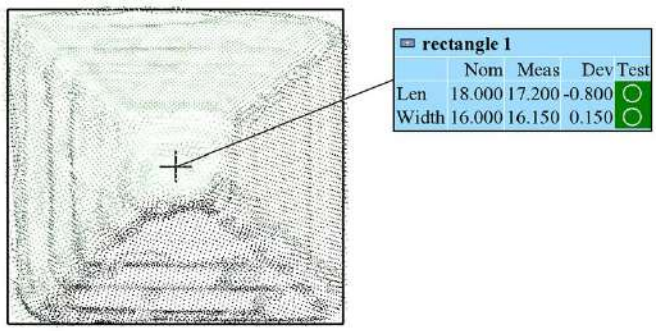


Figure 22. Base measurement of pyramid

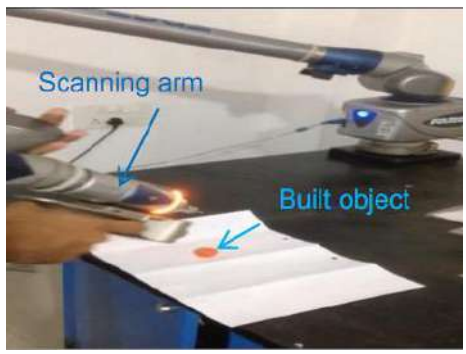


Figure 23. Faro edge 3D scanner

4. CONCLUSIONS

A low cost stereolithography apparatus (SLA) has been developed with DLP projector as a UV light source. The overall cost of the developed SLA is very low as compared to the present commercial SLA available. Therefore, the build cost of the fabricated objects is reduced due to developed low

cost SLA. The optimum curing period per layer is two seconds per layer as the percentage error is minimum for two seconds curing period. Therefore, build speed obtained is two seconds per layer which is remarkable compared with present SLA. The dimensional accuracy of fabricated objects is also satisfactory as the maximum and minimum percentage error is 9.43 and 0.93 respectively which is acceptable comparing with the results available in the literature [33, 36]. The dimensional percentage error is decreased as the curing period or image focusing period is reduced. The pyramid object with maximum 120 numbers of layers with 12 mm dimension along Z-axis is built in 11 minutes. The maximum exposure area obtained which can be cured in X-Y plane is 55 mm x 45 mm. The resolution of the build objects in X-Y plane is 23 microns which is resolution of sliced image focused from DLP projector and Z-stage resolution is 0.1 mm. The advantages of the developed SLA are low build cost, high fabrication speed, excellent resolution in X-Y plane, low resin cost etc. The limitations are low dimensional accuracy, poor resolution of the fabricated objects along Z-stage. The future scope of the work is to introduce the dimensional error correction model in the experimentation to minimize the percentage errors of the build objects. Another future scope is to perform the experiments with values lower than 0.1 mm curing depth so that resolution of build objects along Z- stage will be improved.

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NOMENCLATURE

3D	three dimensional
AM	additive manufacturing
CAD	computer aided design
CAM	computer aided manufacturing
DLP	digital light processing
DMD	digital micro-mirror device
LCD	liquid crystal display
MEMS	micro-electro-mechanical systems
MSL	microstereolithography
PL	photoluminescence
RP	rapid prototyping
SL	stereolithography
SLA	stereolithography apparatus
STL	standard tessellation language
UV	ultra-violet

Parametric Optimization of Biodiesel Fuelled Engine Noise using the Taguchi Method

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***Abstract*—Biodiesel is a renewable, biodegradable, and efficient fuel that can be blended with petro-diesel in any proportion. The noise in the engine resulting from the combustion has a direct effect on the engine's performance. Many studies have examined the engines' vibration and noise when using diesel and biodiesel blends. This study examines the optimization of diesel blends, load, and compression ratio in the aspect of reducing noise on a Kirloskar single-cylinder diesel engine. Noise was measured at the engine and its exhaust on a computerized setup and for different loads. The experimental results showed that a blend with 15% biodiesel, at 7kg load, and 18 compression ratio produced the lowest noise. Moreover, the Taguchi method was utilized, and experimental results were validated by an ANN.**

Keywords-transesterification; biodiesel; noise; optimization

I. INTRODUCTION

Any alternative to diesel fuel should be replicable, economical, and technically acceptable [1]. Biodiesel is produced by the transesterification of renewable vegetable oils and animal fats with the use of alcohol. Biodiesel is highly degradable and nontoxic. Meanwhile, it has low emissions of carbon monoxide, particulate matter, and unburned hydrocarbons. Due to these properties, biodiesel has attracted wide attention as a replacement to diesel fuel [1, 2]. Biodiesel can be used without modifications in conventional compression ignition engines. Noise and vibrations are major issues of diesel engines [3, 4]. Engine body vibrations and noise are rich in information about the engine's operating parameters and physical condition [4, 5]. Excess noise and vibrations wear out components such as bearings, grouting, and couplings, increasing maintenance cost due to more component failures and unplanned operations. Due to noise and vibrations' importance, there is a need to study the effect of biodiesel and its blends on engine's life and performance [6-8]. Noise level depends on the load and the blending ratio of biodiesel [5]. As a result, it is necessary to extend an engine's life by using optimal blends, after analyzing their impact in noise [5-9].

II. EXPERIMENTAL PROCESS

A Kirloskar TV1 VCR single cylinder, four stroke, constant speed, water-cooled diesel engine, having 3.5HP at 1500rpm, was used on a computerized test bed equipped with measuring instruments such as thermocouples, dynamometer, tachometer and flow meters. The engine's specifications are shown in Table I.

TABLE I. ENGINE'S SPECIFICATIONS

Name	Kirloskar
No. of cylinders	1
No. of strokes	4
Type of cooling	Water cooled
Power developing capacity	3.5kW at 1500rpm
Compression ratio range	12-18
Stroke	110mm
Bore	87.5mm
Cylinder volume	661

Noise levels were measured by a noise meter for four different fuel blends on variable load conditions and compression ratios as per the Taguchi array. The study focused on the input parameters of biodiesel blends for examining the diesel engine's operating conditions. Noise was measured at the engine and its exhaust. A noise meter was placed at 0.5m distance from the engine for measuring its noise, and another was placed outside the room near the exhaust pipe end to measure the noise at the exhaust [3-5]. The noise meter and its specifications are shown in Figure 1 and Table II respectively.

TABLE II. NOISE METER'S SPECIFICATIONS

Display	14mm (0.55″) LCD with backlight
Parameter measurement	LP, Lmax, Leq, LN
Frequency range	31.5Hz~8kHz
Measurement range	LP: 30~130dB (A)
Resolution	0.1 dB
Accuracy	±1dB

Fig. 1. Noise meter.

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Four fuel types were tested, namely: B0 consisting of 100% diesel, B15 consisting of 15% biodiesel and 85% diesel, B20 consisting of 20% biodiesel and 80% diesel, and B25 consisting of 25% biodiesel and 75% diesel [2, 3, 9]. Biodiesel blend, load on the engine, and compression ratio were the parameters whose effects on the engine's noise were studied. The parameters' levels are listed in Table III.

TABLE III. PARAMETRIC CONDITIONS

A: Blend	B: Load	C: Compression ratio
A1 = 0	B1 = 0	C1 = 16
A2 = 15	B2 = 4	C2 = 17
A3 = 20	B3 = 7	C3 = 17.5
A4 = 25	B4 = 10	C4 = 18

A. Noise Analysis

The orthogonal array of the input parameters indicates the number of combinations for the experiments. This selection of orthogonal array is based on three parameters and four levels for each parameter [2,5]. The array was obtained by Minitab using the following operating parameters:

Taguchi Design
Design Summary
Taguchi Array L16(4^3)
Factors: 3
Runs: 16
Columns of L16 (4^5) array: 1 2 3

TABLE IV. SAMPLE READINGS OF TAGUCHI ARRAY FOR PARAMETER OPTIMIZATION

Blend	Load	C.R.	Noise at the engine	Noise at the exhaust	Noise at the engine SNR	Noise at the exhaust SNR
0	0	16	92.75	108.9	-39.3463	-40.7406
0	4	17	93	109.25	-39.3697	-40.7684
15	4	16	93.75	112.15	-39.4394	-40.996
15	7	18	95	110.45	-39.5545	-40.8633
15	10	17.5	95.6	110.95	-39.6092	-40.9025
20	0	17.5	91.7	110.45	-39.2474	-40.8633
25	10	16	96.35	111.9	-39.677	-40.9766

The fourth row of Table IV gives the optimum values of input parameters for noise among the various blends. Signal-to-noise ratio (SNR) measures how the response varies relatively to the nominal or target value under different noise conditions. Depending on the goal, different SNRs may be chosen. In this experiment, lower SNRs are better. Optimal conditions were met with B15 blend, 7kg applied load, and 18 compression ratio, where the noise was 95dB at the engine and 110.45dB at the exhaust.

B. Taguchi Analysis: Noise versus Blend, Load, C.R.

Taguchi method analysis results for noise at the engine versus blend, load, and C.R are shown in Table V, while the regression's resulted equation is:

$$Noise\ at\ the\ engine = 96.6 - 0.0507 Blend + 0.371 Load - 0.255 C.R. \quad (1)$$

TABLE V. NOISE AT THE ENGINE MODEL SUMMARY

S	R-Sq	R-Sq(adj)
0.2196	76.30%	40.76%

Taguchi model's analysis results on noise at the exhaust versus blend, load, and C.R are shown in Table VI, and the regression's resulted equation is:

$$Noise\ at\ the\ exhaust = 107.89 + 0.0518 Blend + 0.1900 Loads + 0.044 C.R. \quad (2)$$

TABLE VI. NOISE AT THE EXHAUST MODEL SUMMARY

S	R-Sq	R-Sq(adj)
0.0658	86.48%	66.21%

C. Validation of Experimental Results by Artificial Neural Network (ANN)

The results of noise at the engine and the exhaust were validated by an ANN. An ANN script, shown in Table VII, was used for obtaining the output from the input parameters.

TABLE VII. ANN CONFIGURATION SCRIPT

```
clc; close all; clear all;
x = xlsread('Input1');
y = xlsread('Output2');
net = newff(minmax(x),[20,1],{'logsig','purelin','trainlm'});
net.trainparam.epochs = 1000;
net.trainparam.goal = 1e-15;   net.trainparam.lr = 0.01;
net = train(net, x, y);
y_net = net(x);
plot(y);hold on; plot(y_net, 'r');
error = (y - y_net);
```

III. RESULTS AND VALIDATION

A. Noise at the Engine

The experimental results for noise at the engine, the values calculated by the ANN, and the error between them are shown in Table VIII and a comparative graph of these values is shown in Figure 2. Apparently, there is a small difference, less than 1.2%, between the experimental and the ANN calculated values.

TABLE VIII. EXPERIMENTAL AND ANN RESULTS

Blend	Load	C.R.	Noise at the engine	Noise by ANN	Error	Error %
0	7	17.5	97	96	-1	-1.0%
0	10	18	95.2	96	0.8	0.8%
15	7	18	95	96	1	1.0%
20	10	17	95.9	95.5	0	0.0%
25	7	17	94.8	95.6	0.8	0.8%
25	10	16	96.35	95.2	-1.15	-1.2%

The regression plot obtained by the Taguchi model for the experimental results was compared with the ANN regression plot. The regressions' R-square value was around 80%. The straight line in these plots shows that the data fit a normal probability distribution. There are very low residual values, as

all residuals obtained are almost along the line in both plots. The similarity in these plots validates the results.

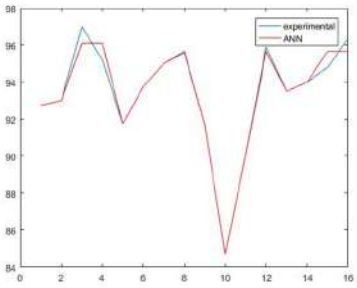
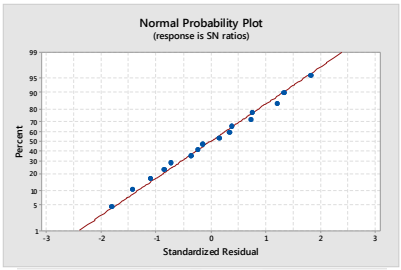


Fig. 2. Comparison of experimental and ANN noise values at the engine.

(a)



(b)

Fig. 3. Residual plot for noise at the engine by (a) Minitab, (b) ANN.

B. Noise at the Exhaust

The experimental results of noise at the exhaust, the values calculated by the ANN, and the error between them are given in Table IX. Moreover, a comparative graph of these values is shown in Figure 4. Apparently, there is a tiny difference between experimental and ANN results, less than 0.3%, for noise at the exhaust.

TABLE IX. EXPERIMENTAL AND ANN RESULTS

Blend	Load	C.R.	Noise at the exhaust	Noise byANN	Error	Error %
0	0	16	108.9	109.2	0.3	0.27%
0	4	17	109.25	109.1	-0.15	-0.14%
15	7	18	110.45	110.45	0	0.00%
15	10	17.5	110.95	110.95	0	0.00%
20	0	17.5	110.45	110.45	0	0.00%
25	10	16	111.9	111.9	0	0.00%

After comparing the regression plots of experimental and ANN results in Figures 3 and 5, we can see that there are very few residual values, and all values obtained are almost along the line indicating a normal probability distribution. The regression's R-square value was 86.48%. The similarity in these plots validates the results.

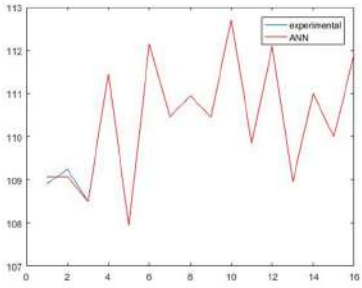
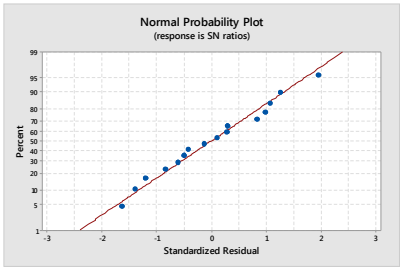


Fig. 4. Comparison of experimental and ANN noise at exhaust.

(a)



(b)

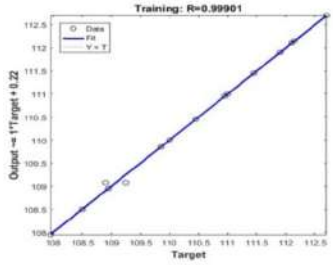


Fig. 5. Residual plot for noise at the exhaust by (a) Minitab, (b) ANN.

IV. CONCLUSION

This study examined the optimization of noise reduction at the engine and its exhaust with biodiesel blend, load, and compression ratio of the engine as input parameters. Analysis was carried out utilizing the Taguchi method, and optimization of the input parameters was performed by using SNR [10, 11]. The experimental results obtained by Minitab were validated by an ANN. The main conclusions of this study are:

- Optimal input parameters were: a blend with 15% biodiesel, applied load of 7kg, and compression ratio 18, resulting to 95dB noise at the engine and 110.45dB at its exhaust.
- R-square values obtained by regression analysis were around 80% and more, indicating that the obtained model fits to the actual data.
- There are small to tiny differences between the experimental and the ANN's noise values.
- All regression residuals of both Minitab and ANN were very low and almost along the line in both methods. The similarities in both plots validated the results.

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Optimization of Biodiesel Synthesis using Heterogeneous Catalyst (SiO_2) from Karanja Oil by Taguchi Method

Satish A. Patil, R. R. Arakerimath

Abstract: ***Biodiesel is renewable and environmental friendly fuel which has the capable to gain comparable engine performance. In this experimental study, Karanja oil synthesized by using Transesterification process. Transesterification of Karanja oil to biodiesel using SiO_2 as a heterogeneous catalyst is studied using five different parameters and levels each. Minitab is used to fix the orthogonal arrays and Taguchi method is used to analyze the interaction effect for the transesterification reaction. The five different parameters responsible for biodiesel yield are molar ratio of methanol to oil, catalyst concentration, reaction temperature, reaction time and stirring speed. Effect of these parameters has studied on small scale. The biodiesel yield obtained experimentally at optimum conditions are 20% methanol to oil molar ratio, 3% SiO2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed is 77%.***

Index Terms -Transesterification, Biodiesel, SiO_2, Heterogeneous catalyst,

I. INTRODUCTION

The world today is getting evolved and needs are growing day by day about everything. The nature has a fixed stock of natural resources but human population is increasing at a tremendous rate. In various zones diesel fuels are utilized and have contribution for the economy of the nations. Due to the rise in environmental consciousness and decrease of petroleum reserves, there is needed to use of alternative fuels [3]. Because of increase in Global warming and more requirements of energy huge research and development is going on for renewable energies [3]. The properties like non-toxic, degradability, less carbon monoxide emission, particulate matter and unburned hydrocarbons, the biodiesel has gained an international focus as an alternative to diesel fuel [3]. The conventional compression engine does not require any modification to use the biodiesel as fuel.

The yields of Karanja oil biodiesel were obtained by 25 different sets of different experimental conditions and noted. All experiments were performed as per array obtained by Taguchi method under the different experimental conditions as mentioned here.

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The analysis of the results has done by Taguchi method using Minitab for optimization of input parameters. The different graphs have plotted here from results obtained during the analysis. The optimum conditions For different input parameters have identified for maximum yield of biodiesel production from Karanja oil using Heterogeneous catalyst.

II. OPERATING CONDITIONS

There the Transesterification process for biodiesel production from Karanja oil using heterogeneous catalyst.

Effect of different input parameters have studied as follows.

1) Variation of Molar Ratio in reaction.
2) Effect of amount of catalyst.
3) Effect of temperature on reaction.
4) Effect of stirring speed on reaction.
5) Effect of reaction time of reaction

The range of operating conditions for each parameter have as follows.

Table 1. Optimizing parameter conditions

A:Molar Ratio %	B: Catalyst %	C: Reaction Temp. ºC	D:Reaction Time	E: Reaction Speed
A1 = 5	B1 = 1.5	C1 = 55 ºC	D1 = 60 min.	E1 = 300rpm
A2 = 10	B2 = 2.0	C2 = 60 ºC	D2 = 90 min.	E2 = 400 rpm
A3 = 15	B3 = 2.5	C3 = 65 ºC	D3 = 120 min.	E3 = 500 rpm
A4 = 20	B4 = 3.0	C4 = 67 ºC	D4 = 150 min.	E4 = 600 rpm
A5 = 25	B5 = 3.5	C5 = 70 ºC	D5 = 180 min.	E5 = 700 rpm

III. EXPERIMENTAL RESULTS SIO2 AS A CATALYST

Initially the esterification process is done, the color of Karanja oil after esterification changed from deep brown to reddish yellow. The transesterification process produces methyl ester (Karanja oil biodiesel) and glycerol form upper and lower layers respectively. Due to more density of glycerin, it was settled at bottom. The catalysts and unused methanol were in the lower glycerol layer. The results shown that, using SiO_2 catalyst the biodiesel production is a considerable potential .

Twenty-five experiments for transesterification process were conducted using Karanja oil with methanol under different conditions of reactions to produce biodiesel. Input parameters and % of yields were noted. Sample readings are given below.

Taguchi Design
Design details

Array obtained by Taguchi Method L25 (5^5)
Factors: Five numbers
Runs: Twenty five
Columns of L25 (5^6) array: 1 2 3 4 5

Molar ratio	Catalyst %	Reaction temp	Reaction time	Reaction speed	Yield %	SNRA1	SRES
5	1.5	55	60	300	50	33.9794	-0.06531
5	2	60	90	400	52	34.3201	-1.24764
10	3.5	55	90	500	72	37.1466	1.83866
15	3	55	120	700	68	36.6502	-0.5516
15	3.5	60	150	300	73	37.2665	0.16741
20	2.5	55	150	400	67	36.5215	-0.94569
20	3	60	180	500	77	37.7298	1.62962
20	3.5	65	60	600	74	37.3846	-0.4575
25	1.5	70	150	500	68	36.6502	0.85144

In above table the row which is highlited by yellow colour gives the optimal values of input parameters for maximum biodiesel yield because of high value of SN ratio. The biodiesel yield obtained experimentally at optimum conditions are 20% methanol to oil molar ratio, 3% SiO2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed is 77%.

TAGUCHI ANALYSIS WITH SiO_2 CATALYST

Taguchi Analysis: yield % versus Molar Ratio %, Catalyst ... reaction Speed
Response Table for Signal to Noise Ratios
Larger is better

Table 3.Response Table for Signal to Noise Ratios

Level	Molar Ratio %	Catalyst %	Reaction Temp.°C	Reaction Time	Reaction Speed
1	35.18	35.34	36.24	36.17	36.26
2	36.06	35.75	36.31	36.24	36.06
3	36.39	36.42	36.20	36.13	36.50
4	36.72	36.80	36.12	36.31	36.35
5	37.12	37.17	36.60	36.62	36.31
Delta	1.93	1.82	0.47	0.49	0.44
Rank	1	2	4	3	5

Main Effects on yield by SN ratio for Individual Parameter: For examine differences between level for one or more factors the main effect plot is used. The graphs shows the response mean for each factor level. [1]

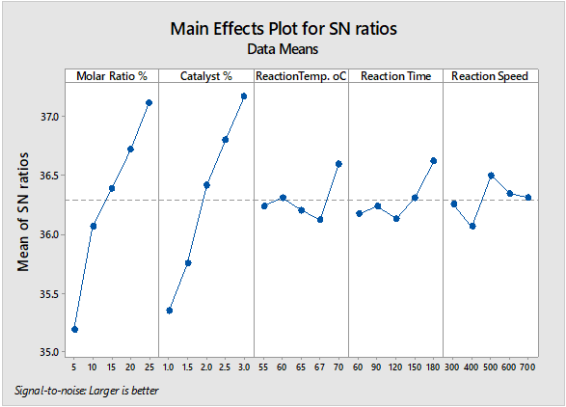

Fig. 1.Main Effects Plot for SN ratios

This figure shows that, the two graphs are steeper than others. First is the mean of S/N ratios vs molar ratio and second is the mean of S/N ratios vs. catalyst%. So, it is concluded that the two parameters affecting the yield mainly are the molar ratio and catalyst %. The effects of other three parameters can be neglected

IV. INTERACTION PLOT FOR PARAMETER A AND B (FOR MOLAR RATIO AND CATALYST %):

Analysis by Taguchi : % yield vs Molar Ratio, Catalyst %
Response Table for Signal to Noise Ratios
Larger is better

Table 4. Response Table for Signal to Noise Ratios

Level	Molar Ratio %	Catalyst %
1	35.18	35.34
2	36.06	35.75
3	36.39	36.42
4	36.72	36.80
5	37.12	37.17
Delta	1.93	1.82
Rank	1	2

Interaction Plot for SN ratios: Main effects were generally focused by Taguchi method, but suspected interactions are important to test. To measure whether the effect of one factor on response characteristic depends on the level of other the interaction plot is used. [1]

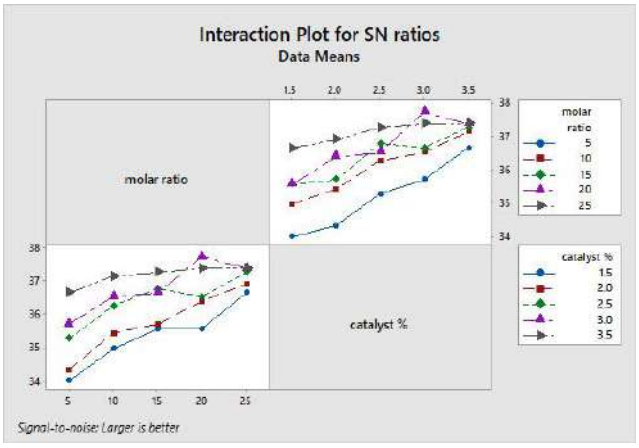

Fig.2. Interaction Plot for parameter A and B (For molar ratio and Catalyst %)

Simultaneously the interaction plots shows, the variation of yield with effect of molar ratio and catalysts are as shown in figure. This shows that the yield has maximum value for 20 % molar ratio and catalyst 3%.

V. REGRESSION ANALYSIS FOR SIO_2

Regression Analysis: yield % versus Molar Ratio %, ... , Reaction Speed Analysis of Variance.

Table 5. Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	5	1165.96	233.191	42.00	0.000
Molar Ratio %	1	544.50	544.500	98.08	0.000
Catalyst %	1	598.58	598.580	107.82	0.000
Reaction Temp. oC	1	1.66	1.657	0.30	0.591
Reaction Time	1	19.22	19.220	3.46	0.078
Reaction Speed	1	2.00	2.000	0.36	0.555
Error	19	105.48	5.552		
Total	24	1271.44			

Model Summary: R square value in model summary provides the measure of, how perfect the model is fitting with the actual data. R square value 91.70% shows that the obtained model is fitted to actual data.

Table 6. Summary of Model

S	R-sq	R-sq(adj)	R-sq(pred)
2.35622	91.70%	89.52%	86.30%

Regression Equation: It is a statistical model that determine the specific relationship between the input and output parameters. It gives the outcome with a relatively small amount of error.

yield % =35.39 + 0.6600 A + 6.920 B + 0.0484 C + 0.0207 D + 0.00200 E

Residuals Normal plot for Yield %: Graphical tool for comparing a data set with the normal distribution is the normal probability plot. The data fit in the normal probability distribution is shown by a straight line in this plot. All residuals obtained are almost along the line and very low residual values .

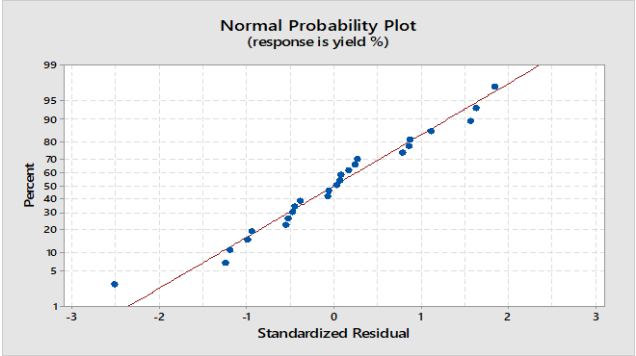

Fig.3. Normal Probability plot

VI. CONCLUSION

The analysis of optimizing the transesterification process has been carried out by Taguchi method for production of biodiesel from Karanja oil [1].

The different input parameters as in above table have been optimized using SNR , The conclusion are as follows;

1) The biodiesel yield obtained experimentally at optimum conditions are 20% methanol to oil molar ratio, 3% SiO2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed is 77%.

2) Main effective plot has concluded that the two parameters affecting the yield mainly are the molar ratio and catalyst %.

3) The interaction plot shows that the yield has maximum value for 20 % molar ratio and catalyst 3%.

4) R square value 91.70% shows that the obtained model is fitted to actual data.

5) The data fit in the normal probability distribution is shown by a straight line. All residuals obtained are almost along the line and very low residual values.

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Experimental Analysis of Karanja Biodiesel blends to Study its effects on Engine Performance, Noise and Vibration Parameters

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Abstract: Biodiesel is renewable and environmental friendly fuel which has the potential to provide comparable performance of engine. In this experimental study biodiesel blends (B00 to B25) were used, which were synthesized using Transesterification process. Study of their effect on brake specific fuel consumption (BSFC), brake thermal efficiency (BTH), noise and vibration parameters have carried out. The output parameters were measured using vibrometer, noise meter and also other measuring instruments. The tests were carried out at different loads and plots are plotted here to study the effect of blends. It has been seen that for B25 the BSFC is considerably less as compared to the diesel. The brake thermal efficiency for biodiesel B10 and B25 is closer to the diesel fuel. For the blend B20 engine has less noise and B10 and B15 have the less engine vibrations. At heavy load it is found that the biodiesel blends have better BSFC, brake thermal efficiency and less noise values for the biodiesel blends compared to the pure diesel fuel.

Index Terms **- Transesterification, Biodiesel, BSFC, BTH, Noise, Vibration**

I. INTRODUCTION

Diesel fuels have significance for the economy of nations because they are utilized in various zones in daily life. The fuel which will be substitute to diesel fuel must be suitable, technically and economically acceptable [3]. Biodiesel is synthesized by transesterification from renewable sources such as vegetable oils and animal fats with alcohols. Because of properties like high degradability, no toxicity, low emission of carbon monoxide, particulate matter and unburned hydrocarbons, biodiesel has gained international attention as an alternative to diesel fuel[3] Biodiesel is an ecofriendly and provides complete combustion with less gaseous pollutant emission[3]. Biodiesel does not require any modification in conventional compression engine.

Engine body vibrations are rich in information about its operating parameters and physical condition and could be measured by attaching vibrometer to the engine block. Study is focused on ways to extract useful information about the diesel engine operating conditions. The diesel engine vibration parameters were studied. The three parameters used in vibration measurement are displacement, velocity and acceleration. Velocity and acceleration are the most important parameters depending on the frequency range [6]. A sensor was fixed on the engine head vertically with the help of magnet.

Excess vibrations wear out components such as bearings, grouting, couplings etc. eventually, damage of support structure can affect the balance, risk of fatigue of components, decreased equipment efficiency. Increased maintenance cost due to more component failures and unplanned operations [6].There is needed to study the effect of biodiesel and its blends on the engine life. Study of different parameters of vibrations is more important because they affect engine performance as well as engine life. It is necessary to enhance engine life by optimal use of blends by analysis of vibrations of the engine. And to find out the best biodiesel blends for better performance and enhanced engine life

II. EXPERIMENTAL SETUP

The setup comprises of four cylinders, four strokes diesel engine associated with hydraulic dynamometer. It has control panel with fuel tank, manometer, and fuel estimating unit, contactless speed indicator and temperature indicator. Temperature indicator is utilized to indicate the engine jacket cooling water inlet, outlet and calorimeter temperature. To analyze the effect of vibration and noise the vibrometer and noise meter were used. The vibrometer is having frequency range of 1 – 20 KHz. The noise meter is having accuracy of 1dB. It is used to record the unwanted noise at the time of engine running. The engine used for the experiment is of Mahindra 4 cylinder, 4 stroke diesel engines having 39 KW capacities at running speed of 5000 RPM and water was used to cool the engine.

Fig 1. Experimental Setup

III. RESULTS AND DISCUSSION

3.1) Brake specific fuel consumption and Brake thermal efficiency:

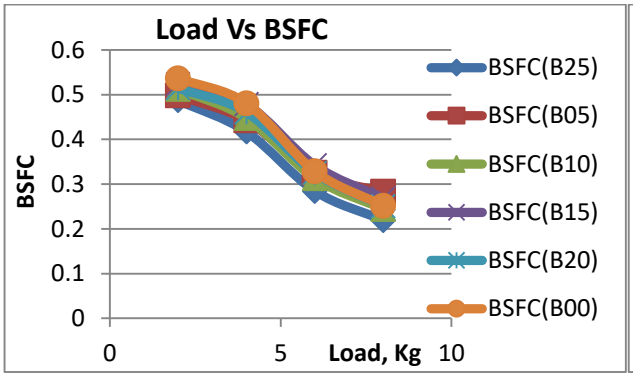

Fig 2. Load vs. BSFC

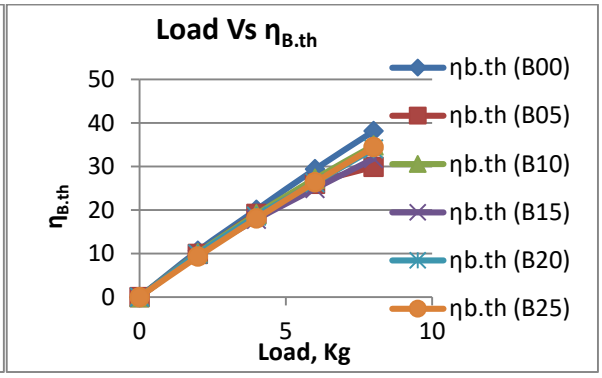

Fig 3. Load vs. BTE

From fig 2, it is observed that diesel has lower BSFC whereas biodiesel blends exhibits higher BSFC at all loads which is due to higher density, viscosity and lower heating value of biodiesel. Bsfc decreases with increasing load for various blends of biodiesel and diesel.

The percentage of energy present in the fuel that is converted into useful work is indicated by brake thermal efficiency. So, BTH is one of the main performance parameter. The comparison of BTE of the various blends of Karanja (B05, B10, B15, B20 and B25) with pure diesel is as shown in Fig 3. The BTE of Karanja blends are lower than diesel for the entire load. The decreasing trend in efficiency with increase in blend of biodiesel is because of lower calorific value of methyl esters than the diesel fuel. Due to its high viscosity the poor atomization may be caused.

3.2) NOISE:

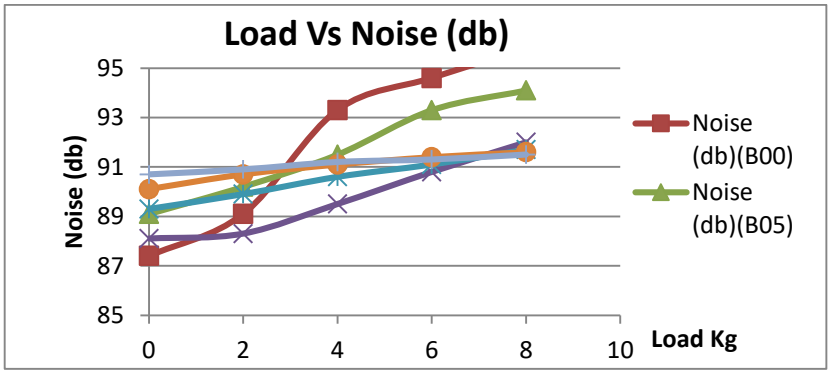

Fig 4. Load VS Noise

Statistical analysis of data and graph, It is cleared that the noise of engine measured at exhaust is lowest for B20 and increased as load increase. The noise of the diesel is less initially and also increases as load increases.

3.3) VIBRATION:

There are three important parameters of vibration viz displacement, velocity and acceleration. These are measured by using vibrometer for analysis.

a) Displacement:

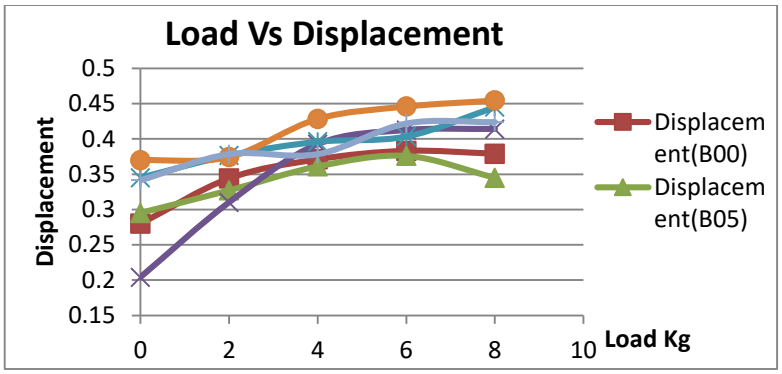

Fig 5. Load vs. Displacement

It is observed that the displacement for the biodiesel blend (B20) is higher at heavy load as compared to the pure diesel fuel. The displacement for B20 at load of 8 kg is near about 0.45mm. For B05 blend the displacement is much less near about 0.33mm compared to the pure diesel fuel.

b) Velocity:

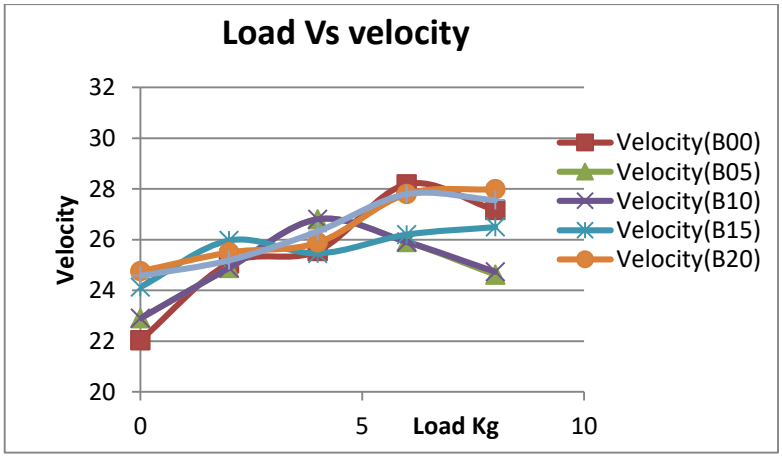

Fig 6. Load vs. Velocity

Statistical analysis of data it is observed that the velocity was lower for B10 and B15 as compared to diesel fuel. Velocity for all blends and also for diesel initially was low and increases with load.

c) Acceleration:

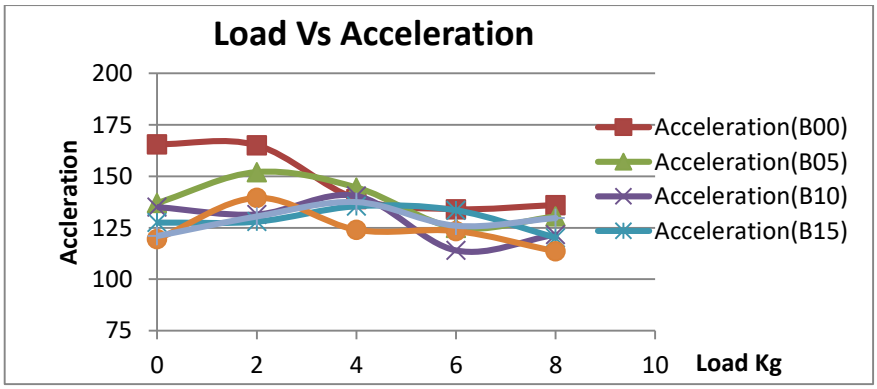

Fig 7. Load vs. Acceleration

From the statistical analysis of data it is observed that the acceleration was lowest for B10, B15 and B20. Diesel having higher acceleration values as compared to all blends. The acceleration values decreased as the load increase.

IV. CONCLUSION

In this experimental study biodiesel blends (B00 to B25) were used, which were synthesized using Transesterification process. Study of their effect on brake specific fuel consumption (BSFC), brake thermal efficiency (BTH), noise and vibration parameters have carried out. The observations and results have as follows.

a) It is observed that diesel has lower BSFC whereas biodiesel blends exhibits higher BSFC at all loads which is due to higher density, viscosity and lower heating value of biodiesel.

b) It has seen that the brake thermal efficiency for biodiesel B10 and B25 is closer to the diesel as fuel. The efficiency for blends also reaches up to 35%.

c) It is observed that the blend B20 is an optimal fuel for diesel engine which gives less noise.

d) Biodiesel blend B10 and B15 have shown the less vibration parameter values in four cylinder four stroke CI engine as compared to diesel.

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CRITERIA 3

3.3.5 Biodiesel Production Optimization using Heterogeneous Catalyst (Al_2O_3) in Karanja oil by Taguchi Method

Satish A. Patil, R. R. Arakerimath

Abstract*: Biodiesel is renewable and environmental friendly fuel which has the potential to obtain considerable performance of engine. The aim of this work is to optimize the transesterification process for production of biodiesel using Taguchi method. In this experimental work, the Karanja oil transesterification is done to produce biodiesel using Al_2O_3 as a heterogeneous catalyst, using five parameters and five levels. Orthogonal array obtained by Minitab to analyze the interaction effect by using Taguchi method for the transesterification reaction. The parameters such as molar ratio of methanol to oil, catalyst concentration, reaction temperature, reaction time and stirring speed are effect on biodiesel yield. Effect of these parameters is investigated on small scale. Experimental yield obtained at optimal conditions i.e. are 20:1 molar ratio of methanol to oil, addition of 3% Al_2O_3 catalyst, reaction temperature 65ºC, reaction time 60 min and 600 rpm stirring speed is 80%.

Keywords: Biodiesel, Transesterification, Heterogeneous catalyst, Optimization

I. INTRODUCTION

Today the world's needs are growing day by day about everything. Nature has a fixed stock of natural resources but the population is increasing at a tremendous rate. Diesel fuels are used in various fields and have significance for the economy of nations. Rise in environmental consciousness and limited petroleum reserves, it is necessary to find out alternative fuels [3]. Biodiesel have the properties like no toxicity, high degradability, low emission of carbon monoxide, particulate matter and unburned hydrocarbons. It has an international attention as an alternative to diesel fuel [3]. Biodiesel does not require any modification in conventional compression engine.

The Karanja oil methyl ester yields, obtained by transesterification process. As per array developed by Taguchi method, there were 25 sets of experiments of transesterification process for production of biodiesel. Ratio of methanol to oil, catalyst concentration, reaction temperature, reaction time and stirring speed [2] were taken as per array obtained by Taguchi method.

A Operating conditions

Different Parameters affecting the Transesterification process

Effect of different parameters studied as follows.[2]

1) Variation of Molar Ratio in reaction.
2) Effect of amount of catalyst.
3) Effect of temperature on reaction.
4) Effect of reaction time of reaction
5) Effect of stirring speed on reaction.

The operating conditions for each parameter and levels are listed below:

For catalyst Al_2O_3

Table I. Optimizing parameter conditions

A:Molar Ratio %	B: Catalyst %	C: Reation Temp. ^oC	D:Reaction Time min	E: Reaction Speed rpm
A1 = 5	B1 = 1.0	C1 = 55 ^oC	D1 = 60 min.	E1 = 300 rpm
A2 = 10	B2 = 1.5	C2 = 60 ^oC	D2 = 90 min.	E2 = 400 rpm
A3 = 15	B3 = 2.0	C3 = 65 ^oC	D3 = 120 min.	E3 = 500 rpm
A4 = 20	B4 = 2.5	C4 = 67^oC	D4 = 150 min.	E4 = 600 rpm
A5 = 25	B5 = 3.0	C5 = 70 ^oC	D5 = 180 min.	E5 = 700 rpm

II. EXPERIMENTAL ARRAY DEVELOPED BY TAGUCHI METHOD AND YIELD OBTAINED WITH SN RATIOS

Taguchi Design
Design Summary
Taguchi Array L25 (5^5)
Factors: 5
Runs: 25
Columns of L25 (5^6) array: 1 2 3 4 5

Revised Manuscript Received on November 15, 2019

Satish A. Patil, Research Scholar, Mechanical Engineering, DYPIT, Pune (MS), India,

Dr. R. R. Arakerimath, HOD Mechanical, G H Raisoni College of Engineering and Management, Wagholi, Pune, India.

Table II. Taguchi array for optimization of parameters (Sample readings)

MOLAR RATIO	CATA-LYST %	REACT TEMP.	REACT TIME	REACT SPEED	% YIELD	SNRA1	SRES
5	1	55	60	300	60	35.5630	0.231455
5	1.5	60	90	400	62	35.8478	-0.1543
10	3	55	90	500	70	36.9020	-1.31158
15	1	65	180	400	65	36.2583	0.231455
15	3	60	150	300	74	37.3846	-0.54006
20	2.5	60	180	500	72	37.1466	-0.54006
20	3	65	60	600	80	38.0618	2.160247
25	1	70	150	500	70	36.9020	0.617213
25	1.5	55	180	600	72	37.1466	0.231455

The highlighted row of above table gives the optimum values of input parameters for maximum yield, because of higher values of SN ratio.

III. ANALYSIS BY TAGUCHI METHOD

Taguchi Analysis: %YIELD versus Molar Ratio %, Catalyst ... tion Speed
Larger is better

Table III. Response Table for Signal to Noise Ratios

Level	Molar Ratio %	Catalyst %	React Temp. ^oC	React Time	React Speed
1	36.37	36.33	36.68	36.96	36.94
2	36.77	36.64	36.83	36.83	36.77
3	36.84	36.84	37.01	36.93	36.75
4	37.11	37.24	36.99	36.90	37.05
5	37.47	37.51	37.05	36.94	37.04
Delta	1.10	1.19	0.37	0.13	0.31
Rank	2	1	3	5	4

Main Effects Plot for SN ratios

Main effect plot is used to examine differences between level means for one or more factors. It graphs the response mean for each factor level. [1]

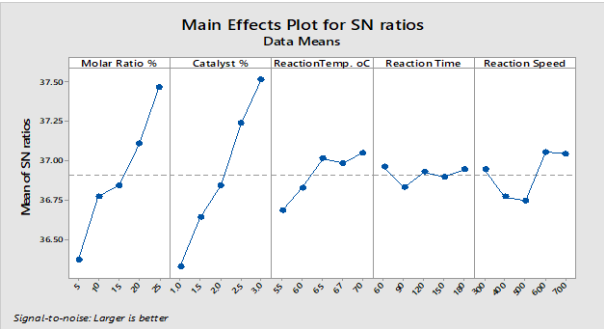

Fig.1. Main Effects Plot for SN ratios

From above graphs it is observed that graphs of mean of S/N ratios vs molar ratio and mean of S/N ratios vs catalyst% are steeper than others, so it is concluded that these two parameters i.e. molar ratio and catalyst % affects the yield mainly and effects of other three parameters can be neglected.

IV. INTERACTION PLOT FOR PARAMETER A AND B (FOR MOLAR RATIO AND CATALYST %) :

Taguchi Analysis: %YIELD versus Molar Ratio %, Catalyst %

Table IV. Response Table for Signal to Noise Ratios

Level	Molar Ratio %	Catalyst %
1	36.37	36.33
2	36.77	36.64
3	36.84	36.84
4	37.11	37.24
5	37.47	37.51
Delta	1.10	1.19
Rank	2	1

Interaction Plot for SN ratios:

Taguchi method generally focuses on main effects, but it is important to test suspected interactions. Interaction plot is used to measure whether the effect of one factor on response characteristic depends on the level of other.[1]

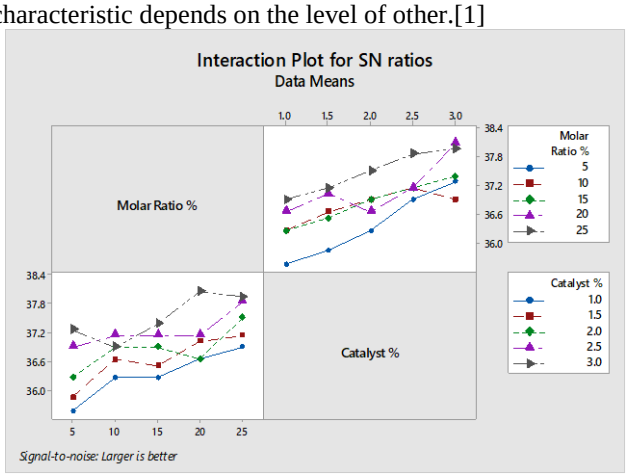

Fig.2.Interaction Plot for parameter A and B (For molar ratio and Catalyst %)

The above interaction plot shows that the maximum value of SNR at catalyst 3% and molar ratio 20 i.e. the maximum yield at this combination.

V. REGRESSION ANALYSIS:

Regression Analysis: %YIELD versus Molar Ratio %, ... , Reaction Speed

Table V. Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	5	528.758	105.752	48.07	0.000
Molar Ratio %	1	208.080	208.080	94.58	0.000
Catalyst %	1	288.000	288.000	130.90	0.000
ReactionTemp. °C	1	26.818	26.818	12.19	0.002
Reaction Time	1	0.080	0.080	0.04	0.851
Reaction Speed	1	5.780	5.780	2.63	0.122
Error	19	41.802	2.200		

Model Summary

In model summary R square value provides a measure of how well the model is fitting the actual data. Here R square value is 92.67%, this shows that the model obtained is fitted to actual data.

Table VI. Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.48327	92.67%	90.75%	87.90%

Regression Equation

Regression equation is statistical model that determine the specific relationship between the input parameters and output parameters. It gives the outcome with a relatively small amount of error.

%YIELD = 40.62 + 0.4080 Molar Ratio % + 4.800 Catalyst % + 0.1949 Reaction Temp. - 0.00133 Reaction Time + 0.00340 Reaction Speed

Normal Probability plot of Residuals for %YIELD

The normal probability plot is a graphical tool for comparing a data set with the normal distribution. A straight line in this plot shows the data fit a normal probability distribution. There are very low residual values and all residuals obtained are almost along the line.

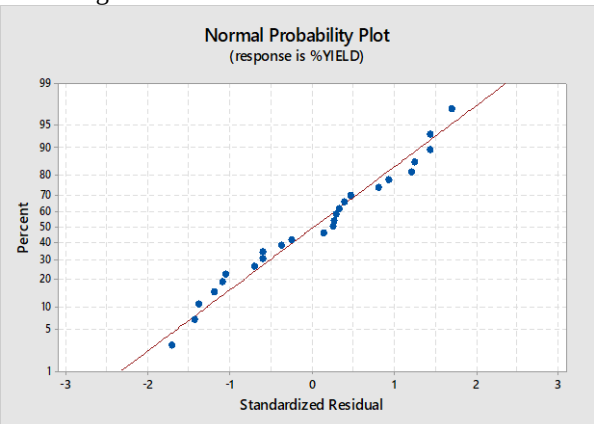

Fig.3. Normal Probability plot

VI. CONCLUSION

The analysis by Taguchi method has been carried out for optimizing the transesterification method for production of biodiesel from Karanja oil [1]. The various input parameters such as molar ratio, catalyst %, reaction temperature, reaction time and stirring speed have been optimized using SNR based on this study, it can be concluded that as follows;

1) Experimental yield obtained at optimal conditions i.e. are 20% molar ratio of methanol to oil, addition of 3% Al_2O_3 catalyst, reaction temperature 65°C, reaction time 60 min and 600 rpm stirring speed is 80%.
2) From main effective plots, it is observed that graphs of mean of S/N ratios vs molar ratio and mean of S/N ratios vs catalyst % are steeper than others, so it is concluded that these two parameters i.e. molar ratio and catalyst % affects mainly on the yield.
3) The interaction plot proves that the maximum value of SNR at catalyst 3% and molar ratio 20% i.e. the maximum yield at this combination.
4) Here R square value is 92.67%, this shows that the model obtained is fitted to actual data.
5) A straight line in the normal probability plot shows the data fit a normal probability distribution. There are very low residual values and all residuals obtained are almost along the line.

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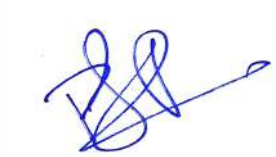

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Brain MR Imaging Tumor Detection Using Monogenic Signal Analysis-Based Invariant Texture Descriptors

Deepak O. Patil[1,2] · Satish T. Hamde[1]

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Abstract

Brain tumor is considered as a fatal disease with low survival rate and has the highest cost of care per patient. This article proposes a computer-assisted system for the recognition of brain tumor image through magnetic resonance imaging based on the monogenic signal analysis. From different monogenic components, textural descriptors are obtained using completed local binary pattern and gray-level co-occurrence matrix. In the pre-processing step, various filtering for noise removal and contrast enhancement techniques are implemented. Local phase, energy and orientation components originated from the monogenic signal analysis method are used for textural feature extraction. Fisher score-based filter approach for feature selection is then employed to derive the discriminating feature set. Finally, the acquired optimal feature set is classified using the support vector machine classifier. Two benchmark MR image datasets, e-health laboratory and Harvard medical laboratory, have been used to validate the system performance. Overall detection accuracy obtained was above 99%. The experimental results demonstrate the effectiveness of the proposed approach and the potential to assist the medical experts in enhancing the detection rate. Furthermore, the presented approach delivers superior performance in brain tumor image recognition as compared to existing techniques.

Keywords Monogenic signal analysis · GLCM · CLBP · Fisher score · MR images · Brain tumor detection · SVM classifier

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Cardiac Arrhythmia Detection on Electrocardiogram Beats based on KPCA and SVR

Criteria 3
3.3.5

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ABSTRACT: Patients suffer from various heart diseases may lead to sudden death. So that prior detection of arrhythmia is important to prevent the sudden deaths. Developing the methods of ECG signal features extraction is required to detect heart abnormalities and different kinds of diseases. This study shows the arrhythmia detection system based on kernel-PCA and support vector regression. Feature of ECG signal are the interval between the points such as RR interval, P, R, Q, S, and T beats having the specific magnitude. The several methods have been proposed to recognize and analyze the ECG signals. In this paper, we employ the combination of kernel-PCA and support vector regression classifier to recognize the ECG signal. The method consists of three steps; first, low pass filter removes the noise in ECG signal. Then Kernel-PCA and higher order statistics are derived for feature extraction of ECG signal. Finally, the obtained feature set is used as input to SVR classifier to classify the ECG signal. Most of the data comes from online MIT-BIH dataset to obtain the ECG records for evaluating the classification performance. The classification performance of the proposed model is also compared with the several conventional machine learning classifiers, which is better classification accuracy.

Keywords: ECG signal, feature extraction, Principal Component Analysis, Arrhythmia detection, Super vector machine and SVR (Super Vector Regression)

Abbreviations : CNN, Convolution Neural Network; ECG,- Electrograph; FFNN, Feed Forward Neural Network; FPN, Fusion of Paced and Normal Beat; PSO, Particle Swarm Optimization ;PVC, Premature Ventricular contraction; PCA, Principal Component Analysis; RMSE, Root Mean Square Error; SVM, Super Vector Machine; SVR, Super vector Regression.

I. INTRODUCTION

In recent year medical science technology has become widely increasing for automatic diagnosis of health problem. The electrocardiogram (ECG) plays a very significant role for diagnosing the health problem such as arrhythmia or other cardiac related issues. The purpose of ECG is to analyse and diagnoses the heart problem efficiently and accurately. The ECG receives the electrical signals from patient and obtains the arrhythmia signal information. In arrhythmia problem and genetic abnormalities change the contour of ECG signal; each portion of electrocardiogram beats contains information relevant to the doctor when a proper diagnosis is obtained.

The Fig. 1 shows the simple Electrocardiogram signal indicating the P, Q, R, S and T parameter [20]. The P beats occurs due to ventricular depolarization, the QRS are beats and the T beats due to ventricular depolarization. Volume of electrocardiogram ECG recorded in medical emergency is now increasing as heart disease patient are expanding at a disturbing rate.

The ECG signal contain various types of noise during the signal receives from patient such noise has some time high frequency or low frequency signal. It may affect the wrong diagnosis. So that noise removal is necessary.

As the technology changing researcher has been develop the many computational techniques or methods to extract the normal ECG signal from noisy data.

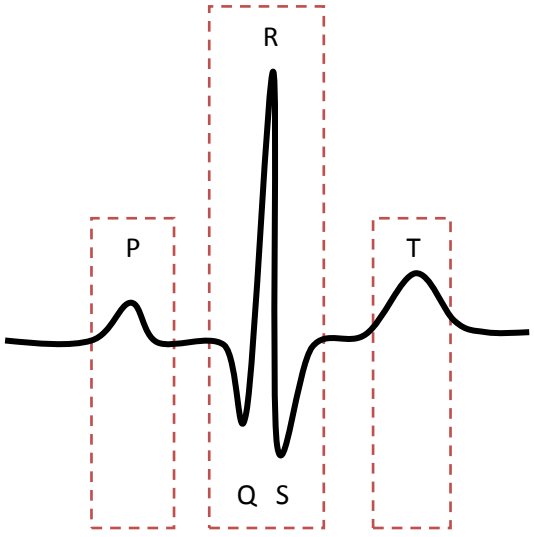

Fig. 1. Shows the simple Electrocardiogram signal.

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In previous studies have been accomplished the various model of different kinds of feature extraction from ECG signals and a classification technique has been proposed. Feature extraction may contain the non-linear, time, frequency domain and multi domain feature extraction [2, 3]. For the classification classical methods is used such as Artificial Network, Support Vector Machine (SVM), Super vector regression (SVR) etc. In the time domain the ECG signal can be easily figure out by the noise and has low accuracy level [4, 5]. Another approach for extracting the ECG feature based on convolutional neural network model. The model has two sections; the first part extract the feature from ECG signals and second part perform the classification of feature based on the first section. Feature extraction was discussed based on principle component analysis to reduce the multidimensional data and input is processed by three pooling layer approach [6]. These signals cannot be consider as the accurate parameter of ECG signals for accomplishing high arrangement correctness. There are various combination of methods have been proposed for ECG feature extraction classification. For the feature optimization the genetic algorithm and the SVM based classifier designated for classification of ECG waveforms [7, 22, 23]. The Extreme learning machine algorithm calculates the minimum weight Single Hidden Layer Feed forward Neural Network for classification [8]. The KNN based approach for cardiac arrhythmia classification. The model is one of the types of recurrent neural network for classification is based on the LSTM in time serious domain. In the recent study, echo state network was implemented based on the morphology for classifying the normal and abnormal ECG signals of heart. The classification is based on the two classes SVEB and VEB [10]. The feature extraction from non-linear process in time and space domain based on the T complexity is applied to the RR and for classification used 13 different classes [11, 12].

Although, all above mentioned classification techniques or methods have good result, they used a combined space, time, frequency, linear and non-linear domain for ECG beat classification. So that present research proposed ECG waveform detection model that extracting the features in multi domain based on the empirical mode decomposition with linear discriminate analysis [13]. The combined approach of polyhedral conic separation and k-means clustering was applied as classifier to differentiate the ECG waveforms with 5 different classes such as N for Normal, RBBB for Right Bundle Branch Block, LBBB for Left Bundle Branch Block, APC for Atrial Premature Contraction and VPC for Ventricular Premature Contraction [14-15]. Kutlua and Kuntalp proposed a new cloud based model for automatic classification of ECG beats with minimum processing of signals [16]. The proposed model is based on the compression based similarity (CSM) and classification is done by KNN with one Bayesian classifier for better accuracy. An effective method to classify the ECG signal based on the super vector regression analysis on 400 samples of data set of various arrhythmias was proposed [24]. Proposed Model is tested and compared with the various neural network classifiers techniques and observed that it gives better accuracy than existing system. The purpose of this research is to propose an efficient arrhythmia detection techniques based on the kernel principle component analysis and support vector regression methods. In this research select 5 classes; normal Beat (N), Aberrant atrial premature Beats (S), Ventricular Ectopic beats (V), Combination beat (F), Unclassifiable beats (Q). We used Support vector regression classifier to classify the instances of ECG beats. In section II brief description of proposed methodology gives the data handling and signal pre-processing procedures. In section III and IV discusses the evaluation, result analysis and discussion and in section V conclusions.

II. PROPOSED METHODOLOGY

The entire schematic diagram of recommended model as present in Fig. 2. The Model based on the Kernel-PCA and SVR classifier for feature extraction and classification of ECG signal to detect the arrhythmia. First raw ECG signal is pre-processed using low pass filter to remove the noise after that applied Kernel-PCA and Higher Order Statistics method for feature extraction from ECG. The extracted feature is further processed for classification using the SVR algorithm.

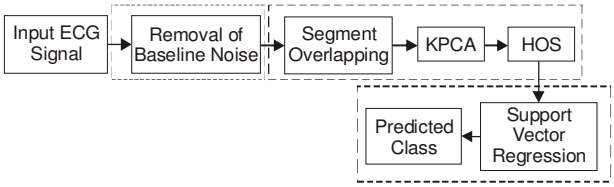

Fig. 2. Schematic diagram of Recommended Model for Classification of ECG signal.

Fig. 2 shows the proposed system can be categorized of three different sections such as pre-processing, obtaining feature and classification of beats. The working principle of proposed model as shown in following steps.

The raw ECG waveform are input to the system, and then pre-processed to remove the unwanted frequencies called as noise using the low pass filter.

Optimized the inputted ECG data by KPCA. KPCA is implemented to reduce the dimension and extract the ECG features. The wavelet transform techniques are used to extract the feature in frequency domain.

The KPCA are designated by non-linear and frequency domain parameter, which is useful for feature input to instruct and analyse the SVR classifier and finally predicted class of ECG signal, is classified from the MIT-BIH dataset.

A. ECG Signal pre-processing based on Low Pass Filter

The ECG beats are weak and it contains the noise so that pre-processing is required before the feature extraction [19]. Sometimes noise is distinct. We proposed the noise removal technique based on the low pass filter and pass the small frequency of ECG data and attenuates the high frequencies. Low pass filter function is proposed with cut-off frequency from 5 to 15Hz is used for noise removal is described below:

$$H(x_m, x_n) = \begin{cases} 1, & \sqrt{x_m^2 + x_n^2} \le X; \\ 0, & \sqrt{x_m^2 + x_n^2} > X. \end{cases} \quad (1)$$

where, X is the cut-off frequency

The Present techniques shows to verify the ECG Pre-processing. As adding the noisy data for pre-processing with the proposed techniques with 360 Hz interference.

$$RMSE = \left[\frac{1}{N}\sum_{i=0}^{n}(Y_i - \widehat{Y}_i)^2\right]^{\frac{1}{2}} \quad (2)$$

Where Y_i sample of ECG noisy signal, N is the sample length. ECG beat class from the dataset has been select for pre-processing by threshold.

B. Segmentation

The primary step is applied to show the lowest slope of ECG waveform such as goes down the waveform from R to S. and is also shows the higher slope of ECG waveform such as signal moving from lower Q to higher R.

$$y(x) = \frac{1}{2\Delta t}\big(y(x+1) - y(x-1)\big), \quad x = 0,\ 1,\ 2,\ 3 \ldots \ldots N-1 \quad (3)$$

Where, $2\Delta t$ for sample frequency and N for number of sample. Starting conditions are set to reduces error i.e., beginning condition is indicated for x = 0, and x - N-1.

C. KPCA for Feature Extraction

The ECG signal has uncertain amount of data and most of the significant data is incorporated into the nonlinear procedure. The non-linear process of feature extraction easier to finding out the normal ECG signals [20]. We present the KPCA method to extract the feature of ECG signals. The high-dimensional F-Space highlight (with measurement N) enables to acquire features (non-linear primary segments) with higher-request connections between information factors, and we can separate nonlinear segments up to n information point numbers (expecting n N). Portion PCA depends on standard direct PCA calculation in an element space where information x info is mapped by means of some non-linear capacity x [21]. Finally, we utilize part capacity to compute authorized location item in space.

First consider nonlinearly mapping all data points x to $f(x)$ in a higher dimensional feature space F. the covariance matrix can be estimated as

$$\sum f = \frac{1}{N}\sum_{n=1}^{N} f(X_n) f(X_n)^T \quad (4)$$

Plugging this into the eigen equation of the covariance matrix

$$\sum f\, \Phi_i = \lambda_i \Phi_i \quad (5)$$

Get the,

$$\left[\frac{1}{N}\sum_{n=1}^{N} f(X_n) f(X_n)^T\right]\Phi_i = \frac{1}{N}\sum_{n=1}^{N}(f(X_n)\,.\,\Phi_i) f(X_n) = \lambda_i \Phi_i \quad (6)$$

The eigen Φ_i vector is a linear combination of the N mapped data points

$$\Phi_i = \frac{1}{\lambda_i N}\sum_{n=1}^{N}(f(X_n)\,.\,\Phi_i) f(X_n) = \sum_{n=1}^{N} a_n^{(i)} f(X_n) \quad (7)$$

where, $a_n^{(i)} = \frac{1}{\lambda_i N}(f(X_n)\,.\,\Phi_i)$ (8)

Multiply $f(X_m)^T$ in equation 8 to both sides

$$(f(X_n)\,.\,\Phi_i) = \lambda_i N a_n^{(i)} = \sum_{n=1}^{N} a_n^{(i)} f(X_m)\,.\,f(X_n)) = \sum_{n=1}^{N} a_n^{(i)} k(X_m, X_n) \quad (9)$$

Where,

$$k(X_m, X_n) = ((X_m)\,.f(X_n)) \quad (m, n = 1 \ldots \ldots N) \quad (10)$$

Kernel representing a inner-product of two vectors in space F. If we consider $(m, n = 1 \ldots \ldots N)$

Equation 10 is scalar equation becomes the m-th component of the vector

$$\lambda_i N a_n^{(i)} = K a_i \quad (11)$$

Where, N is eigen vectors of K, which is obtained by solve the eigen value of K. The eigen value of K is proportional to eigen value of λ_i of the converiance matrix $\sum f$ for the feature selection of ECG beats in high dimensional space.

D. Higher Order System (HOS)

Depending upon the types of cardiac arrhythmia the ECG signals has some variation in shape. The proposed techniques should receive and eliminates these differences of signals. The cumulants are the good statistical function to eliminate the differences of ECG signals [18]. The normal signal amplitude varies from 1.15 to 1.36 which is same as the length of 0.39. The cumulant is a very powerful tool to reduce the error in ECG signals during the classification process [25]. The second, third and fourth order comulant are as follows:

$$\text{cumulant}(x_m,\ x_n) = E[x_m,\ x_n] \quad (12)$$

$$\text{cumulant}(x_m, x_n) = E[x_m, x_n, x_o] \quad (13)$$

$$\text{cumulant}(x_a, x_b, x_c, x_d) = E[x_m, x_n, x_o, x_p] - E[x_m, x_n]\,E[x_o, x_p] - E[x_m, x_o]\,E[x_n, x_p] - E[x_m, x_p]\,E[x_n, x_o] \quad (14)$$

Where, x_m, x_n, x_o, x_p is the Gaussian noise sequence independent from the data. Every order of function has certain feature. Where the second order function is signal variance, third order function is signal skewness and the fourth order function is signal kurtosis. These three functions disclose the HOS of ECG signals. This function can be used in combine the shows the classification result more accurately.

In our research, HOS gives the better result as compare the Gaussian noisy signal in ECG data. It is foreseen that higher order statistics could likewise eliminate the impact of other unwanted signals in cardiac arrhythmia dataset [25].

The length of the sample for feature extraction is the major problem in utilizing the higher order statistics. In our research, applied the KPCA model for sustain the shape of signals that shows the minimum length. So that by combining the HOS and KPCA to maintaining the morphology in proposed model.

E. SVR for Classification

After obtaining the feature of proposed model; each sample of ECG beats are classified individually based on the K-PCA and SVR. In this case each beat were not the same as the others, the most of the frequent output between the three component vectors as recent output.

Support Vector Regression (SVR): SVR is a Novel technique of learning system. This for solving supervised classification problems due to its generalization ability. In essence, SVM classifiers maximize the margin between training data and the decision boundary (optimal separating hyper plane), which can be formulated as a quadratic optimization problem in a feature space. The subset of patterns those are closest to the decision boundary are called as support vectors Regression. SVR uses undefined benchmarks from the SVM for gathering, with only two or three minor changes. As issue of first significance, since yield is a certified number it ends up being uncommonly difficult to foresee the present information, which has boundless possible results.

Because of backslide; an edge of obstruction (epsilon) is set in estimation to the SVM which would have adequately requested from the issue. However, other than this reality, there is in like manner an increasingly befuddled reason; the estimation is progressively tangled as such to be taken in thought.

Regardless, the rule thought is reliably the equivalent: to constrain botch, individualizing the hyper plane which enlarges the edge, recollecting that bit of the goof is persevered.

Kernel Function as

For Polynomial

$$k(x_m, x_n) = (x_{m,}, x_n)^d \quad (15)$$

Where m, n is constant term and d is for degree of kernel. In equation 5 calculate the dot product of two vector term by increasing the power of kernel.

For Gaussian RBF

$$k(x_m, x_n) = \exp\left(-\frac{|x_m - x_n|^2}{2\sigma^2}\right) \quad (16)$$

$|x_m - x_n|$ is for Euclidean distance between x_m and x_n.

To determine the performance of proposed model of SVR classifier six parameters are used which is Sensitivity, Specificity, Accuracy, false positive rate, false negative rate and precision. All the parameters are calculated as follows.

$$\text{Specificity} = \frac{T\_P}{(T\_P + F\_N)} \quad (17)$$

$$\text{Sensitivity} = \frac{T\_N}{(T\_P + T\_P)} \quad (18)$$

$$\text{Accuracy} = (T\_P + T\_N)/(T\_P + F\_P + T\_N + F\_N) \quad (19)$$

$$FAR = (F\_P)/(F\_P + T\_N) \quad (20)$$

$$FRR = (F\_N)/(T\_P + F\_N) \quad (21)$$

$$\text{Precision} = (T\_P)/(T\_P + F\_P) \quad (22)$$

Where, T_P is for the True Positive, T_N is for True Negative, F_N is for False Negative, F_P is for False positive, FAR is for false positive rate and FRR is for false negative rate.

III. EVALUATION AND RESULT ANALYSIS

The proposed method characterizes the five different classes

ECG beat annotations:

N - beats starting in the sinus hub
S - Aberrant atrial premature Beats
V - Ventricular Ectopic beats
F - Combination beat
Q - Unclassifiable beats

In this Experimental analysis, the MIT/BIH arrhythmia database dataset is utilized for validate the proposed Method. The database contains comment for both planning data and beat class data checked by free specialists. A total of 1800 samples from the MIT-BIH arrhythmia database are equally divided into training sets. A total of 400 samples of N are derived from records 100, 101, 103 and 105. Similarly, 400 samples of APC are derived from records 109, 111, 207 and 214, and 400 samples of VFN are derived from records 118, 124, 212 and 231. We also derive 400 samples of PVC from records 106, 119, 200 and 203 and 200 samples of FPN from records 209 and 222. A total of 1800 samples are used as ECG data after sampling and pre-processing the ECG signals. It is suggested that every ECG beat be ordered into the accompanying five heartbeats composes: N, S, V, F and Q beats.

N-Beat. Normal ECG sample from MIT/BIH dataset is shown Fig. 3.

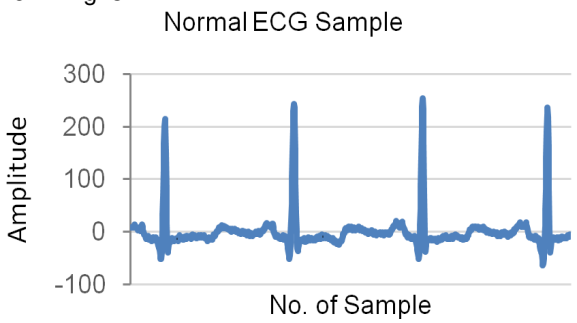

Fig. 3. N-beat ECG Sample.

Fig. 3 shows ECG signal to extract Time and Frequency based features. Those features are classified using SVR.

Table 1: Performance Analysis of Normal Class.

Parameter	Accuracy Level
Accuracy	0.9840
Sensitivity	0.92
Specificity	0.988571429
FAR	0.005747
FRR	0.148148
Precision	0.92

Table 1 shows the Performance Analysis of Normal Class. For Normal Class Total Accuracy for 100 randomly picked ECG sample of the MIT-BIH is 98.4 %. Below Figure shows the Accuracy, Sensitivity, Specificity, False Positive Rate, false Negative Rate and Precision.

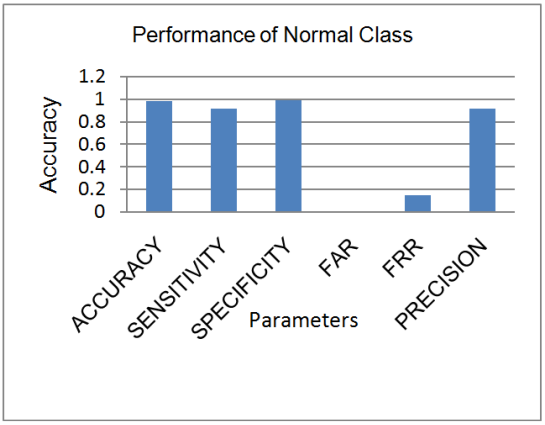

Fig. 4. Performance Analysis of N-beat Class.

S-Beat. Atrial premature complexes (APCs) are a common kind of heart arrhythmia characterized by premature heartbeats originating in the atria. Another name for atrial premature complexes is premature atrial contractions. When a premature beat occurs in the upper chambers of your heart, it's known as an atrial complex or contraction. Premature beats can also occur in the lower chambers of your heart. These are known as ventricular complexes or contractions. Causes and symptoms of both types of premature beats are similar.

Fig. 5 shows the Aberrant atrial premature signal to extract the Time and frequency based feature and classify those feature using SVR.

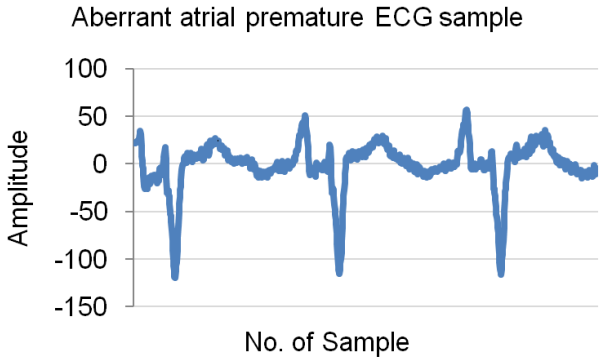

Fig. 5. Aberrant atrial premature ECG sample.

Table 2: Performance Analysis of Aberrant atrial premature Class.

Parameter	Accuracy Level
Accuracy	0.981333
Sensitivity	0.92
Specificity	0.985714
FAR	0.005764
FRR	0.178571
Precision	0.92

Table 2 shows Performance Analysis of Aberrant atrial premature Class. For Aberrant atrial premature Class Total Accuracy for 100 randomly picked ECG sample of the MIT-BIH dataset is 98.1 %.

Fig. 6 shows the performance analysis of S-beat with different parameter such as Accuracy, Sensitivity, Specificity, False Positive Rate, false Negative Rate and Precision.

V-Beat. Premature ventricular complexes/contractions (PVCs; also referred to a premature ventricular beats, premature ventricular depolarizations, or ventricular extra systoles) are triggered from the ventricular myocardium in a variety of situations. PVCs are common and occur in a broad spectrum of the population. Premature Ventricular Contraction ECG sample from combined dataset is shown Fig. 7.

Table 3 shows the Performance Analysis of Premature Ventricular Contraction Class. For Premature Ventricular Contraction Class Total Accuracy for 100 randomly picked ECG sample of the MIT-BIH data is 98.9 %.

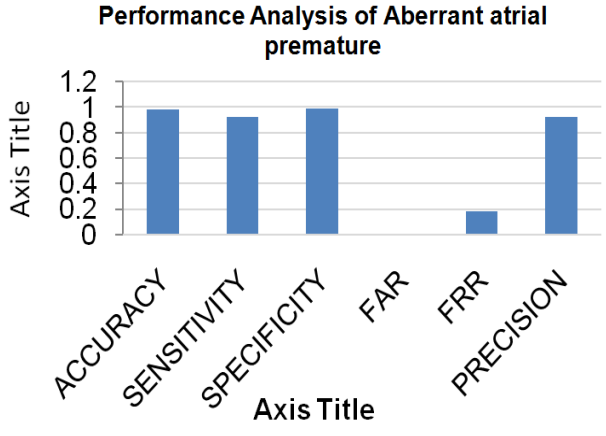

Fig. 6. Performance Analysis of S-Beat Class.

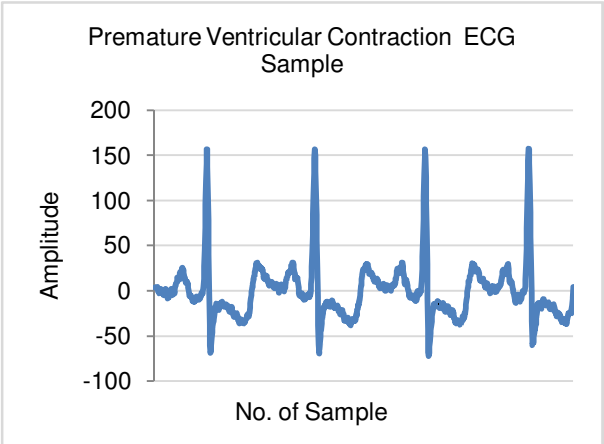

Fig. 7. V-beat class ECG Sample.

Table 3: Performance Analysis of Premature Ventricular Contraction Class.

Parameter	Accuracy Level
Accuracy	0.989333
Sensitivity	0.88
Specificity	0.997143
FAR	0.008523
FRR	0.043478
Precision	0.88

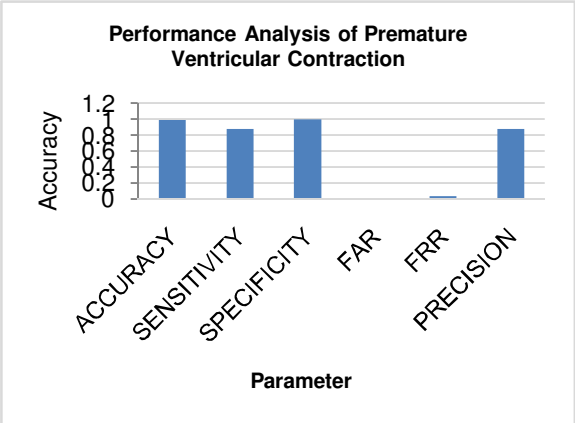

Fig. 8. Performance Analysis of V-beat class.

Fig. 8 shows the performance analysis of V-beat with different parameter such as Accuracy, Sensitivity, Specificity, False Positive Rate, false Negative Rate and Precision.

F-Beat. Combinational beat occurs when electrical impulses from different sources act upon the same region of the heart at the same time. If it acts upon the ventricular chambers it is called a ventricular combinational beat, whereas colliding currents in the atrial chambers produce atrial fusion beats. Ventricular combinational beats can occur when the heart's natural rhythm and the impulse from a pacemaker coincide to activate the same part of a ventricle at the same time, causing visible variation in configuration and height of the QRS complex of an electrocardiogram reading of the heart's activity. Combinational (Fusion) of ventricular and normal ECG sample from Combined dataset is shown Fig. 9.

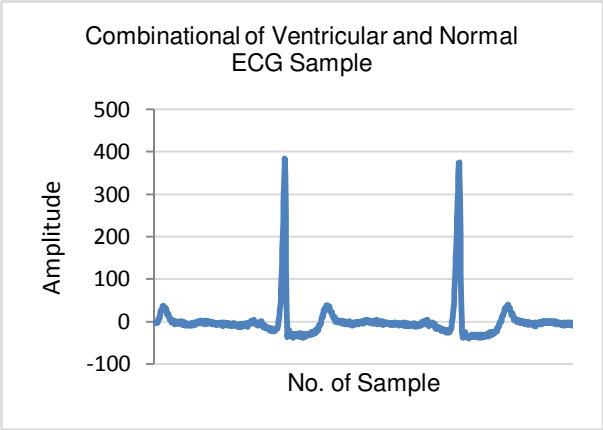

Fig. 9. Fusion of Ventricular and Normal ECG Sample.

Table 4: Performance Analysis of Fusion of Ventricular and Normal Class.

Parameter	Accuracy Level
Accuracy	0.986667
Sensitivity	0.88
Specificity	0.994286
FAR	0.008547
FRR	0.083333
Precision	0.88

Table 4 shows the Performance Analysis of Fusion of ventricular and normal Class. For Fusion of ventricular and normal Class Total Accuracy for 100 randomly picked ECG sample of the MIT-BIH data is 98.6 %.

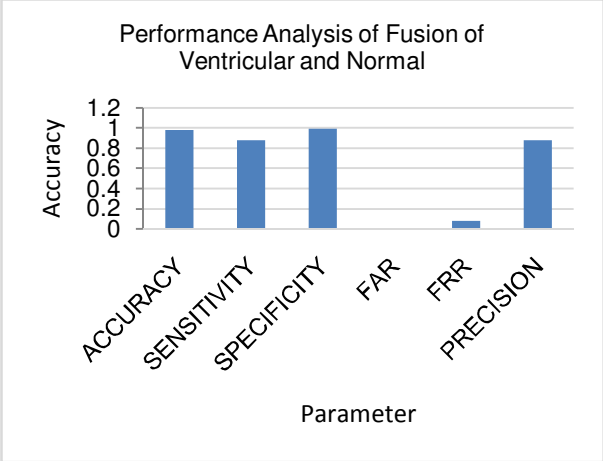

Fig. 10. Performance Analysis of F-Beat Class.

Fig. 10 shows the Performance Analysis of Fusion of ventricular and normal ECG beats such as Accuracy, Sensitivity, Specificity, False Positive Rate, false Negative Rate and Precision.

Q-Beats. Label that marks a segment of unreadable data. Unclassifiable ECG sample from combined dataset is shown in Fig. 11. Table 5 shows the Performance Analysis of Unclassifiable Class. For Unclassifiable Class Total Accuracy for 100 randomly picked ECG sample of the MIT-BIH data is 98.9 %.

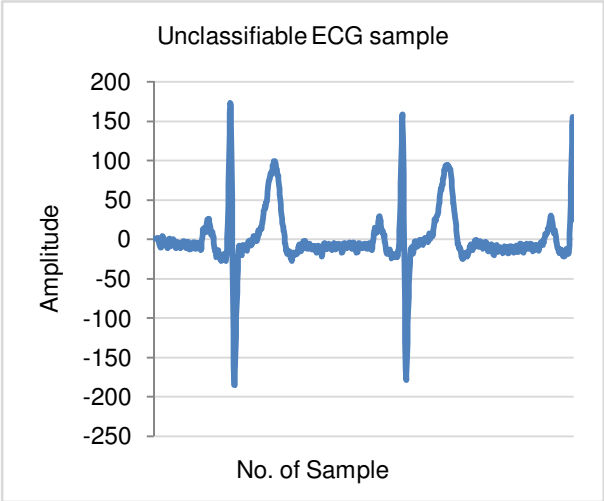

Fig. 11. Unclassifiable ECG sample.

Table 5: Performance Analysis of Unclassifiable Class.

Parameter	Accuracy Level
Accuracy	0.989333
Sensitivity	0.88
Specificity	0.997143
FAR	0.008523
FRR	0.043478
Precision	0.88

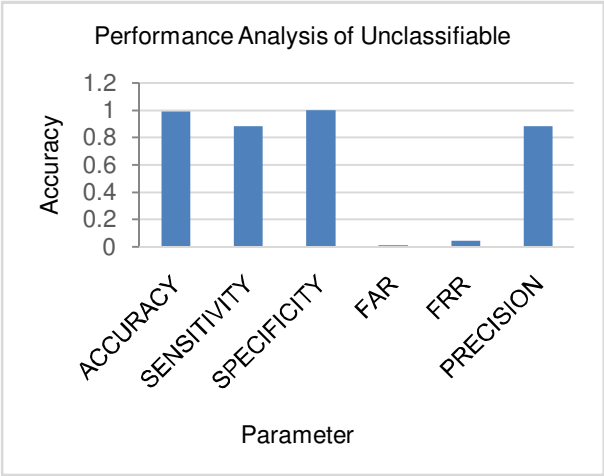

Fig. 12. Performance Analysis of Q-Beat Class.

Fig. 12 shows the Performance Analysis of Fusion of Unclassifiable ECG beats such as Accuracy, Sensitivity, Specificity, False Positive Rate, false Negative Rate and Precision. From Fig. 13 shows the comparing performance of several methods [1, 24, 26] with proposed KPCA-SVR method. It observed that specificity, sensitivity, positive prediction and false prediction rate of arrhythmia detection obtained by the suggested algorithm are better than the previous methods.

Table 6: Performance Evaluation of Several Methods and Proposed Methods.

Parameters	ANN	MD	SVM	KPCA-SVR
Sensitivity	0.93	0.98	0.94	0.98
Specificity	0.92	0.93	0.93	0.96
Positive Prediction	0.91	0.91	0.95	0.98
False Prediction	0.2	0.3	0.2	0.04

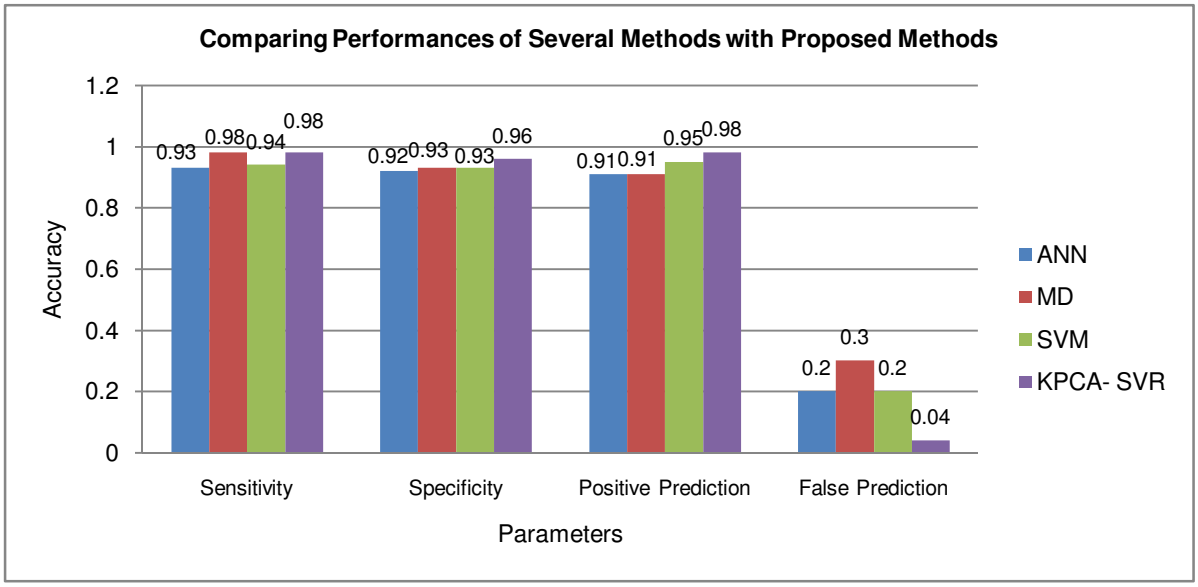

Fig. 13. Accuracy Comparisons of KPCA-SVR with other methods.

IV. RESULT AND DISCUSSION

Arrhythmia detection is an active research area in biomedical engineering with rapidly analysing the normalities and abnormalities of heart. The standard criteria for RR interval or ECG signal have number of limitations when discriminate the SVT from VT and alternative techniques have been suggested as the EGM width criterion which have the some limitation for QRS detection [10-13] and morphological techniques such as wavelet transform and Probability Density Function which do not have effective classification result [7, 22, 23]. The mechanism of feature extraction is proposed to extract the effective features for ECG recognition. The ECG data is sampled from MIT-BIH arrhythmia dataset and the data is pre-processed with low pass filter method with the 360 Hz interference. The various features have been proposed in the literature for classification of ECG beats. The classification performance of ECG beats is depends on feature extraction, feature reduction and classification algorithm. As the obtained results clearly indicate, ECG beats classification technique based on the combination of Kernel-PCA and SVR feature extraction to increase the accuracy, sensitivity, specificity and precision. This improvement can be caused by good performance of SVR classifier with reduced the number of ECG features.

V. CONCLUSION

In medical practices, computer based diagnosis of heart diseases or other kinds of heart problem can reduces the workload of medical practitioner and more concentrate on treatment rather than diagnosis. In this paper, an efficient Kernel-PCA and Support Vector Regression based ECG classification system is proposed to carry out automatic ECG arrhythmia detection by classify the patient's ECG into corresponding five kinds of cardiac arrhythmia condition such as Normal, Aberrant atrial premature, Ventricular Ectopic, Combination and Unclassifiable beats. Low pass filter method is used for pre-processing the ECG signal and removes the noise interference. The Proposed model uses the MIT-BIT cardiac arrhythmia dataset for ECG signal classification. The ECG signals have been classified into six common parameter are measure like Accuracy, sensitivity, specificity, False Positive Rate, false Negative Rate and Precision. The results show that the proposed algorithm is effective for prediction of cardiac arrhythmias, with an accuracy of 98%, sensitivity is 98%, Specificity is 96%, Positive Prediction is 98% and False Prediction is 0.4%. The proposed model can accomplish the better classification output so that diagnosis of cardiac arrhythmia effectively. The detection of arrhythmia by accuracy, specificity, sensitivity and prediction is superior to previous research because of the combination of KPCA and SVR in model. The higher order Statistics of cumulants are efficiently eliminates the variation in similar types of ECG signals so that easily classify the cardiac arrhythmia.

VI. FUTURE SCOPE

In our further research, we intend to focus on following points: (i) classification is performing on all the ECG beats of cardiac arrhythmia (ii) Optimal selection of feature sub-set to reduce the training time (computational requirements), (iii) achieving high classification accuracy with small sized input feature vector and limited training dataset.

Conflict of Interest. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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of Sinhgad College of Engineering

has presented a paper entitled Development of RP based Stereolithography System

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Dr. Johan Bin Mohamad Sharif
Universiti Teknologi Malaysia
Johor, Malaysia

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N. Vivekanandan

Mr. N. Vivekanandan
Scientist - Ministry of Jal Shakti, Dept. of Water Resources
River Development and Ganga Rejuvenation
Central Water and Power Research Station - Pune, India

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Outward No. : IOT/ 213 / 2019-20 Date: 04 /10/2019

To,
Prof. S. A. Patil
Professor, Mechanical Dept
PDEAs. College of Engineering Manjari.
Pune.

Subject: Invitation for Guest Lecture on"Carrier Guidance and Job opportunities in Industry"

Dear Sir,

We hope this letter finds you in the best of health. In view of above mentioned subject PDEA's Institute Of Technology , Hadapsar , Pune 28. I would like to take little efforts in enhancing the awareness among students by organizing Lecture on **"Carrier Guidance and Job opportunities in Industry"** on 04/10/2019.On this occasion, we take this opportunity to invite you in our esteem organizationand share your views and experience with the delegates by delivering the lecture on **"Carrier Guidance and Job opportunities inIndustry"** on **4th October** 2019, hoping to meet you on this eve.
Travelling and other expenses will be borne by the organizing institution. Eagerly waiting for your acceptance.

Thanking you.

P.D.E.A.'s INSTITUTE OF TECHNOLOGY HADAPSAR, PUNE-411 028.

Yours sincerely,

Principal
प्राचार्य
इन्स्टिट्युट ऑफ टेक्नॉलॉजी
हडपसर, पुणे - २८

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ESTD. 10 OCT. 1995 25 YEARS रौप्य महोत्सवी व 2019-20

Outward No. : IOT/ 213 / 2019-20 Date: 04/10/2019

To,
Prof. S. A. Patil
Professor, Mechanical Dept
PDEAs, College of Engineering Manjari,
Pune

Sir,

We are very much thankful to you for accepting our invitation and delivering anguest Lecture **"Carrier Guidance and Job opportunities inIndustry"** on **04th Ocober** 2019, organized by PDEA's Institute Of Technology , Hadapsar , Pune 28.

P.D.E.A.'s INSTITUTE OF TECHNOLOGY HADAPSAR, PUNE-411 028.

Principal
प्राचार्य
इन्स्टिट्युट ऑफ टेक्नॉलॉजी
हडपसर, पुणे - २८

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25 YEARS रौप्य महोत्सवी व 2019-20

Outward No. : IOT/ 185 / 2019-20 Date: 10 /09/2019

To.
Prof. R. K. Moje
Asst.Professor, E&TC Dept
PDEAs, College of Engineering Manjari,
Pune.

Subject: Invitation for Guest Lecture on **"Job opportunities inIndustry after Covid-19**

Dear Sir,
In view of above mentioned subject PDEA's Institute Of Technology, Hadapsar, Pune 28. I would like to take little efforts in enhancing the awareness among students by organizing Lecture on **"Job opportunities inIndustry after Covid-19"** on 11/09/2019.On this occasion, we take this opportunity to invite you in our esteem organizationand share your views and experience with the delegates by delivering the lecture on **"Job opportunities inIndustry after Covid-19"** on **11th Septmber** 2019, hoping to meet you on this eve.
Eagerly waiting for your acceptance.

Thanking you.

P.D.E.A.'s HADAPSAR, PUNE-411 028. INSTITUTE OF TECHNOLOGY

Yours sincerely,

Principal
प्राचार्य
इन्स्टिट्युट ऑफ टेक्नॉलॉजी
हडपसर, पुणे - २८

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ESTD. 10 OCT. 1995 25 YEARS रौप्य महोत्सवी वर्ष 2019-20

Outward No. : IOT/ 185 / 2019-20 Date: 11/09/2019

To,
Prof. R. K. Moje
Asst.Professor, E&TC Dept
PDEAs, College of Engineering Manjari,
Pune

Sir,

We are very much thankful to you for accepting our invitation and delivering a guest Lecture **"Job opportunities inIndustry after Covid-19 "** on **11th Sept** 2019, organized by PDEA's Institute Of Technology , Hadapsar , Pune 28.

P.D.E.A.'s INSTITUTE OF TECHNOLOGY HADAPSAR, PUNE-411 028.

Principal
प्राचार्य
इन्स्टिट्यूट ऑफ टेक्नॉलॉजी
हडपसर, पुणे - २८

Criteria 3

Criteria 3.4.4:

Sr.No.	Type of Events
01	**Plant Sampling Distribution**
02	**River Cleaning Programme**
03	**Swachhata Abhiyan in College Campus**
04	**Patravali Distribution in Wari**
05	**Sinhgad Fort Cleanning**

Criteria 3

Criteria 3.4.1:

Name of Event: Plant Sampling Distribution

Name of Event President: Dr. R.V.Patil, Principal, PDEA's COE, Pune

Name of Coordinator: Prof.K.B.Dumbre
Participants: Teaching, Non-Teaching Staff and Students
Date: 22/06/2019

Event Report:

The plant sampling distribution programme has been organized by NSS Department, Savitribai Phule Pune University for Gunnies World Record. Our NSS volunteers accepted the appeal of Savitribai Phule Pune University Vice Chancellor Dr.Nitin Karmalkar and participated plant sampling distribution programme at Savitribai Phule Pune University Campus. The NSS volunteers have taken an imitative along with all departments and it has been successfully conducted. All students gave overwhelming response to this activity.

Dumbre

Prof.K.B.Dumbre
Coordinator, NSS Cell,
PDEA's COE,
Pune -412307

Criteria 3

Criteria 3.4.1:

Criteria 3

Criteria 3.4.1:

Name of Event: River Cleaning Programme

Name of Event President: Dr. R.V.Patil, Principal, PDEA's COE, Pune

Name of Coordinator: Prof.K.B.Dumbre
Participants: Teaching, Non-Teaching Staff and Students
Date: 02/10/2019

Event Report:

The river cleaning programme has been organized by NSS Department; Savitribai Phule Pune University. Our NSS volunteers accepted the appeal of Savitribai Phule Pune University Vice Chancellor Dr.Nitin Karmalkar and participated river cleaning programme at Mundhva Bridge, Pune on the occasion birth anniversary of Mahatma Gandhi i.e. October 02, 2019. The NSS volunteers have taken an imitative along with all departments and it has been successfully conducted. Under Swachha Bharat Abhiyan the NSS volunteers cleaned all the river area and collected the garbage at one location. The collected garbage was handed over to the corporation garbage vehicle. All students gave overwhelming response to this activity.

Dumbre

Prof.K.B.Dumbre
Coordinator, NSS Cell,
PDEA's COE,
Pune -412307

Criteria 3

Criteria 3.4.1:

Criteria 3

Criteria 3.4.1:

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अभिमहा/रासेयो/२०१९-२०/४५६ दि.०१/१०/२०१९

प्रति,
मा. कार्यक्रम समन्वयक,
राष्ट्रीय सेवा योजना,
सावित्रीबाई फुले पुणे विद्यापीठ,
गणेशखिंड, पुणे

विषय : स्वच्छता ही सेवा उपक्रमातंर्गत नदी स्वच्छता व प्लॅस्टीकमुक्त अभियान अहवाल सादर करणेबाबत...

संदर्भ : रासेयो/१९-२०/३३५ दि.३०.०९.२०१९

मा. महोदय,

उपरोक्त विषयास व संदर्भिय पत्रास अनुसरुन आपणास कळविण्यात येते की, दि.०२.१०.२०१९ रोजी पुणे व पिंपरी चिचंवड शहरामध्ये सावित्रीबाई फुले पुणे विद्यापीठ राष्ट्रीय सेवा योजनेच्या वतीने "नदी स्वच्छता व प्लॅस्टीकमुक्त अभियान" राबविण्यात आले. यामधील खराडी मुंढवा ब्रिज नदी परिसरामध्ये सदर उपक्रमामध्ये १० महाविद्यालये सहभागी झालेली होती. याबाबतचा सविस्तर खालीलप्रमाणे

Sr.No.	College NSS Code	College Name
01	A- 59	PDEA's,College of Engg.Manjari(Bk)
02	A- 94	PDEA's,Shankarrao Ursal Colleg of Pharmacetical Science & Research,Kharadi
03	ASF - 185	Jaywantrao Sawant Commerce & Science College,Hadapsar
04	B- 73	JSPM, ICOER,Wagholi
05	A- 101	Arihant Arts,Commerce, Science College,Pune
06	A- 98	JSPM, BSIOTR, Wagholi
07	ASF- 128	PDEA's,Law College, Hadapsar
08	A - 39	S.M.Joshi College, Hadapsar
09	A- 1	PDEA's,Annasaheb Magar College,Hadapsar
10	A- 48	Vidya Bhavan College of Commerce,Pune

कळावे

आपला विश्वासु

प्रा.के.वी.डुंबरे
विभागीय समन्वयक

डॉ.आर.व्ही.पाटील
प्राचार्य
पुणे जिल्हा शिक्षण मंडळाचे
अभियांत्रिकी महाविद्यालय
मांजरी (बु!!), पुणे - ४१२३०७.

सावित्रीबाई फुले पुणे विद्यापीठ, राष्ट्रीय सेवा योजना आयोजित
राष्ट्रीय सेवा योजना सुवर्ण महोत्सवी वर्षानिमित्त व महात्मा गांधी १५० व्या जयंती निमित्त
स्वच्छता ही सेवा उपक्रम अंतर्गत नदी स्वच्छता व प्लॅस्टीकमुक्त अभियान, दि. २ ऑक्टोबर २०१९
सहभागी स्वयंसेवक नावनोंदणी

महाविद्यालयाचा रासेयो क्र.	A-59	कार्यक्रम अधिकारी नाव	Prof. Ketan Dumbre
महाविद्यालयाचे नाव	PDEA's College of Engineering, Manjari Bk, Pune.	संपर्क	9970922682
सहभागी स्वयंसेवक संख्या	68	स्वच्छता अभियान ठिकाण	Kharadi - Mundhwa Bridge

क्र.	स्वयंसेवकाचे नाव	संपर्क	स्वाक्षरी
१	Komal Yashram Shende	7083575637	Shen
२	Vinayak Patil	9172814004	Patil
३	Sujit bhosale	8605778152	Bhosale
४	Vaibhav Dattatraya Kunde	7719039828	Vkunde
५	Vaibhav Vilas Kadam	9766812131	Vvkadam
६	Lalit Motiram Bhoyar	7028476745	LBhoyar
७	Sunny Bhosale	9960109070	Sunny
८	Rakesh Agalave	9146909722	Rajalave
९	Kshitijkumar patil	9860200302	Kpatil
१०	Shubham Kshirsagar	7875595855	Shirsagar
११	Swapnil Hilal	7020201310	Swapnil
१२	mangesh darade	7744010738	mangeshdarade
१३	Rahul Kamble	7057107885	Rahul
१४	Lad Sujit	8830306714	Sujit

PTO

क्र.	स्वयंसेवकाचे नाव	संपर्क	स्वाक्षरी
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१६	Aadesh Sirsat	9168781799	
१७	Ashutosh Kumar	7254014562	
१८	Ankush Gadge	7038503887	
१९	Abhi Thombare	8999942419	
२०	Pritam Khot	8928609453	
२१	Pawan Jadhav	9766295015.	
२२	Pranita Dalui	9011940807	
२३	Shraddha Utekar.	7350359612	
२४	Shewta Shinare.	8888380538.	
२५	Vaishnavi Wayal.	7350740544	
२६	Pranita Dasgaonkar.	8237427232.	
२७	Swarali Athat.	7517832914	
२८	Sebastian D'CRUZ	7276259363	
२९	AKANKSHA KEDARI	9689172707	
३०	Mansi Sawant	9764826057.	
३१	Vaishali Chaudhari	9552369476.	
३२	Payal Deshmukh	7420907569	
३३	Prachi Sabale	8668237508.	
३४	Nikita Solanke.	8007237716.	

Criteria 3

Criteria 3.4.1:

Name of Event: Swachha Bharat Abhiyan

Name of Event President: Dr. R.V.Patil, Principal, PDEA's COE, Pune

Name of Guests: HOD, All Department

Name of Coordinator: Prof.K.B.Dumbre
Participants: Teaching, Non-Teaching Staff and Students
Date: 03/10/2019

Event Report:

The Swachha bharat abhiyan has been announced by Hon. Prime Minister Shri. Narendra Modi. Our NSS volunteers accepted the appeal of our Prime Minister and conducted Swachha Bharat Abhiyan in and outside of our campus on the occasion birth anniversary of Mahatma Gandhi i.e. October 02, 2018. The NSS volunteers have taken an imitative along with all departments and it has been successfully conducted. Under Swachha Bharat Abhiyan the NSS volunteers cleaned all the campus and collected the garbage at one location. The collected garbage was handed over to the corporation garbage vehicle. All students gave overwhelming response to this drive. All teaching and non teaching staff and students from SE, TE and BE have participated in the cleaning mission.

Dumbre

Prof.K.B.Dumbre
Coordinator, NSS Cell,
PDEA's COE,
Pune -412307

Criteria 3

Criteria 3.4.1:

Photographs:

Criteria 3

Criteria 3.4.1:

पुणे जिल्हा शिक्षण मंडळाचे

अभियांत्रिकी महाविद्यालय, मांजरी (बु) , पुणे ४१२३०७

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अभिमह/कार्यालय/२०१९-२०/४४१ **परिपत्रक** दि.३०/९/२०१९

सर्व शिक्षक व शिक्षकेत्तर सेवकांना कळविण्यात येते की, महात्मा गांधी जंयती निमित्त महाविद्यालयात दिनांक ०३/१०/२०१९ रोजी दुपारी ठिक ३.०० वाजता स्वच्छता अभियान हा उपक्रम राबविण्यात येणार आहे. तरी सर्व शिक्षक व शिक्षकेत्तर सेवकांनी सदर उपक्रमात सक्रिय सहभाग घ्यावा.

डॉ.आर.व्ही.पाटील
प्राचार्य
पुणे जिल्हा शिक्षण मंडळाचे
अभियांत्रिकी महाविद्यालय

प्रत महितीस्तव : ०१. अधिष्ठाता प्रशासन/अधिष्ठाता शैक्षणिक / अधिष्ठाता विद्यार्थी कल्याण ४१२३०७.
०२. यांत्रिकी /इले ॲण्ड टेलीकम्युनिकेशन /संगणक /उपकरणीकरण /माहिती तंत्रज्ञान /प्रथम वर्ष /ग्रंथपाल/ कार्यशाळा/एम.बी.ए/कार्यालय/टेनिंग ॲण्ड प्लेसमेट विभाग /भांडार /कार्यालय/ सदरचे परिपत्रक विभागातील शिक्षक व शिक्षकेत्तर सेवकांच्या निदर्शनास आणावे व नोटीस बोर्डवर लावण्यात यावी.
०३. आस्था विभाग - कार्यालयीन दफ्तरी ठेवावी.

पुणे जिल्हा शिक्षण मंडळाचे

अभियांत्रिकी महाविद्यालय, मांजरी (बु) , पुणे ४१२३०७

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अभिमह/कार्यालय/२०१९-२०/४४१ **परिपत्रक** दि.३०/९/२०१९

सर्व महाविद्यालयीन विद्यार्थ्यांना कळविण्यात येते की, महात्मा गांधी जंयती निमित्त महाविद्यालयात दिनांक ०३/१०/२०१९ रोजी दुपारी ठिक ३.०० वाजता स्वच्छता अभियान हा उपक्रम राबविण्यात येणार आहे. तरी सर्व विद्यार्थ्यांना सेवकांनी सदर उपक्रमात सक्रिय सहभाग घ्यावा.

डॉ.आर.व्ही.पाटील
प्राचार्य
पुणे जिल्हा शिक्षण मंडळाचे
अभियांत्रिकी महाविद्यालय

प्रत महितीस्तव : ०१. अधिष्ठाता प्रशासन/अधिष्ठाता शैक्षणिक / अधिष्ठाता विद्यार्थी कल्याण
०२. यांत्रिकी /इले ॲण्ड टेलीकम्युनिकेशन /संगणक /उपकरणीकरण /माहिती तंत्रज्ञान /प्रथम वर्ष /ग्रंथपाल/ कार्यशाळा/एम.बी.ए/कार्यालय/टेनिंग ॲण्ड प्लेसमेट विभाग /भांडार /कार्यालय/ सदरचे परिपत्रक विद्यार्थ्यांच्या निदर्शनास व नोटीस बोर्डवर लावण्यात यावा.
०३. आस्था विभाग - कार्यालयीन दफ्तरी ठेवावी.
विभागातील विद्यार्थ्यांच्या निदर्शनास आणावे व नोटीस बोर्डवर लावण्यात यावी.

Notice M\moremam\30-Sep-19

Criteria 3

Criteria 3.4.1:

Name of Event: Patravali Distribution in Wari

Name of Event President: Dr. R.V.Patil, Principal, PDEA's COE, Pune

Name of Coordinator: Prof.K.B.Dumbre

Participants: NSS Students

Date: 27/06/2019

Event Report

The Patravali distribution programme has been organized by NSS Department; Savitribai Phule Pune University. Our NSS volunteers accepted the appeal of Savitribai Phule Pune University Vice Chancellor Dr.Nitin Karmalkar and participated Patravali distribution programme at Hadapsar, Pune. The 'Swachha Bharat Abhiyan' is a massive mass movement that seeks to create a Clean India. Now the time has come to devote ourselves towards 'Swachchhata' (cleanliness) of our motherland. The 'Swachh wari- Swasth Wari- Nirmal Wari –Harit wari' campaign is important for maintaining the balance of the nature. The Patravali distribution programme is environment friendly activity.

Dumbre

Prof.K.B.Dumbre
Coordinator, NSS Cell,
PDEA's COE,
Pune -412307

Criteria 3

Criteria 3.4.1:

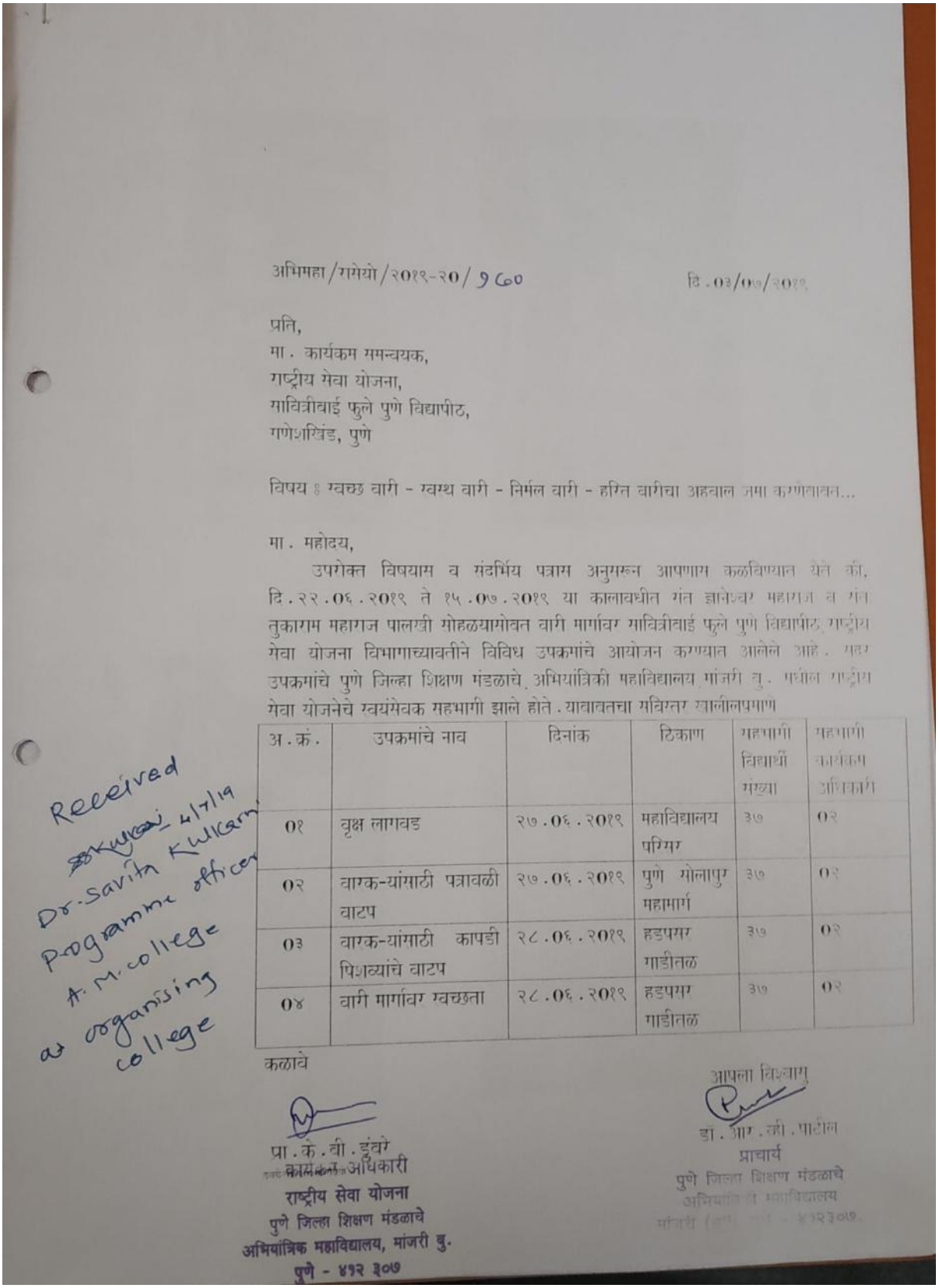
Photographs:

Criteria 3

Criteria 3.4.1:

Criteria 3

Criteria 3.4.1:



अभिमहा/रासेयो/२०१९-२०/ ९६०

दि.०३/०७/२०१९

प्रति,
मा. कार्यक्रम समन्वयक,
राष्ट्रीय सेवा योजना,
सावित्रीबाई फुले पुणे विद्यापीठ,
गणेशखिंड, पुणे

विषय : स्वच्छ वारी - स्वस्थ वारी - निर्मल वारी - हरित वारीचा अहवाल जमा करणेबाबत...

मा. महोदय,

उपरोक्त विषयास व संदर्भिय पत्रास अनुसरून आपणास कळविण्यात येते की, दि.२२.०६.२०१९ ते १५.०७.२०१९ या कालावधीत संत ज्ञानेश्वर महाराज व संत तुकाराम महाराज पालखी सोहळ्यासोबत वारी मार्गावर सावित्रीबाई फुले पुणे विद्यापीठ, राष्ट्रीय सेवा योजना विभागाच्यावतीने विविध उपक्रमांचे आयोजन करण्यात आलेले आहे. सदर उपक्रमांचे पुणे जिल्हा शिक्षण मंडळाचे, अभियांत्रिकी महाविद्यालय, मांजरी बु. यांचेकडील राष्ट्रीय सेवा योजनेचे स्वयंसेवक सहभागी झाले होते. याबाबतचा सविस्तर खालीलप्रमाणे

अ.क्रं.	उपक्रमांचे नाव	दिनांक	ठिकाण	सहभागी विद्यार्थी संख्या	सहभागी कार्यक्रम अधिकारी
०१	वृक्ष लागवड	२७.०६.२०१९	महाविद्यालय परिसर	३७	०२
०२	वारक-यांसाठी पत्रावळी वाटप	२७.०६.२०१९	पुणे सोलापुर महामार्ग	३७	०२
०३	वारक-यांसाठी कापडी पिशव्यांचे वाटप	२८.०६.२०१९	हडपसर गाडीतळ	३७	०२
०४	वारी मार्गावर स्वच्छता	२८.०६.२०१९	हडपसर गाडीतळ	३७	०२

कळावे

आपला विश्वासू

प्रा.के.वी.इंगवे
कार्यक्रम अधिकारी
राष्ट्रीय सेवा योजना
पुणे जिल्हा शिक्षण मंडळाचे
अभियांत्रिक महाविद्यालय, मांजरी बु.
पुणे - ४१२ ३०७

डॉ.आर.जी.पाटील
प्राचार्य
पुणे जिल्हा शिक्षण मंडळाचे
अभियांत्रिकी महाविद्यालय
मांजरी (बु.), पुणे - ४१२३०७.

Received
4/7/19
Dr. Savita Kulkarni
Programme officer
A.M. college
as organising
college

Criteria 3

Criteria 3.4.1:

Name of Event: Sinhgad Fort Cleaning

Name of Event President: Dr. R.V.Patil, Principal, PDEA's COE, Pune

Name of Coordinator: Prof.K.B.Dumbre

Participants: Teaching, Non-Teaching Staff and Students

Date: 23/02/2020

Event Report

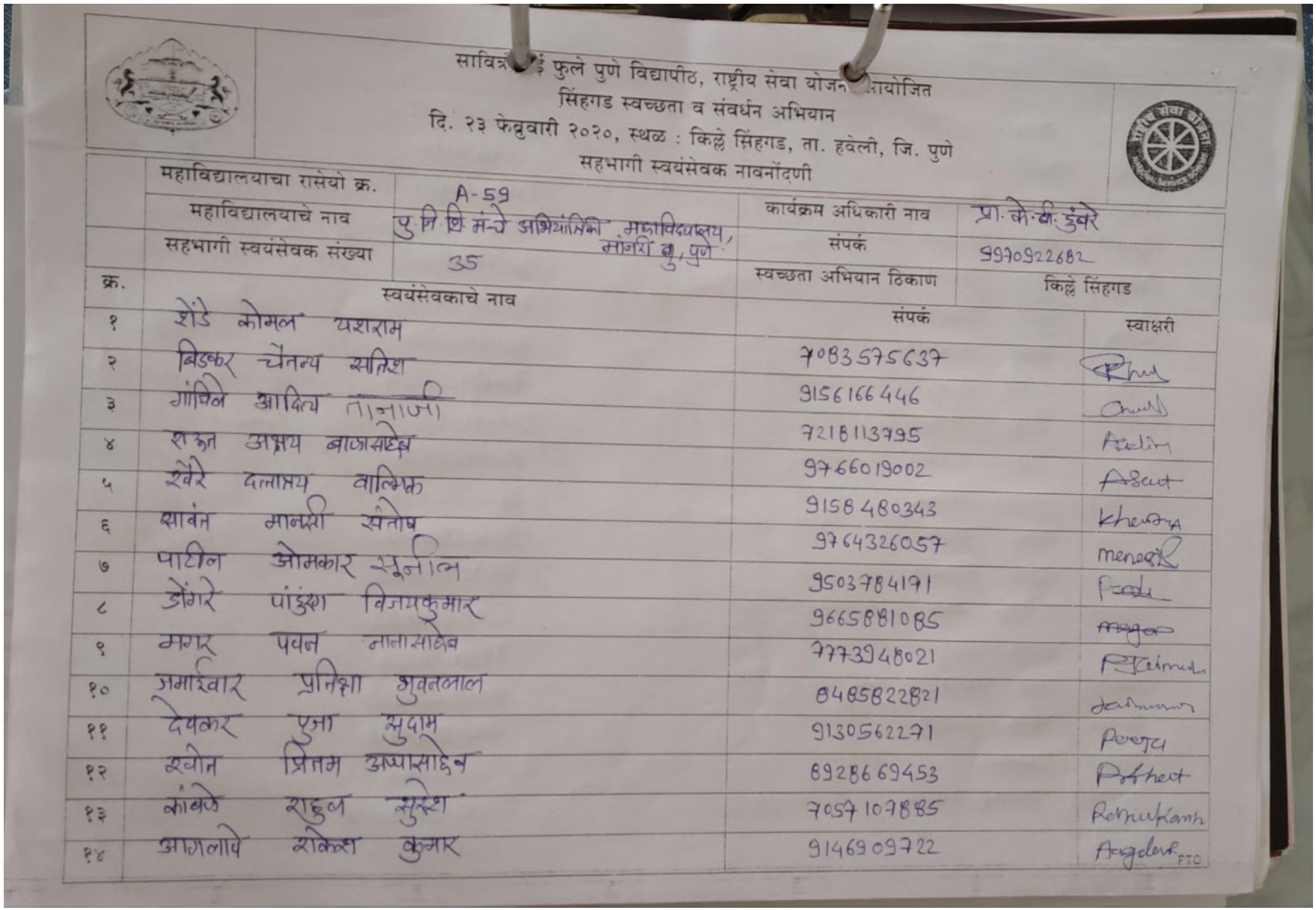
The Sinhgad fort cleaning programme has been organized by NSS Department; Savitribai Phule Pune University. Our NSS volunteers accepted the appeal of Savitribai Phule Pune University Vice Chancellor Dr.Nitin Karmalkar and participated Sinhgad fort cleaning programme at Sinhgad Fort, Pune. The 'Swachha Bharat Abhiyan' is a massive mass movement that seeks to create a Clean India. The magnificent forts around Maharashtra have been a matter of pride for the state for centuries. Under Sinhgad Fort Cleaning Abhiyan the NSS volunteers cleaned all the fort area and collected the garbage at one location. The collected garbage was handed over to the corporation garbage vehicle. All students gave overwhelming response to this activity.

Dumbre

Prof.K.B.Dumbre
Coordinator, NSS
Cell, PDEA's COE,
Pune -412307

Criteria 3

Criteria 3.4.1:



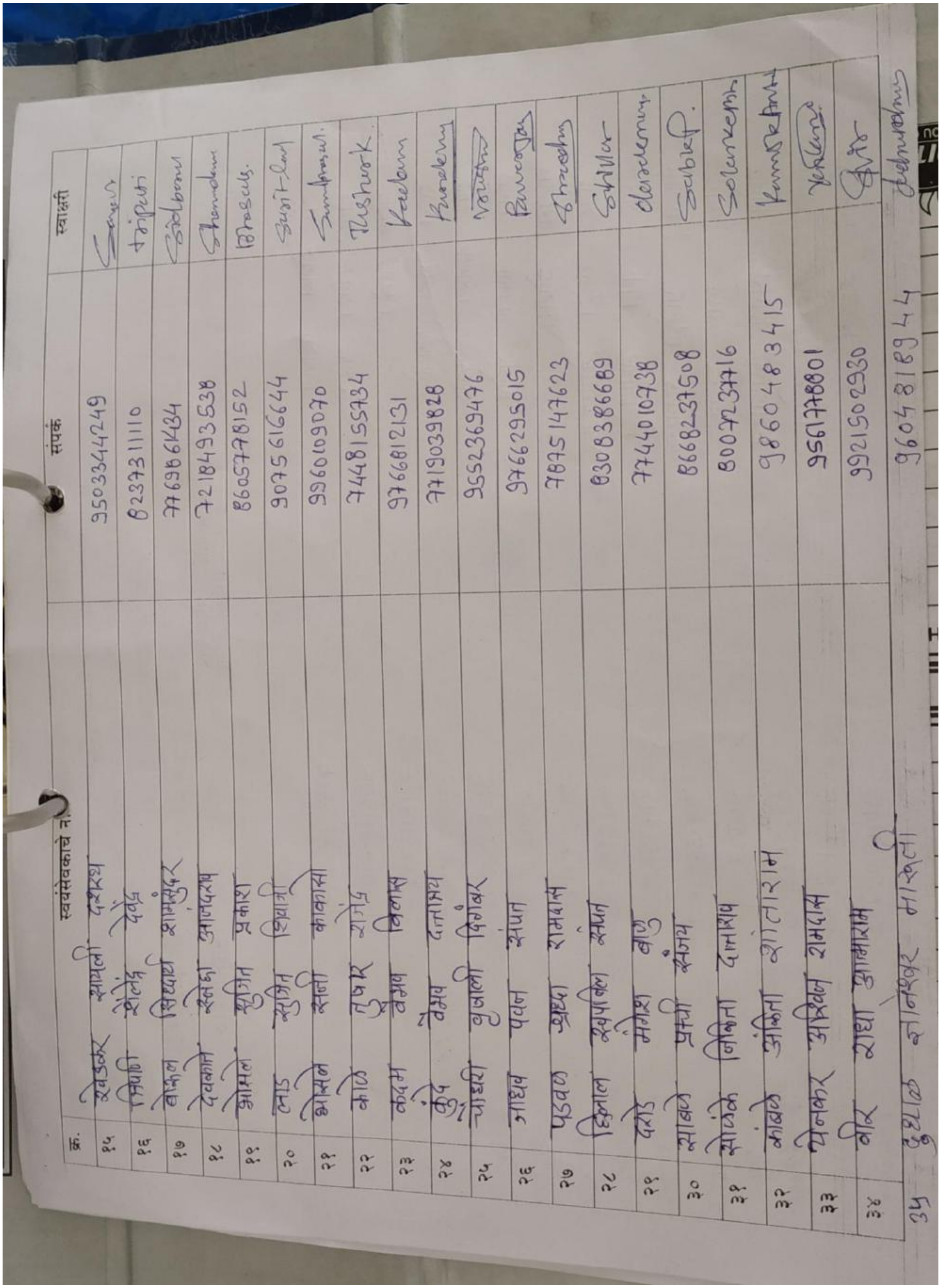
सावित्रीबाई फुले पुणे विद्यापीठ, राष्ट्रीय सेवा योजना आयोजित
सिंहगड स्वच्छता व संवर्धन अभियान
दि. २३ फेब्रुवारी २०२०, स्थळ : किल्ले सिंहगड, ता. हवेली, जि. पुणे
सहभागी स्वयंसेवक नावनोंदणी

महाविद्यालयाचा रासेयो क्र.	A-59	कार्यक्रम अधिकारी नाव	प्रा. के. वी. डुंबरे
महाविद्यालयाचे नाव	पु. ल. दे. मंचे अभियांत्रिकी महाविद्यालय, मांजरी बु, पुणे	संपर्क	9970922682
सहभागी स्वयंसेवक संख्या	35	स्वच्छता अभियान ठिकाण	किल्ले सिंहगड

क्र.	स्वयंसेवकाचे नाव	संपर्क	स्वाक्षरी
१	शेंडे कोमल यशराम	7083575637	
२	बिडकर चैतन्य सतिश	9156166446	
३	गांधिले आदित्य तानाजी	7218113795	
४	शेख अक्षय बाजासाहेब	9766019002	
५	खैरे दत्तात्रय वाल्मिक	9158480343	
६	सावंत मानसी संतोष	9764326057	
७	पाटील ओमकार सुनील	9503784171	
८	डोंगरे पांडुरंग विजयकुमार	9665881085	
९	मगर पवन नानासाहेब	7773948021	
१०	जमाईवार प्रतिक्षा गुवनलाल	8485822821	
११	देवकर एजा सुदाम	9130562271	
१२	खोत प्रितम अप्पासाहेब	8928669453	
१३	कांबळे राहुल सुरेश	7057107885	
१४	आगलावे रोकेश कुमार	9146909722	

Criteria 3

Criteria 3.4.1:



क्र.	स्वयंसेवकाचे नाव	संपर्क	स्वाक्षरी
१५	खेडकर सायली दशरथ	9503344249	Sayali
१६	त्रिपाठी शैलेंद्र देवेंद्र	8237311110	Tripati
१७	बोकल सिध्दार्थ शामसुंदर	7769866434	Siddharth
१८	देवकाते स्नेहा आनंदराव	7218493538	Snehadevkate
१९	भोसले सुजित प्रकाश	8605778152	Bhosale
२०	लाड सुजित शिवाजी	9075616644	Sujit lad
२१	भोसले सनी काकासो	9960109070	Sunibhosale
२२	काळे तुषार राजेंद्र	7448155734	Tushark
२३	कदम वैभव विलास	9766812131	Kadam
२४	कुंदे वैभव दत्तात्रय	7719039828	Kundeeny
२५	चौधरी वृजाली दिगंबर	9552369476	[illegible]
२६	जाधव पवन संपत	9766295015	Pawanjadhav
२७	पडवळ श्रध्दा रामदास	7875147623	Shraddha
२८	हिलाल स्वपनिल संपत	8308386689	Shilal
२९	दराडे मंगेश बापु	7744010738	darademan
३०	साबळे प्राची संजय	8668237508	Sable P.
३१	सोळंके निकिता दत्तात्रय	8007237716	Solankenik
३२	कांबळे अंकिता शांताराम	9860483415	KambleAnkita
३३	येनकर अखिल रामदास	9561778801	Yenkar
३४	वीर राधा आत्माराम	9921502930	[illegible]
३५	दुधाळ ज्ञानेश्वर मारुती	9604818944	dudhaldnyan