# Study & optimization of Noise level & Cost for DG set Enclosures Using Taguchi Method

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**Abstract: Diesel engine generator (DG) sets used in industrial plants and residential/official buildings. It is observed that diesel generator sets are noisy and cause health hazards such as permanent hearing loss, physiological traumas, stress etc. In order to avoid health risks, Central Pollution control Board (CPCB) the maximum permissible sound pressure level for new DG set should be less than 75dB(A) at a one meter from enclosure surface. Taguchi technique has been used to determine the most important control variables that will result in lower noise level of DG set of comparable CRCA steel material. To optimize process parameters including foam density, Rockwool density and on noise level, Taguchi Design of Experiment (DOE) and optimization method was used. The optimum levels of process parameters were identified by using the Taguchi parametric design concept. The results show that Rockwool density is more contributing process parameter than the foam density and sheet thickness in getting lower noise level and cost of DG set enclosure.**

**Keywords: DG generator, Taguchi Method, Signal to Noise (S/N) Ratio, Optimization, Noise level.**

## I. INTRODUCTION

In today's world Diesel Generator (DG) set is used widely in industries, hospitals, malls, airports, and many other places as the main or standby source of power generation. The noise levels generated by diesel engines are high and can cause health hazards like permanent hearing loss, psychological traumas, stress etc. In order to avoid health risks ,Central Pollution Control Board (CPCB) has specified that the maximum permissible sound pressure level for new DG set with rated capacity up to 1000KVA, shall be less than 75dB(A) at one meter distance from enclosure surface.

Noise is one of the most common hazards we face today. It is all around us: in our homes, in our workplaces, in our cars. All too often, its negative effects are ignored. Overexposure to noise can cause immediate symptoms like irritability, stress, and inefficiency in the workplace. The long term effects of noise exposure however, are more daunting. Permanent hearing loss can occur as a result of continued exposure. Once the damage occurs, it is irreversible, but hearing loss is preventable. In recent years, noise control and hearing loss prevention have become common concerns. Many consumer products, including cars, machinery, and office equipment are limited to prescribed noise levels. In fact, even buildings are now subject to code requirements which limit the amount of noise transmitted through their walls along with this, manufacturers and researchers have become increasingly concerned with better ways of noise reduction and control. The prevention of hearing loss has been named among the 21 priority areas of research in the next century by the National Institute for Occupational Safety and Health. There are many common ways to reduce noise. Perhaps the best method of reducing noise in a product is to incorporate it into the design process by limiting soured noise through such methods as minimizing input forces, limiting the interaction of moving parts, and using materials with inherent damping. These methods, however, are only useful to an extent and often leave more to be desired. Then designers must rely on other methods to further limit the noise output, particularly treating the noise emitted by the source. Some common methods might include mufflers, barriers, or enclosures. Mufflers are commonly used in exhaust systems, such as in car engines, and they are made up of some combination of absorptive material to dissipate the sound as well as reactive elements that work by reflecting sound waves to create destructive interference of sound waves and effectively "cancel" the noise. Barriers are generally used to block noise sources that are too large to enclose, such as traffic noise

## II. EXPERIMENTATION

### A. Methodology of Experiment

There are several optimization techniques to develop product, process or operation. Various techniques can be applied to optimize DG set process. Sometimes different techniques are required integrate to get statistically significant results, which can lead to better conclusions and recommendations. Some extensively used methods in developing a process or a product are Build Test Fix (BTF), Design of Experiment (DOE) and One Variable at a Time (OVAT); BTF is very primitive and unorganized approach. It is iterative method of developing a process focused on improvement from last experiment. DOE is highly efficient method of investigating the effect of parameters as it varies multiple parameters at once. As more parameters are investigated, more number of new combinations is required. DOE cannot control individual parameters and more relies on statistical data. In one variable at a time (OVAT) approach, variation is done with one variable at a time and other parameters are kept constant until the effect of one parameter is studied.

It is highly precise method to study effect of each parameter at different levels. Foam density, Rockwool density and sheet thickness were identified as most predominant parameters affecting the DG Generator. Based on the observation, Taguchi method has been used to optimize the process parameters. OVAT analysis has been conducted to find out effective range of parameters for optimization study. L9 orthogonal array (OA) has been selected from available designs. Standard notation for OA is given below
OA = Ln (Xm)

Where n= number of experiments, X= number of levels and m= number of parameters under study. From available designs for 3 levels 3 parameters, OA with least number of experiments required to conduct (L9) has been selected. ANOVA has been conducted to find out contribution of each parameter in the output. Minitab 19 software has been used for analysis.

### B. Experimental Machine Selection

**Figure 1.** Engine for Diesel Generator

| **Make and Model** | **30kVA (G30-II, TCIC)** |
|---|---|
| Type | 900x 450 mm |
| No. of cylinders | 3 |
| Cylinder arrangement | Inline |
| Displacement, L | 2.15 (131.2) |
| Bore and stroke, mm | 91 x 110 (3.58 x 4.33 |
| Compression ratio | 17.5:1 |
| Governor: type, Class | Mechanical, Class A2 |
| Frequency regulation, steady state | ISO 8528 G2 |
| Max. power kWm (BHP) @ rated speed (rpm) | 31.2 (42) @ 1500 |
| Overall Size, L x W x H (mm) | 1997 x 950 x 1410 |
| Dry weight, max (kg) | 890 |

**Table 1**. Diesel Generator machine Specification.

### C. Selection of material

**CRCA-D Grade**

- Superior Strength & Toughness
- Corrosion Resistant
- Can withstand Extreme Temperature
- Capable of being fabricated into a variety of parts

**Fig. 2** CRCA Steel

| **Compound** | C | Mg | S | P |
|---|---|---|---|---|
| **Value** | 0.12 | 0.5 | 0.04 | 0.04 |

**Table 2** Chemical Composition of CRCA Steel

## III. RESULTS AND DISCUSSION

To get complete understanding of effects of input parameters Foam density, Rockwool density and sheet thickness angle on output Noise Level, you usually assess signal to noise ratio or main effects plot for means. For this purpose, Minitab 19 statistical software has been used. Noise Level has been done. ANOVA has been conducted to find out effect of each parameter on the Noise Level and linear regression model has been established to predict the values of Noise Level.

### A. Experimental Result

Table 4 shows the L9 orthogonal array with measurement of Noise Level for runs one to nine. It also shows S/N ratio for all nine experiments.

| Experiments | Inputs Factors | | | Output Responses | |
|---|---|---|---|---|---|
| **Trial No.** | **Foam Density kg/m$^3$** | **Rockwool Density kg/m$^3$** | **Sheet Thickness mm** | **Noise Level** | **SNRA1** |
| **1** | 28 | 64 | 1.2 | 74.2 | -37.4081 |
| **2** | 28 | 80 | 2.0 | 73.6 | -37.3376 |
| **3** | 28 | 96 | 2.5 | 74.5 | -37.4431 |
| **4** | 30 | 64 | 2.0 | 72.4 | -37.1948 |
| **5** | 30 | 80 | 2.5 | 71.9 | -37.1346 |
| **6** | 30 | 96 | 1.2 | 73.6 | -37.3376 |
| **7** | 32 | 64 | 2.5 | 73.9 | -37.3729 |
| **8** | 32 | 80 | 1.2 | 71.2 | -37.0496 |
| **9** | 32 | 96 | 2.0 | 74.4 | -37.4315 |

**Table 3** L9 orthogonal array with response characteristic.

The S/N ratio values are calculated with help of Minitab 19 software. It can be seen that variation in S/N ratio is minimum for all experiment.

### B. Main Effects of Noise Level

Figure 4 shows the main effects plot from S/N ratios.

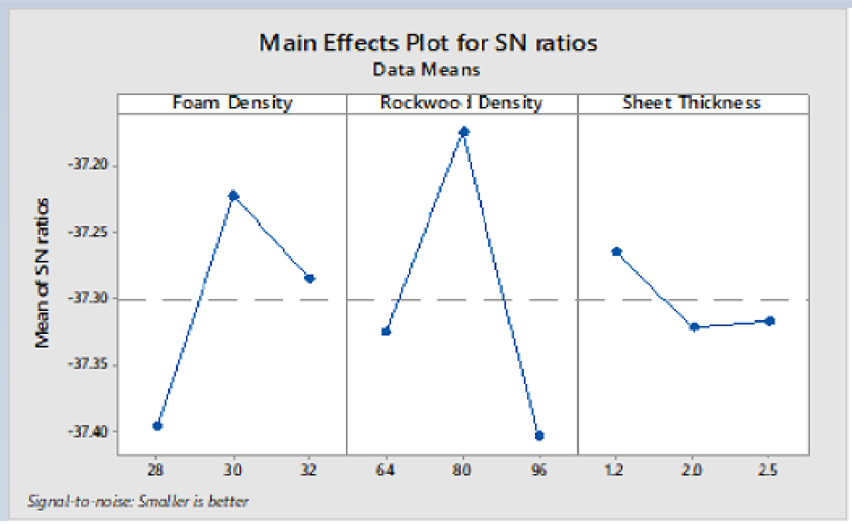

**Figure 4** Main Effects Plot for S/N Ratio

The optimal input parameters were Foam Density 30 kg/m3 (level 2), Rockwool Density 80 kg/m3 (level 2) and Sheet Thickness 1.2 mm (level 1). The graph graphically shows the effect of the control factors on CRCA steel material. The configuration of the process parameters with the highest ratio always provides the optimum quality with a minimum variation. The graph shows the relationship change when the control factor configuration was changed from one level to another.

### C. ANOVA Result

ANOVA, the ratio between the variance of the DG parameter and the error variance is called Fisher's ratio (F). It is used to determine whether the parameter has a significant effect on the quality characteristic by comparing the F test value of the parameter with the standard F table value at the P significance level. If the F test value is greater than P test the cutting parameter is considered significant. Relevance of the models is tested by analysis of variance (ANOVA). It is a statistical tool for testing the null hypothesis for planned experiments, in which several different variables are studied simultaneously. ANOVA is used to quickly analyze the variances in the experiment using the Fisher test (F test). ANOVA table shown the result of the ANOVA analysis. ANOVA analysis makes it possible to observe that the value of P is less than 0.05 in the three parametric sources. It is therefore clear that Foam density, Rockwool density and sheet thickness of the material have an influence on the CRCA material. The last column of cumulative ANOVA shown the percentage of each factor in the total variance that indicates the degree of impact on the outcome. Table 5 shows results obtained from analysis of variance

| Source | DF | Adj SS | Adj MS | F-Value | P-Value | % Contribution |
|---|---|---|---|---|---|---|
| Foam Density | 2 | 0.046602 | 0.023301 | 7.75 | 0.0278 | 29.36 |
| Rockwool Density | 2 | 0.082074 | 0.041037 | 14.01 | 0.0144 | 51.71 |
| Sheet Thickness | 2 | 0.024175 | 0.012087 | 4.12 | 0.0491 | 15.23 |
| Residual Error | 2 | 0.005858 | 0.002929 | | | |
| Total | 8 | 0.158708 | | | | |

Table 4 ANOVA Result.

It shows that the The table shows that the Foam Density (29.36%), the Rockwool Density (51.71 %%) and the Sheet Thickness (15.23%) have a major influence on the Noise Level.

### D. Development of Regression Model for UTS

Regression model has been developed using Minitab software. Substituting the experimental values of the parameters in regression equation, values for moisture content have been predicted for all levels of study parameters. Graphical representation also shows that a predicted and experimental value of moisture content correlates with each other.

Regression Equation –

Noise Level = 77.96 - 0.233 Foam Density + 0.0208 Rockwool Density + 0.357 Sheet Thickness

Table number 5 gives comparison between experimentally measured and predicted moisture content by developed mathematical equation

| Sr. No. | Experimental value | Predicted value | Error % |
|---|---|---|---|
| 1 | 74.2 | 73.19 | 1.37 |
| 2 | 73.6 | 73.81 | 0.28 |
| 3 | 74.5 | 74.32 | 0.26 |
| 4 | 72.4 | 73.01 | 1.28 |
| 5 | 71.9 | 73.52 | 2.17 |
| 6 | 73.6 | 73.39 | 0.17 |
| 7 | 73.9 | 72.70 | 1.65 |
| 8 | 71.2 | 72.59 | 1.91 |
| 9 | 74.4 | 73.21 | 1.16 |

Table 5 Experimental and Predicted Values of UTS

Difference between Noise Level values calculated using regression equation and experimental values for each experience found less than 10%. Hence, we can say that the regression equation developed is valid. Figure 5 shows the graphical representation of experimental and values calculated using regression equation.

### E. Confirmation Experiment Result

Table 5 shows the difference between value of moisture content of confirmation experiment and value predicted from regression model developed.

| Parameter | Predicted value | Experimental value | Error % |
|---|---|---|---|
| Noise Level | 73.13 | 70.4 | 3.04 |

Table 6 Confirmation Experiment Result

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the noise level value obtained has been compared with value predicted by the regression model keeping the parameters at same levels. It can be seen that the difference between experimental result and the predicted result is 3.04%. This indicates that the experimental value correlates to the estimated value.

## IV. CONCLUSIONS

This study covers the observations about the Noise Level over CRCA-D steel material by the process of DG set Enclosures for the different input parameters to thoroughly study over the effect of DG set Enclosures process on the CRCA-D grade steel material. Throughout the experimentation I got some results as under.

- The optimal solution obtained for Noise Level based on the combination of DG set Enclosures parameters and their levels is (i.e. were Foam Density 30 kg/m3 at level 2, Rockwool Density 30 kg/m3 at level 2 and Sheet Thickness 1.2 mm at level 1. The Rockwool density more significant Parameters than foam density and sheet thickness

- ANOVA results indicate that Rockwool density plays prominent role in determining the noise level. The contribution of Foam Density, Rockwool Density, and Sheet Thickness to the quality characteristics Noise level is 29.36%, 51.71% and 15.23% respectively.
- The optimal parameters are determined using Taguchi methods match with the experimental values by minimum errors i.e 3.04%.
- Through the developed mathematical models, any experimental results of DG set Enclosures with any combination of parameters can be estimated.

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