RESEARCHERID
THOMSON REUTERS

[ICAME-2018]
ISSN 2348 – 8034
Impact Factor- 5.070

# GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

# OPTIMIZATION OF PROCESS PARAMETERS OF AN ENGINE RADIATOR USING TAGUCHI METHOD

**K.P.V. Krishna Varma*[1], N. Chakravarthi[2] & M. Raj Kumar Nayak[3]**
[*1]Assistant Professor, CMR College of Engineering & Technology, Telangana, India
[2]Assistant Professor, M.N.R. College of Engineering and Technology, Telangana, India
[3]Research Graduate student, University of Western Ontario, London, Canada

## ABSTRACT

In the present work an attempt is made to optimize the heat transfer parameters of an engine radiator which has water-based Aluminum oxide nanofluid and air as coolants using MiniTab17.0. Taguchi method is adopted to optimize the heat transfer parameters like the outlet nanofluid temperature and outlet air temperature. The input parameters considered are the % concentration of the nanofluid, air velocity at the inlet of the radiator, Engine speed. Regression equations are developed for the responses like the outlet nanofluid temperature, outlet air velocity. S/N ratios, Main effects plots are developed, contours for the responses have been generated, significant contribution of the parameter for optimization is found. Contours for normal probability, histogram have been done. Annova is used to arrive at the significant contribution of parameters of heat transfer.

***Keywords:*** *Taguchi method, S/N ratio, mean, regression equation, normal probability, significant contribution.*

## I. INTRODUCTION

Around 30-35% of the total heat from the internal combustion engines is being removed by the cooling system. Most of the internal combustion engines uses either air or liquid run through a heat exchanger (Radiator) cooled by air. One key requirement is to serve the entire engine as the whole engine fails if just one part overheats. Therefore, it is necessary for the cooling system keep all parts at suitably low temperatures. Radiators are widely used to cool the components of internal combustion engines. Not only in automobiles but also in piston-engine aircraft, railway locomotives, motorcycles, stationary generating plants and other places where such engines are used. Heat is absorbed from the engine block as the coolant passes from the radiator to the engine by forced circulation. The hot coolant controlled by thermostat is then fed into the inlet tank of the radiator located on the top of the radiator, or along one side. The coolant is circulated across the tubes where it gets cooled by convection. Fins are provided on the periphery of the tubes to increase the heat transfer. Ethylene glycol is added in order to prevent the water to freeze in cold areas and avoid corrosion. Fins increase the area of contact and thus enhance the heat transfer rate. Normally, the radiator does not reduce the temperature of the coolant back to ambient air temperature, but it is still sufficiently cooled to keep the engine from overheating. The coolant which is now cooled will be sent back to the engine to remove further heat.

This coolant is usually water-based, with the addition of glycols to prevent freezing and other additives to limit corrosion, erosion and cavitation. However, the coolant may also be an oil. Early engines used thermo-siphons to circulate the coolant; today, however, all but the smallest engines use pumps. With the advent of Nano fluids, which are colloidal suspensions of Nano-sized particles suspended in base fluids like water etc., there is a possibility for the improvement of the radiator performance. In the present work CFD is used to simulate the effect of Aluminum oxide Nano fluid on the performance of a car radiator. Many Researchers carried out their work to improve the performance of the Radiator. Some of them have been mention below:

V. Niveditha et.al. [1] Analyzed the performance of a radiator with Aluminum oxide, silicon oxide, ethylene glycol and copper oxide. They found that copper oxide Nano fluid provided better performance properties for the improvement of radiator performance.

Toure Ismael et.al [2] studied heat dissipation performance of about five different geometry of radiators by varying the fin pitch wave distance, simulated them and then compared with that of the experimental results. The results showed that as the fin phase is increased, the better performance will be achieved.

JP Yadav et.al [3] presented a set of numerical parametric studies on automotive radiator using finite difference method and thermal resistance method. They compared the performance of radiator for different mass flow rates and two different coolants, one of which is water and other one propylene glycol –water mixture (40-60). From the results it is found that the performance increases when the coolant is changed from water to mixture it is concluded that water is the best coolant despite its corrosive nature.

Aditya Choure[4] carried out experimental investigation for the improvement of performance of automotive radiator using water and ethylene -based Aluminum oxide Nano fluid. It is found that Nano fluids perform better than conventional fluids like water, ethylene glycol etc**.**

P. Suganya et.al [5] carried out experimental investigation on radiators using water and copper oxide Nano fluids as cooling medium. The results indicated that copper oxide Nano fluid offers more thermal conductivity and convective properties than compared to that of water. There is an improvement in performance of the Radiator by 45% for copper oxide Nano fluid when compared to that of the water.

P. Sai Sasank et.al.[6] tested an automotive Radiator with water and Aluminum oxide Nano fluid at low volume concentrations of 0.025%,0.5%,0.1%.Heat transfer enhancement from the obtained results is found to be augmented when the concentration of the Nano particles is increased.

Tushargaidhane et.al[7] hybrid Nano fluid at concentrations of 0.5%,1% and 1.5% as a coolant in the automobile radiator and compared the heat transfer by hybrid Nano fluid with that of the conventional coolants like water and green coolant experimentally. The experimental results are compared with that of the CFD values. It is found that there is an enhancement in heat transfer coefficient up to 41% for hybrid Nano fluid (Cuo+$Fe_2O_3$).

J.R. Patel et.al. [8] Presented CFD simulation of a Maruthi van Radiator using commercial software CCM+. Analysis is carried out for water +ethylene glycol solution, CUO/water and TI/water Nano fluids. Comparative Analysis is carried out between these and from the results, it showed that CUO/water Nano fluid provides optimum results for the air temperatures**.**

Paresh Machhar et.al**.**[9] carried out experimental investigation for the enhancement of forced convective heat transfer in anAutomobile radiator using TiO2 Nano fluids and water as the cooling medium with concentrations of 0.1-1%. Test section consisted of 34 tubes of elliptical cross section. The effect of inlet temperature to the radiator on heat transfer is also analyzed. Increasing the fluid rate increased the heat transfer. The Nano fluid increased the rate of heat transfer by an amount of 45%.

P. Gopal et.al. [10] carried out experiments with water -based copper oxide nanofluids and found out that the convective heat transfer and pressure drop increases.

K.P. VasudevanNambeesan et.al [11] carried out experimental analysis of $Al_2O_3$- ethylene glycol nanofluids for enhancement of heat transfer in a radiator. The results showed a decrease in UA. The results showed a decrease of the radiator performance with the addition of EG and increase with the addition of EG and nanoparticles.

M. Gajendiran et.al [12] conducted experiments on radiator with $Al_2O_3$nanofluid and transformer oil and found that the performance of the radiator is more with the nanofluid compared to transformer oil.

John Babu Male et.al[13] tried to improve the performance of the radiator using louverd fins. CFD analysis is carried out to analyze the rate of heat transfer. It is found that the radiator fitted with louvered tapes provide more heat transfer than the one without them.

ThirumalaVenkateswar Reddy K et.al [14]carried out his experiments with a radiator fitted with louvered fins and considered the material as Aluminium 6061 for the fins. The thermal flux is found to be increased for the radiator fitted with louvered fins.

S.Krishna, et.al. [15] carried out CFD analysis of a radiator with $Al_2O_3$ and $TiO_2$nanofluids with different concentrations and copper and aluminum as fin materials. The fins considered are louvered fins. It is found that $Al_2O_3$Provides better heat transfer compared to $TiO_2$.

Monika R. Kohale et.al. [16]carried out experimental investigation on $Al_2O_3$with different concentrations. The result show that nano particle concentration play a major role in the enhancement of heat transfer.

M. Sabeel Khan et.al [17] carried out experimental investigations on $Al_2O_3$, $TiO_2$and CUO nano particles and found that CUO nano particles provide better heat transfer than the other nanofluids. The rate of heat transfer increases with increase in the nano particle concentration.

NavidBozorgan, [18] carried out experimental investigations on an automotive radiator using CUO nanofluids.The results showed that the heat transfer coefficient and pumping power are more for CUO nanofluid when compared to base fluid.

## II. DOE ANALYSIS FOR NANO FLUID TEMPERATUREANDAIRTEMPERATURE

In general, the experimental analysis becomes difficult with the increase in process parameters increase. Moreover, the process parameters when there are controllable factors and the uncontrollable factors in the process, Taguchi method is used to study the behavior of the process with least number of experiments. S/N ratio, statistical Analysis of variance can be employed to indicate the significance of each parameter on the performance of the radiator. The steps adopted in this study are: select noise and control factors, Select Taguchi Orthogonal Array, analyze results and predict optimum performance. Table.1. shows the different parameters considered and their levels as used for the design of experiments. Table2. Shows the L9 Taguchi orthogonal Array

***Table1 Parameters for Design of Analysis***

| S.No | Parameters | Level 1 | Level2 | Level 3 |
|---|---|---|---|---|
| 1 | Speed | 1000 | 1300 | 1500 |
| 2 | %Conc NF | 0.2 | 0.4 | 0.6 |
| 3 | Air velocity | 3 | 6 | 9 |

***Table2 Taguchi L9 Orthogonal Array***

| *EXP No* | *A* | *B* | *C* |
|---|---|---|---|
| *1* | *1000* | *0.2* | *3* |
| *2* | *1000* | *0.4* | *6* |
| *3* | *1000* | *0.6* | *9* |
| *4* | *1300* | *0.2* | *6* |
| *5* | *1300* | *0.4* | *9* |
| *6* | *1300* | *0.6* | *3* |
| *7* | *1500* | *0.2* | *9* |
| *8* | *1500* | *0.4* | *3* |
| *9* | *1500* | *0.6* | *6* |

After performing the DOE using the L9 orthogonal Array, the responses/results are tabulated as shown in the Table3

ISSN 2348 – 8034
Impact Factor- 5.070

## III. RESULTS AND DISCUSSION

**Effect of parameters on nano fluid temperature**

The Taguchi method stresses the importance of the analysis of response variables using signal to noise ratio i.e., S/N ratio resulting in minimization of quality characteristics. To enhance the performance of the radiator, it is needed to have nano fluid temperature on lower side, so with the concept of "Smaller is the better" as quality characteristics for Nanofluid temperature is considered. From main effect plot and S/N graph as shown in the Fig.1 (a) and (b) It is observed that the nano fluid temperature decreases with the increase in air velocity and minimum at level one and three.

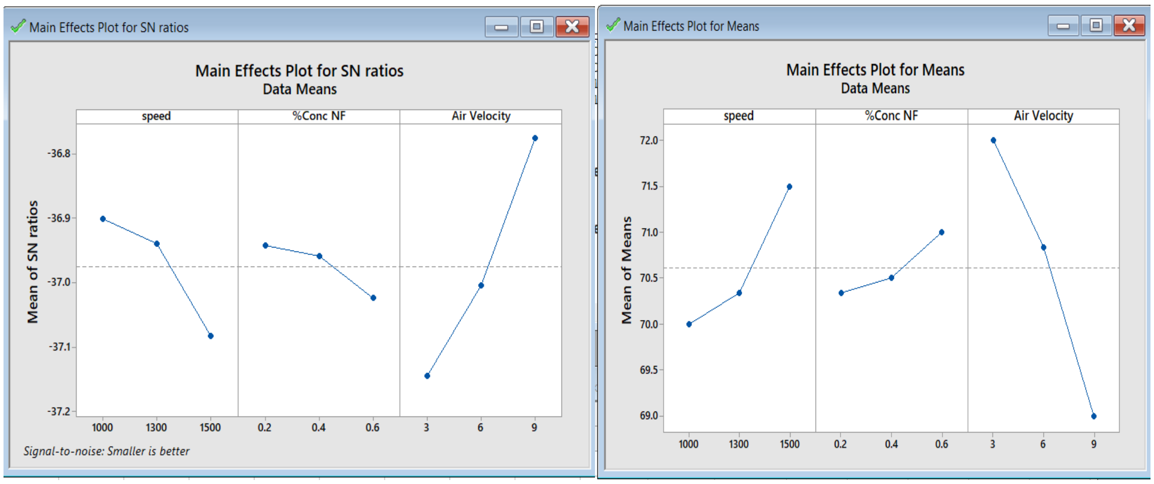


*Fig.1. (a) Mean of S/N ratios for NFT 1 (b) Mean of means for NFT*

It is also observed that the nanofluid temperature decrease with increase in nano fluid concentration and engine speed. It is also observed from S/N graph that for optimum nano fluid temperature, the speed should be 1500 Rpm, %concentration of NF should be 0.6% and Air velocity should be 3m/s. Therefore, A3 B3 C1 is defined as the optimum condition for parameters related to the nano fluid temperature.

***Table 3 Parameters and their responses***

| *Parameters and Levels* | | | *Res* | *N FT S/N Ratio* | *Means* | *Air Temperature Res Means* | | *S/N Ratio* |
|---|---|---|---|---|---|---|---|---|
| *1000* | *0.2* | *3* | 70.5 | 36.96 | 70.5 | 44.6 | 32.98 | 44.6 |
| *1000* | *0.4* | *6* | 70.0 | 36.90 | 70.0 | 46.0 | 33.25 | 46.0 |
| *1000* | *0.6* | *9* | 69.5 | 36.83 | 69.5 | 48.3 | 33.67 | 48.3 |
| *1300* | *0.2* | *6* | 71.0 | 37.02 | 71.0 | 48.4 | 33.69 | 48.4 |
| *1300* | *0.4* | *9* | 68.0 | 36.65 | 68.0 | 48.8 | 33.76 | 48.8 |
| *1300* | *0.6* | *3* | 72.0 | 37.14 | 72.0 | 47.4 | 33.51 | 47.4 |
| *1500* | *0.2* | *9* | 69.5 | 36.83 | 69.5 | 48.9 | 33.78 | 48.9 |
| *1500* | *0.4* | *3* | 73.5 | 37.32 | 73.5 | 47.9 | 33.60 | 47.9 |
| *1500* | *0.6* | *6* | 71.5 | 37.08 | 71.5 | 49.4 | 33.87 | 49.4 |

ISSN 2348 – 8034
Impact Factor- 5.070

**Contour plots for nano fluid temperature**

Contour plots are used to express the three -dimensional relationship in two dimensions with x and y factors(predictors) plotted on the x- & y-scales & response values represented by contours.

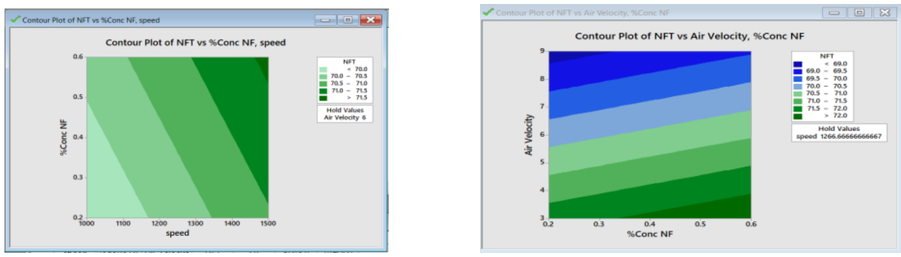


*Fig.2(a)NFT vs % conc. NF, speed (b) NFT vs Air velocity, %conc NF*

Fig.2(a) & (b) show the contour plot of the Nanofluid temperature vs %conc NF, speed and Nanofluid Temperature vs Air velocity, %conc NF. Fig.3(a) & (b) show the Normal probability plot and histogram for Nano fluid Temperature. Blue colour shows the low value and the green colour in the contour shows the higher value.

*Table 4: Response Table for Signal to Noise Ratios for NFT (smaller is better)*

| Level | Speed | % conc NF | Air velocity |
|---|---|---|---|
| 1 | 36.90 | 36.94 | 37.15 |
| 2 | 36.94 | 36.96 | 37.00 |
| 3 | 37.08 | 37.02 | 36.78 |
| Delta | 0.18 | 0.08 | 0.37 |
| Rank | 2 | 3 | 1 |

*Table.5. Response Table for means for NFT*

| Level | Speed | % conc NF | Air velocitiy |
|---|---|---|---|
| 1 | 70.00 | 70.33 | 72.00 |
| 2 | 70.33 | 70.50 | 70.83 |
| 3 | 71.50 | 71.00 | 69.00 |
| Delta | 1.5 | 0.67 | 3.00 |
| Rank | 2 | 3 | 1 |

**Analysis of variance for nanofluid temperature**

Analysis of Variance (ANOVA) is done to find out significant process parameter at 95% confidence level, p-value for this factor is less than 0.05. The ANOVA table 6 shows that the engine speed is the most significant parameter which contributes to 47.98%. Next significant process parameter is Air Velocity which contributes up to 33.52%. The last one is the % concentration of nano fluid which contributes to 17.64%.

**Regression Equation**

**Regression Equation for Nano fluid temperature**

NFT = 69.33 + 0.00285 speed + 1.67 %Conc NF - 0.500 Air Velocity

ISSN 2348 – 8034
Impact Factor- 5.070

**Effect of Parameters on Air Temperature**

As per the expectation that the air temperature should be higher, so the criteria of selection for the Air temperature would be "Larger is the better for this study. From the Fig 4(a) and (b) Mean of S/N ratios and Mean of Means plots it is observed that the air temperature increases with the increase in speed and Air velocity. It is also observed that the air temperature also increases with increase in concentration of the nano fluid. But not as much compared to the speed and air velocity. Here the optimum condition for the maximization of the Air Temperature is A3B3C3.

***Table.6. General Liner Model Table for Nano fluid Temperature***

| Level | Speed | %conc NF | Air velocity |
|---|---|---|---|
| 1 | 33.31 | 33.41 | 33.37 |
| 2 | 33.58 | 33.54 | 33.53 |
| 3 | 33.76 | 33.69 | 33.74 |
| Delta | 0.45 | 0.28 | 0.37 |
| Rank | 1 | 3 | 2 |

***Table.7. Response Table for Signal to Noise Ratios Larger is better***

| Source | DF | Seq SS | Cont | Adj SS | Adj MS | F-value | P-value |
|---|---|---|---|---|---|---|---|
| Speed | 2 | 8.63 | 47.98 | 8.63 | 4.31 | 55.53 | 0.018 |
| %conc NF | 2 | 3.15 | 17.64 | 3.17 | 1.58 | 20.42 | 0.047 |
| Air velocity | 2 | 6.03 | 33.52 | 6.03 | 3.01 | 38.8 | 0.025 |

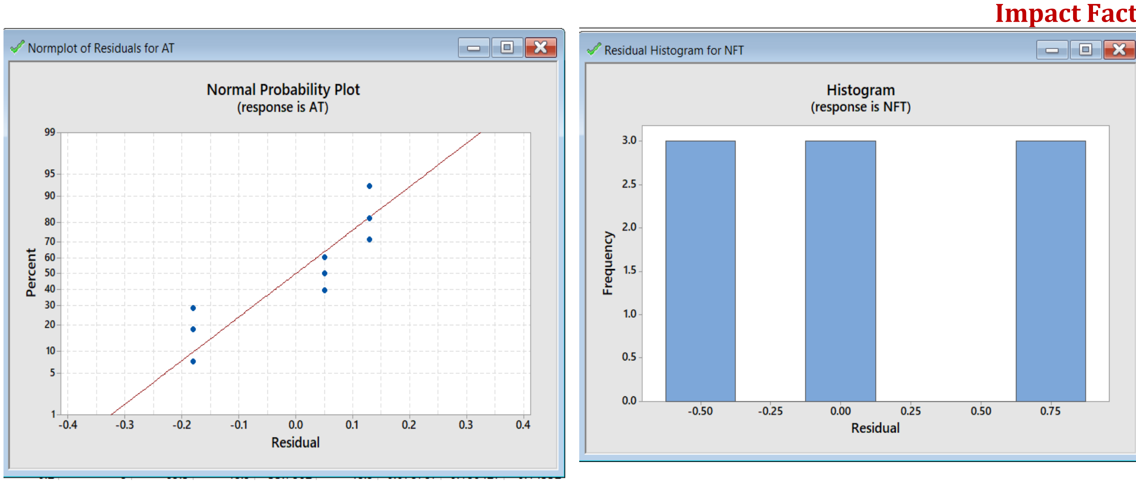


***Fig. 4(a) Mean of Signal to Noise Ratios for AT (b) Mean of Means for AT***

***Table.8: Response Table for Means***

| Level | Speed | %conc NF | Air velocity |
|---|---|---|---|
| 1 | 46.3 | 46.87 | 46.63 |
| 2 | 47.77 | 47.57 | 47.50 |
| 3 | 48.73 | 48.37 | 48.67 |
| Delta | 2.43 | 1.5 | 2.03 |
| Rank | 1 | 3 | 2 |

From the tables of Response for Signal to Noise Ratios and Response to Means for Air Temperature Table 6 and Table 7 it is found that the Engine Speed plays a major role for the maximization of the Air temperature then the Air Velocity plays the key role and then % concentration of the Nanofluid.

**Contour Plots for Air Temperature**

The following Fig(a) and (b) show the *Contour plot of AT vs %conc NF, speed and Contour plot of AT vs %conc NF, speed respectively. The blue colour regions show the low values of the Air Temperature and the green colour region shows the higher value of the Air Temperature. Table.3 shows the response table for the signal to noise ratio and Table.4 shows the response table for mean of means. From Table 3 and 4 it is found that the engine speed has a greater effect and it is the significant parameter for higher Air Temperature where Air velocity is the next one. Nanofluid concentration is having the least contribution.*

ISSN 2348 – 8034
Impact Factor- 5.070

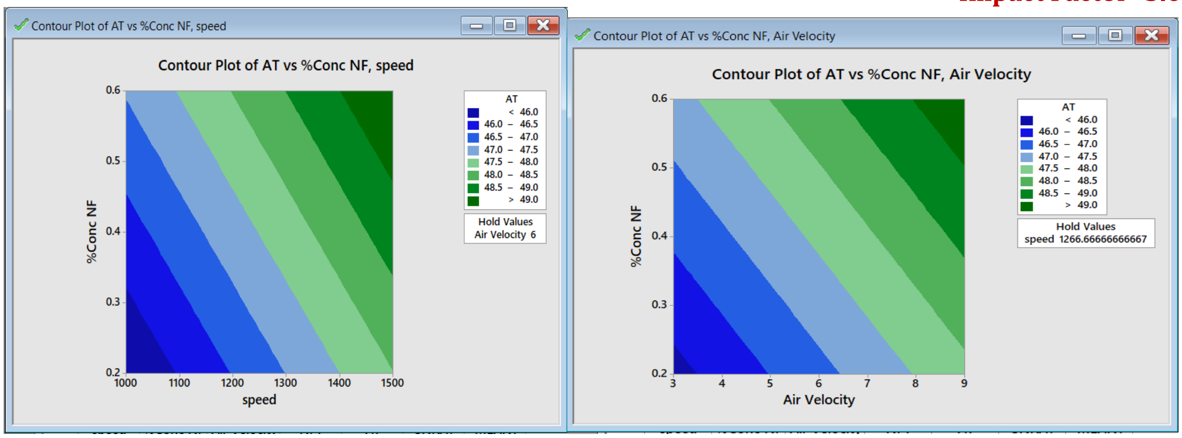


*Fig.5 (a) Contour plot of AT vs %conc NF, speed (b) contour plot of AT vs %conc NF, Air velocity*

**Normal Probability and Histogram Plots**

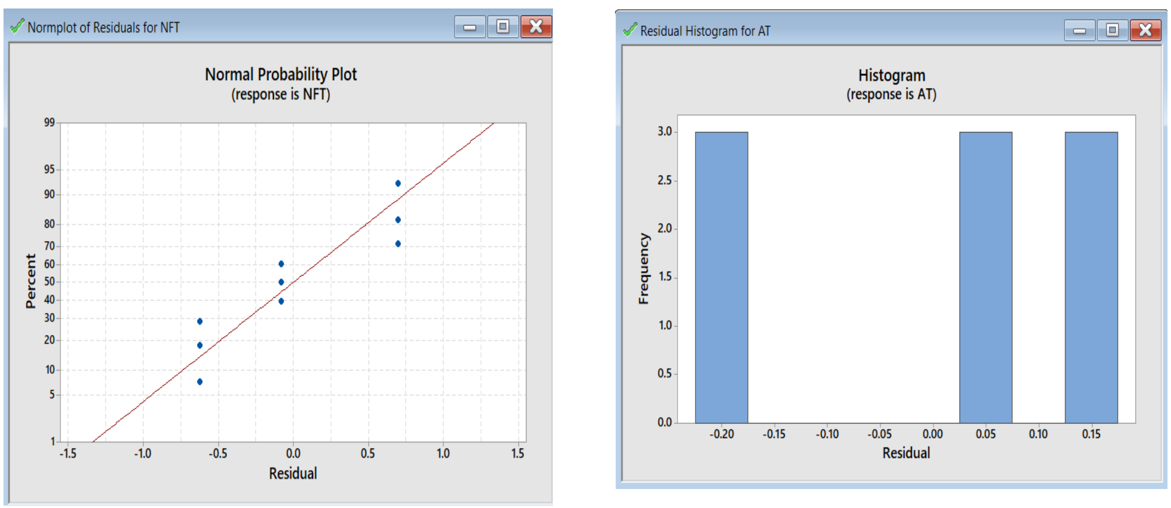


*Fig.6 (a) Normal probability plot for AT (b) Histogram plot for AT*

*Table.8. Work sheet for the Taguchi method*

| ↓ | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| | speed | %Conc NF | Air Velocity | NFT | AT | SNRA1 | MEAN1 |
| 3 | 1000 | 0.6 | 9 | 69.5 | 48.3 | 33.6789 | 48.3 |
| 4 | 1300 | 0.2 | 6 | 71.0 | 47.1 | 33.4604 | 47.1 |
| 5 | 1300 | 0.4 | 9 | 68.0 | 48.8 | 33.7684 | 48.8 |
| 6 | 1300 | 0.6 | 3 | 72.0 | 47.4 | 33.5156 | 47.4 |
| 7 | 1500 | 0.2 | 9 | 69.5 | 48.9 | 33.7862 | 48.9 |
| 8 | 1500 | 0.4 | 3 | 73.5 | 47.9 | 33.6067 | 47.9 |
| 9 | 1500 | 0.6 | 6 | 71.5 | 49.4 | 33.8745 | 49.4 |

**Analysis of variance for air temperature**

Table 8 shows the significance of the contribution of the various parameters on the response Air Temperature. The table shows that the contribution of the parameter Air velocity has got the maximum significance. The contribution of the parameter Air velocity is around 66.82%. Then the other parameter which is contributes to greater extent is the Engine speed. The least contribution is by the % concentration of the Nanofluid.

***Table.8. General Linear model Table for Air Temperature***

| **Source** | **DF** | **Seq ss** | **Cont** | **Adj SS** | **Adj MS** | **F-value** | **P-value** |
|---|---|---|---|---|---|---|---|
| **Speed** | **2** | **3.43** | **16.6** | **3.43** | **1.71** | **1.3** | **0.435** |
| **%conc NF** | **2** | **0.78** | **3.79** | **0.78** | **0.39** | **0.3** | **0.771** |
| **Air velocity** | **2** | **13.82** | **66.82** | **13.82** | **6.91** | **5.23** | **0.161** |

**Regression Equation for Air Temperature**

AT = 37.900 + 0.004868 speed + 3.750 %Conc NF + 0.3389 Air Velocity

Table.9. Analysis of Variance for Air Temperature

## IV. CONCLUSIONS

In this analysis the optimal performance parameters are designed to have maximum Air temperature and minimum Nanofluid temperature by Taguchi method. The parameters considered are Engine speed, % Concentration of Nanofluid and Inlet Air velocity. The results obtained from the present study are discussed as shown below:

For optimization of Nanofluid temperature the most effective parameter is the Air velocity. Other parameters that contributed are engine speed and the %concentration of Nanofluid. Their contributions are 47.98% and 33.52% respectively. It is observed that for the minimization of the Nanofluid temperature, only two factors that are to be controlled are Air velocity and engine speed. Optimum combination found is ***A3 B3 C1***. Optimum values are Air velocity 3m/s, Engine speed 1500 RPM and % concentration of Nanofluid as 0.6%.

Similarly, for maximization of outlet Air Temperature the most effective parameter is Engine speed. Other parameters which contribute to this response are Air velocity and % concentration of Nanofluid. The contribution of these parameters is Air velocity 66.82% Engine speed 16.6% and %concentration of Nanofluid 3.79%. Optimum combination found for this response is **A3B3C3.** Optimum values for the above said parameters are Air velocity 9m/s, Engine speed 1500RPM, %concentration of Nanofluid 0.6.

## REFERENCES

1. *V.Niveditha, Dr. S. Sunil Kumar Reddy Thermal Analysis of Radiator with Different Nano Fluids,International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 4 Issue IX, September 2016, ISSN: 2321-9653, Pg. Nos: 143-148*
2. *Toure Ismael, Sheng Bu Yun, FayzimatovUlugbek Radiator Heat Dissipation Performance, Journal of Electronics Cooling and Thermal Control, 2016, 6, Pg. Nos: 88-96*

3. *JP Yadav, Bharat Raj Singh Study on Performance Evaluation of Automotive Radiator, S-JPSET, ISSN: 2229-7111, Vol. 2, Issue 2, June 2015 DOI:10.18090/samriddhi. V2i2.1604,Pg Nos 47-56.*
4. *Choure, RavibalaPatil, KishoreDolare Performance investigation of automobile radiator using al2o3 as base Nano fluid, Aditya, Proceedings of 23rd IRF International Conference, 1st May2016, Bengaluru, India, ISBN: 978-93-86083-05-0 Pg. Nos: 53-56.*
5. *P.Suganya, G.Subburaj, S.Raghupathi, T.Ajith, K.Vinothkambly,Advance Cooling Of Radiators by Using Copper-Oxide Nano fluids, International conferences on Explorations and Innovations in Engineering and Technology, ISSN:2349-9362.Pg Nos: 43-48.*
6. *P. Sai Sasank, V. GovindaNaik Experimental Studies on Automotive Radiator Performance using Water and Al2O3 Nano fluid, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181,Vol. 3 Issue 9, September- 2014, Pg Nos 1347-1350.*
7. *TusharGaidhane, Sameer Bhosale CFD analysis and experimental investigation of percentage heat transfer enhancement of cfhx with hybrid Nano fluid as a coolant, , International Journal of Mechanical and Production Engineering, ISSN: 2320-2092, Volume- 4, Issue-9, Sep.-2016 Pg Nos: 1-5*
8. *Effect of Nano fluids and mass flow rate of air on heat transfer rate in automobile radiator by cfd analysis, J.R. Patel, A.M. Mavani, IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.*
9. *Heat Transfer Enhancement of Automobile Radiator with TiO2/Water Nano fluid PareshMachhar, FalgunAdroja, International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 5, May – 2013*
10. *Experimental Investigation on Heat Transfer Enhancement in Automotive Radiator Using Copper Nano Particles in Engine Coolant*
11. *K.P. VasudevanNambeesan, R. Parthiban, K. Ram Kumar, U.R. Athul,M. Vivek * and S. Thirumalini, Experimental study of heat transfer enhancement in automobile radiator using Al2O3/water–ethylene glycol nanofluid coolants, International Journal of Automotive and Mechanical Engineering (IJAME), ISSN: 2229-8649, Volume 12, pp. 2857-2865, July-December 2015, Pg No 2857 to 2865.*
12. *M. Gajendiran1, E. Saravanakumar1, N. Madhan Raj and N. Nallusamy, Heat transfer enhancement of thermic fluid by using nanofluids in radiator, ISSN: 0975-7384, Pg.No 686-692*
13. *John Babu Male, S.Rajasekhar, A.V. Sridhar, Performance Improvement of an Automobile Radiator Using CFD Analysis, International Journal a& Magazine Engineering, Technology management and Research, Volume 2, Issue12,Pg No1811-1820*
14. *ThirumalaVenkateswarReddy K., K. Sandhya Rani, Performance Improvement of an Automobile Radiator using CFD Analysis, International Journal of Advanced Technology and Innovative Research, ISSN 2348–2370 Vol.08,Issue.01, January-2016, Pages:0131-0134*
15. *S.KrishnaPrasad,N.Raghunadham, Enhancement of Heat Transfer in Automobile Radiator Using Nano Fluids through CFD Analysis, International Journal a& Magazine Engineering, Technology management and Research, Volume3, Issue 11, Pg No 556-562*
16. *Monika R. Kohale, Al2O3 a Nanofluid in Radiator to Increase Cooling Performance Based on Water, International Journal for Research in Applied Science & Engineering Technology, Volume 4 Issue VII, July 2016Pg No 430-435*
17. *M. Sabeel Khan, Heat transfer enhancement of automobile radiator using H2O–CuOnanofluid, AIP Advances 7, 045018 (2017)*
18. *NavidBozorgan, Numerical Study on Application of CuO-Water Nanofluid in Automotive Diesel Engine Radiator, Modern Mechanical Engineering, 2012, 2, 130-136.*