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TAGUCHI: FACTORS INFLUENCING NO_X EMISSIONS FROM A DIESEL ENGINE FUELLED WITH CRUDE RICE BRAN OIL METHYL ESTER BLEND

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Abstract - The major goal of this research is to reduce smoke density and brake thermal efficiency without sacrificing NOX emissions from a stationary diesel engine running on a crude rice bran oil methyl ester blend. The research will also look into the elements that may be affecting the goal. NOX emission, smoke density, and BTE are taken into consideration as the objective's promising elements, while fuel injection timing, percentage of exhaust gas recirculation, and fuel injection pressure are chosen as the response variables. The most effective combination of the factor levels in achieving the objective was found, and the same was confirmed experimentally. Tests were carried out in accordance with the L9 orthogonal array, the most influencing factor for each response variable, as well as the graphs also drawn for each response variable.

***Key Words*:** Crude rice bran oil, NOx emissions, Diesel engine, Transesterification, Taguchi method.

1.INTRODUCTION

In order to fulfil the rising demand for petroleum diesel, biodiesel, a promising sustainable energy source made from vegetable oils, has received greater attention over the past two decades. Along with other benefits, the engine's NOx emission when powered by biodiesel was relatively greater than that of diesel, which hinders the marketability of the product. For engines running on biodiesel, NOX reduction techniques such as water injection, exhaust gas recirculation (EGR), and combustion modification through delayed injection timing were also tried. If the emission criteria cannot be fulfilled by changing the combustion process alone, the later technique can be taken into consideration. NOx reduction by change of the combustion process is the most economical method when compared to treatment of exhaust gases with the use of various. Researchers found that increasing smoke density and decreasing brake thermal efficiency occur in conjunction with a reduction in NOx emissions from diesel and biodiesel when fuel injection and EGR are delayed (BTE). Researchers found that for a three crank angle degree (CAD) delay, biodiesel's NOx emission greatly decreased while its smoke emission dramatically increased. Tsolakisa achieved a 16 percent reduction in NOx with a 20 percent rise in smoke emission at the same retardation angle while using rapeseed methyl ester. It has been demonstrated that cooled EGR is a highly effective NOx reduction approach that lowers the peak flame temperature and oxygen partial pressure in the first part of the flame and lowers NOx generation. Research on biodiesel with 15 percent EGR produced a 74 percent reduction in NOx with a 20 percent rise in smoke. Additionally, it was stated that raising the EGR by more than 15% would increase fuel consumption and smoke emissions. In order to decrease NOx emissions without raising smoke emissions or fuel consumption, fuel injection timing and EGR percentage must be optimized. Additionally, it was implied that the fuel injection time and EGR should be researched in order to determine which has the greatest impact on NOx control. In this study, fuel injection timing and EGR percentage are both changed at the same time to examine the impact on NOx control of a stationary diesel engine running on a biodiesel blend. Because fuel injection pressure also two affects IC engine combustion, it fluctuated along with injection time and EGR %.**1.1** layout.

2. Alternative fuels:

Vegetable oil, biodiesel, Fischer-Tropsch (F-T) diesel, and dimethyl ether are the four alternative fuels that can be used in conventional compression ignition engines (CIE) quite easily (DME). You can utilise vegetable oils as an alternative fuel for diesel engines, including olive, palm, soybean, sunflower, and peanut oils. Natural gas may be used to make F-T and DME, therefore the availability of feedstock is not a constraint. Catalyst composition has a significant impact on Fischer-Tropsch product composition: product from iron catalyst higher in olefins and oxygenates and product from cobalt catalyst higher in paraffin's. Biodiesel, often known as vegetable oil (m) ethyl esters, is a leading contender for alternative diesel fuels. Technically speaking, biodiesel is comparable to and superior to traditional petroleum diesel fuel. The viscosities of the vegetable oils used as alternative engine fuels range from 10 to 20 times higher than that of petroleum diesel fuel. The transesterification procedure is used to reduce the oil's viscosity. The term "bio-diesel" describes a diesel fuel made from animal or vegetable fats that contains long chains of alkyl esters (methyl, ethyl, or propyl). Vegetable oil, soybean oil, or animal fat are chemically combined with an alcohol created

from various fatty acids to create biodiesel. The procedure known as transesterification is utilized to turn these oils into biodiesel. The use of biodiesel in conventional diesel engines makes it distinct from the use of waste and vegetable oils in fuel-converted diesel engines. It is possible to utilize biodiesel either on its own or in a specific ratio with petroleum diesel. The term "mono-alkyl ester with long chain fatty acids" is frequently used to describe biodiesel. Diesel instrumentation can be used with blends containing 20% biodiesel or less with very modest adjustments. Scientists are presently investigating new feedstock's for biodiesel production that are less restricted by the availability of land. For instance, some varieties of algae may make oil. Energy crops may also be produced on terrain that is unsuitable for growing food crops, such as soil that is too acidic or salty, too mineral-rich, too shallow, or in danger of eroding. In these situations, energy crops could aid in restoring and stabilizing the land. Additionally, researchers are experimenting with the production of fuel from non-oilseed feedstock, such as low-cost, non-edible biomass (agricultural waste, waste from the wood products industry, switch grass, and other 12 grasses) that can be used to substitute diesel. While turning vegetable oil or animal fat into biodiesel is a relatively straightforward process, turning cellulosic feedstock into fuel is more difficult. The biomass is often first transformed into a synthetic gas using high heat before being turned into a hydrocarbon fuel. The gas can then be processed to create liquid diesel fuel. The Renewable Fuel standard's requirements for advanced biofuels and biomass-based diesel are both satisfied by biodiesel is a liquid fuel that is often expressed as B100 or neat biodiesel when it is in its purest, unhomogenized form. Similar to petroleum diesel, biodiesel is used as fuel in compression-ignition engines. It performs differently in various weather conditions depending on the biodiesel blend. The less biodiesel in the blend, the better it performs in cold temperatures. Numerous diesel vehicles can run on biodiesel, which is most usually used as a blend with conventional diesel fuel, without requiring any engine modifications. The most common biodiesel blend is B20, which is 6% to 20% biodiesel blended with petroleum diesel. B5 (5% biodiesel, 95% diesel) is commonly used in fleets. Before using biodiesel, it's necessary to check the engine's warranty to make sure that higher-level blends of alternative fuel do not void or have an effect on it. One advantage of biodiesel is that it can impart satisfactory lubricate to diesel fuels at blend levels as low as 1%.

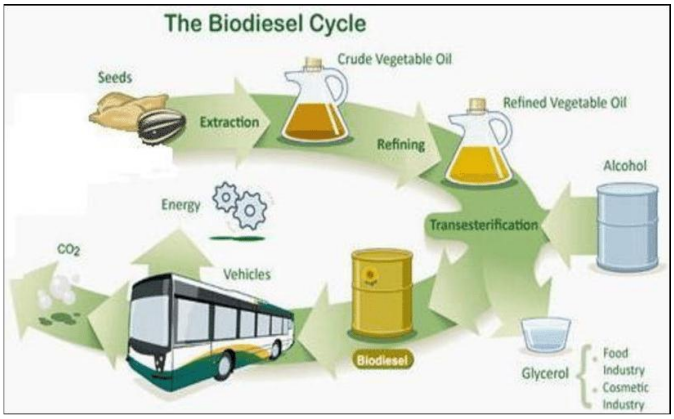


Fig.1 The Biodiesel Cycle (Transformation of biodiesel)

2.1 NOx emissions:

NOx refers to nitrogen oxides. The purists would say that it refers to nitric oxide (NO) and nitrogen dioxide (NO2) only, but most include nitrous oxide (N2O) in this description. There are some other variants, but their concentrations in the atmosphere are too low. There are three main causes of NOx emissions:- (a) High temperature combustion of fuels where the temperature is hot enough (above about 1300°C/ 2370°F) to oxidize some of the nitrogen in air to NOx gases. This includes burning hydrogen, as it burns at a very high temperature. Comments on diesel engines are shown below. (b) Burning plant material releases nitrogen oxides, as all plants contain nitrogen. (c) Chemical and industrial processes which use nitric acid, nitrates or nitrites will release NOx gases. Reduction of NOx emissions: NOx emission can be reduced by primary methods such as retard injection, fuel nozzle modification, change of compression ratio, water direct injection, water emulsification, exhaust gas recirculation (EGR) and secondary method such as selective catalytic reduction (SCR).

2.2 Minitab Software:

Minitab is a software product that helps you to analyze the data. This is designed essentially for six sigma professionals. It provides a simple, effective way to input the statistical data, manipulate that data, identify trends and patterns, and then extrapolate answers to the current issues. Minitab provides a quick, effective solution for the level of analysis required in most Six Sigma projects. The Minitab worksheet is arranged by rows and columns. The columns, C1, C2, C3, and so on, correspond to the variables in your data, the rows to observations. The columns can be viewed in the Data window. In addition, the worksheet may also include stored constants, K1, K2, K3, and so on. Most of the Minitab commands address the columns. In general, a column contains data for one variable, and each row contains all the data for a subject or observation. Columns can be referred to by number (C1, C2, C3, and so on.) or by name such as ―height‖ or ―weight.‖

2.3 Taguchi method:

Taguchi Method is a process/product optimization method that is based on 8-steps of planning, conducting and evaluating results of matrix experiments to determine the best levels of control factors. The primary goal is to keep the variance in the output very low even in the presence of noise inputs. The

Taguchi method of quality control is an approach to engineering that emphasizes the roles of research and development (R&D), and product design and development in reducing the occurrence of defects and failures in manufactured goods. The Taguchi method optimizes design parameters to minimize variation before optimizing design to hit mean target values for output parameters. The Taguchi method uses special orthogonal arrays to study all the design actors with minimum of experiments.

2.4 L9 Orthogonal array

The Taguchi's orthogonal array L9 (3^4) is used in order to estimate the factors that influence the performance criteria and which factors are more important than others. The Analysis of Mean (ANOM), S/N ratio, Turkey Method and Analysis of variance (ANOVA) is used in order to get the objectives of this paper. Taguchi Orthogonal Array (OA) design is a type of general fractional factorial design. It is a highly fractional orthogonal design that is based on a design matrix proposed by Dr. Genichi Taguchi and allows you to consider a selected subset of combinations of multiple factors at multiple levels. An orthogonal array (more specifically a fixed-element orthogonal array) of s elements, denoted by OAN(sm) is an N × m matrix whose columns have the property that in every pair of columns each of the possible ordered pairs of elements appears the same number of times. The Minitab worksheet is arranged by rows and columns. The columns, C1, C2, C3, and so on, correspond to the variables in your data, the rows to observations. The columns can be viewed in the Data window. In addition, the worksheet may also include stored constants, K1, K2, K3, and so on. Most of the Minitab commands address the columns. In general, a column contains data for one variable, and each row contains all the data for a subject or observation. Columns can be referred to by number (C1, C2, C3, and so on.) or by name such as ―height‖ or ―weight.

Table -1: Orthogal Array

Orthogonal Array

Test case ↓	Parameter 1	Parameter 2	Parameter 3
1	1	1	3
2	1	2	2
3	1	3	1
4	2	1	2
5	2	2	1
6	2	3	3
7	3	1	1
8	3	2	3
9	3	3	2

2.5 Signal to Noise Ratio:

A signal-to-noise ratio is a measure of robustness, which can be used to identify the control factor settings that minimize the effect of noise on the response. Minitab calculates a separate signal-to-noise (S/N) ratio for each combination of control factor levels in the design. The signal-to-noise ratio measures how the response varies relative to the nominal or target value under different noise conditions. You can choose from different signal-to-noise ratios, depending on the goal of your experiment. S/N ratio is the most significant and useful parameter in taking into account of target and variation in comparing two sets of samples, when compared comparing the mean alone. Taguchi method of DoE uses S/N ratio in ANNOVA calculations. In an experiment if one observes for a given Quality characteristic say "Nominal is Better" or "Bigger is Better" S/N values as negative.

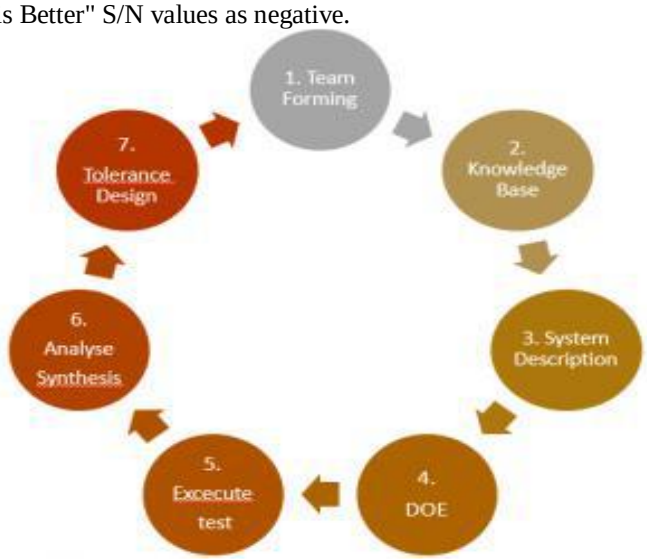


Fig.2 Stages in Taguchi Method

2.6 Exhaust Gas Analyzer

The key components are an infrared source, a light tube, an interference (wavelength) filter, and an infrared detector. The gas is pumped or diffuses into the light tube and the electronics measures the absorption of the characteristic wavelength of light.

Fig 3.Exhaust Gas Analyser

3.0 Transesterification:

Transesterification is a chemical reaction used for the conversion of triglycerides (fats) contained in oils, (Feed stocks) into usable biodiesel. Biodiesel produced by the process of Transesterification has a much lower viscosity, making it capable of replacing petroleum diesel in diesel engines. Transesterification is the conversion of a carboxylic acid ester into a different carboxylic acid ester. The most common method of Transesterification is the reaction of the ester with an alcohol in the presence of an acid catalyst.

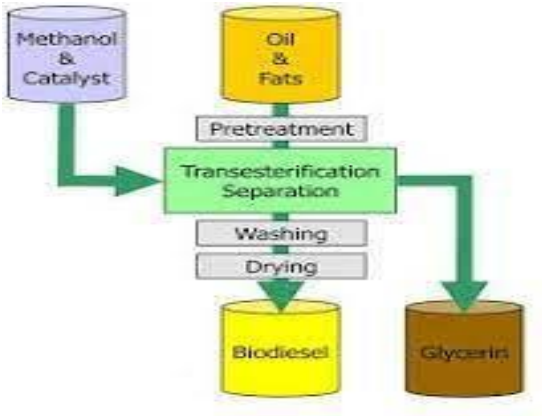
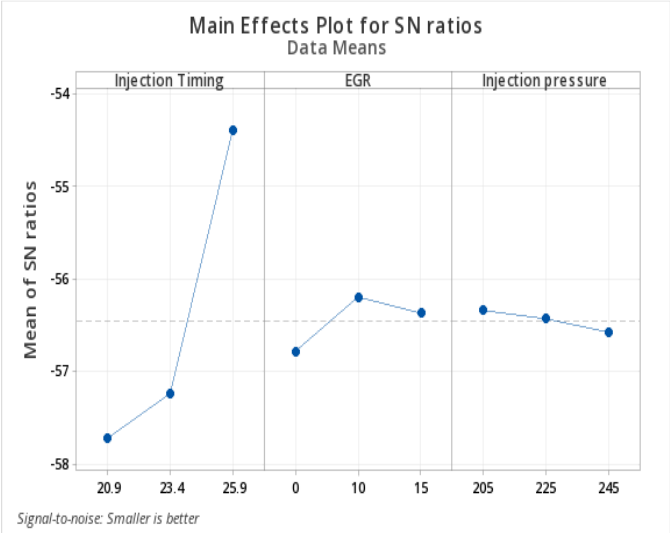
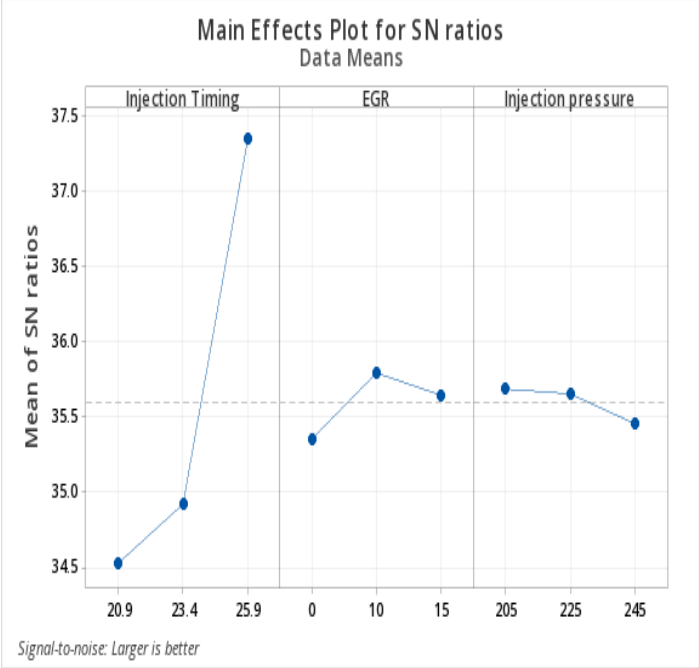


Fig.4 Preparation of Biodiesel by Transesterification

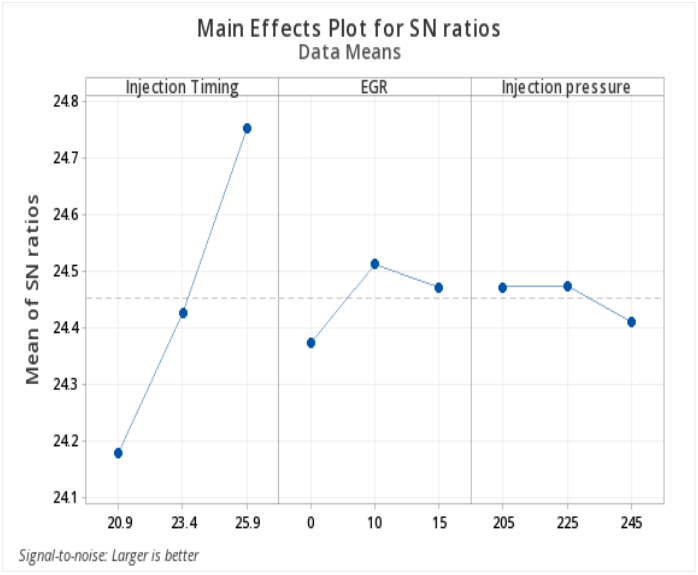
3.1 Response Graphs:.



Graph: 1. Response graph for NOx Emissions



Graph: 2. Response graph for Smoke Density



Graph: 3. Response graph for Brake Thermal Efficiency

3.2 CONCLUSIONS

In the present work, the most influencing factor in controlling the NOx emission, smoke density and BTE of CRBME blend as a stationary CI engine fuel was obtained by employing ANOVA. With the help ANOVA and response graph, optimum combination of injection timing, percentage EGR and fuel injection pressure in reducing the NOx emission with less sacrifice on smoke density and BTE was arrived. From the experiment results and ANOVA following conclusions are drawn: NOx emission can be reduced with lower trade-off with smoke and BTE through combination of injection timing, percentage EGR and injection pressure. Reduction in NOx emission is independent of a single factor and depends upon the levels of other factors. Fuel injection timing is the most influencing factor in reducing the NOx emission and smoke density of CRBME blend. (4) Percentage EGR is the most influencing factor in controlling the BTE of the engine fuelled with CRBME blend. (5) Retarded injection timing with 10% EGR at standard injection pressure is the optimum combination for controlling the NOx with less sacrifice on smoke density and BTE.

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