Multi-response optimization of the Thermal properties of Bio fluids using Taguchi-Grey Analysis

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Abstract. In order to study and investigate the overall performance of bio fluids for solar thermal applications, this work consists of integration of Taguchi method with Taguchi Grey Relational Analysis. The preparation of bio fluids has three levels of input control parameters such as Type of oil, Percentage of concentration and Stirrer speed. Output optimization indicators for the experiment were chosen as Thermal conductivity, Density and Viscosity. The comparative study made consists of coconut oil, sunflower oil and castor oil in the bio fluids preparation. These oils are available readily in the market and are quite inexpensive. The bio fluids are prepared by mixing the above oil with water in appropriate concentration. The experiment is run for the optimal solution using Taguchi analysis using L9 orthogonal array. The influential parameters which are significant in contributing the performance of bio fluids were studied using ANOVA table. After multi objective parametric optimization, the control parameters optimization level shows the use of Sunflower oil with 15% concentration at 15000 RPM stirrer speed produces the optimal performance. Based on the Ranking and Sum of squares from ANOVA table, it is evident that the most influential parameter is the type of oil followed by Percentage of concentration and Stirrer speed respectively.

Keywords: Taguchi Grey Relational Analysis, Type of oil, Percentage of concentration, Stirrer speed, Thermal conductivity, Density, Viscosity

1. Introduction

In solar thermal applications various modification are made to improve the heat transfer and overall performance of the collector. Among those modifications the change of heat transfer fluid plays a vital role. Uses of Nano fluids are increasing due to their ability to improve their respective system performance. [1] Use of Aluminum oxide (Al₂O₃) with water at various proportions like 0.1%, 0.4%, and 0.8% in the heat exchanger results in enhanced performance. Also there is an improvement of 18%, 25%, 30% of heat transfer coefficient with the respective proportion of nano fluids and water. Properties like thermal conductivity and pressure drop also shows higher percentage of improvement. Thermos fluids are also used to improve the cavitation flow [2]. Liquid nitrogen is used as a thermal fluid and it causes a temperature drop, which outcomes in a smaller cavity. Nano fluid properties are
measured and analyzed by Leticia Raquel Oliveira et.al in which Titanium Iso propoxide was used as a nano fluid and led to increase in thermal conductivity and viscosity of about 6% and 4% respectively. C. Selvam et.al considered the thermo physical properties of silver nano fluids used with ethylene glycol and water. This led to increase in the thermal performance and also had significant effect on various other properties such as thermal conductivity, viscosity, density and specific heat and showed an increase of about 12%, 35%, 2.16% and 7% for the respective properties when measured by different devices and processes. The use of water with copper nano fluid in a separate layer of a heat exchanger was investigated by Joanna Wilk et.al also the evaluation of the thermo physical properties obtained was carried out. Nano fluids are used as a heat transfer fluid in solar collector [6]. A stable ionic nano fluid improves the optical properties where it acts as a superior absorption material. The stability of this nano fluids found to be good since this fluid can be used for 20 days without any settlement. [7] The thermo physical properties of Nano fluids and various contributing parameters in thermal applications were reviewed. Metals with good thermal conductivity are used as a nano fluids and this goes to a next level where Bio fluids were developed. Bio fluids are derived from some biological plant parts and it is used in the nano form. The properties of brominated vegetable oil which is a bio derived additive is measured and compared with natural, unmodified oil [8]. The results provide in increase in density and viscosity and also show a good solubility. Also study on Bio fluids derived from weed and the thermal conductivity compared with various Nano fluids were investigated [09]. Two such different weeds are taken and the enhancement of the thermal conductivity was found to be around 8%.to 103% at different temperature levels. The performance of biofluids also shows some good improvement in the thermal properties, Hence the various bio fluid properties were measured and estimated in this research. Bio fluids can be prepared at various level of concentration and stirrer speed but the best combination is needed to be established so that there is a maximum gain in the performance level. A best optimization technique is required to get better results with various combinations in the bio fluids. Many have employed optimization techniques in them researches to generate better results. In the case of multi-response optimization, Input Parameters of electric discharge machining were optimized for the optimum condition by grey relational analysis [10]. Conditions such as input voltage, capacitance, resistance, feed rate and spindle speed were optimized and this condition provided a micro hole of about 40μm average diameter with 10 aspect ratio. From Taguchi Method analysis it was Found out that Squeeze pressure is an important parameter which improvises the mechanical property in squeeze casting process [11]. The optimized parameters completely eliminate the defects that were produced before using optimal condition.

Grey Taguchi method is also used to optimize the emulsion process parameters of water in diesel emulsion. Properties like surfactant concentration, stirrer speed and water concentration are optimized for a good output response [12]. Deformation temperature and friction coefficient affect the forging process of helical gear and an optimal value for the above parameter is estimated using Taguchi Method [13].

Optimal parameters are used by [14] in diesel engine and the performance of brake specific fuel consumption and brake thermal efficiency were improvised to 13.3% and 15.1% respectively. [15] 10% of water concentration in diesel was optimized by Taguchi method and the optimized concentration showed reduced NOx emission by 32.5%. The present study deals with the preparation of bio fluids using water and selective oils by stirring action and optimizing its vital input and output parameters. The parametric optimization of input parameters which influence the overall performance of prepared bio fluids such as type of oil, Percentage of concentration, Stirrer Speed are individually optimized for high thermal conductivity, High density and minimum absolute viscosity using normal Taguchi method. The collective overall results were optimized by integrating Normal Taguchi and Grey Taguchi analysis. The main novelty of this work lies in the use of normal Taguchi and grey analysis with a combination of Anova technique to investigate and determine the overall performance of bio fluids and its effective application in solar applications.

2. Materials and Properties
2.1 Materials

Table 1 Properties of Oils

| Properties           | Coconut oil | Sunflower oil | Castor oil |
|----------------------|-------------|---------------|------------|
| Density (Kg/m³)      | 924         | 918.8         | 961        |
| Boiling point (°C)   | 177         | 232           | 313        |
| Viscosity (Centipoise) | 80          | 49.14         | 650        |
| Thermal conductivity at 25°C | 0.1665 W/mK | 0.168 W/mK  | 0.180 W/mK |

The purpose of preparing the bio fluids is to find the feasibility as a Heat transfer fluid in solar thermal applications. The comparative study made consists of coconut oil, sunflower oil and castor oil in the bio fluids preparation. These oils are available readily in the market and are quite inexpensive. The bio fluids are prepared by mixing the above oil with water in appropriate concentration. The properties of the different oil used for experiments is listed in the Table 1. The research was carried out using the Coconut oil (Parachute brand), Sunflower oil (Saffola brand) and Castor oil (Generic brand) respectively.

2.2 Bio fluids preparation

The preparation of bio fluids is carried out in room temperature, using an electric variable speed Stirrer (0-15000 RPM). The experimental setup is shown in figure 1. Water is employed as the base fluid for the preparation of bio fluid. Both oil and water were mixed in desired proportions in a transparent glass container and agitated for nearly 30 minutes in order to obtain blending. Photographs were taken at every stage of the sample preparation for documentation purpose and is shown in figure 2. Similar process is repeated for preparation of all the biofluids sample. The prepared bio fluid blends have enhanced properties compared to its base fluids, water and oil.

![Figure 1](image-url) Experimental setup of the BioFluid preparation process
2.3 Measurement of Bio Fluid Thermal properties

2.3.1 Thermal Conductivity

The thermal conductivity of the prepared fluids was measured by a KD2 Pro Thermal Properties Analyzer device shown in figure 3. For measurement of thermal conductivity, 50 ml of prepared sample were utilized. For accurate results, the experiment is conducted after 20 minutes to allow the system to attain thermal equilibrium. The liquid sample was poured into the measuring cylinder kept inside the chamber to avoid heat convection losses. The needle and the probe of the analyzer were dipped into the test sample and attached to the monitor respectively. Thus the thermal conductivity of the test samples displayed in the monitor is recorded.

2.3.2 Density

For measuring density, the hydrometer, an instrument used to measure relative density is utilized. The measuring cylinder is filled with 500 ml of the prepared sample and the measurement is done as shown in figure 4. The hydrometer is carefully inserted into the cylinder. When the hydrometer
takes its position, the density of the sample is recorded. The experiment was repeated for accurate results as the sample has to stay still without vibrations.

**Figure. 4 Density Measurement**

### 2.3.3 Viscosity
The viscosity measurement of the prepared sample is carried out by using Redwood Viscometer as shown in figure 5. For measurement of viscosity, 50 ml of prepared sample is used. Initially, the viscometer cup was cleaned using ether and dried. The sample was poured into viscometer cup and the outer bath was filled with water. A clean thermometer is inserted into the cup along with the stirrer. Heater is switched on until the temperature of the sample reaches 30 °C. Now the sample is made to flow through the orifice to measure Redwood seconds. Time taken for collection of 50 ml samples in the volumetric beaker was measured using a stopwatch. Using the above recordings, absolute viscosity of the samples is calculated.

**Figure. 5. Redwood Viscometer**

### 2.4 Taguchi-Grey analysis
The Design of experiment using the Taguchi orthogonal array approach is the mostly sought and very economical one. It is a type of general fractional factorial design that is based on a design matrix proposed by Dr. Genichi Taguchi and considers a selected subset of combinations of multiple factors at multiple levels, and satisfies the needs of solving problem and products design optimization projects. By applying the Taguchi’s method one can reduce the time, resources and money required for little experimental investigation. The DOE provides the relation existing between the input and output variables. In order to determine the factors that influence the performance criteria, Taguchi’s orthogonal array L9 (3^4) is used. Also it is possible to determine
the factors that are more important than others using this array. The Taguchi technique uses an orthogonal array to deliver the core of input factors with a least number of experiments [16]. In the outdated Taguchi technique, individual response only is optimized in the experimental domain [17-19]. To solve multi-objective optimization problems, the Taguchi method is combined with Grey relational analysis [20-22]. The current research involves a Taguchi L9 orthogonal array for evaluation of performance. In the preparation of bio fluid process, the recognize is made for three control variables that act as input parameters: (i) Type of oil (ii) Percentage of Oil Concentration and (iii) Stirrer speed. Table 2 shows the Preparation of bio fluid process parameters and their levels.

**Table 2. Bio Fluid Preparation Variables and Levels**

| VARIABLES       | LEVELS            |
|-----------------|-------------------|
|                 | 1                | 2                | 3                |
| A Type of oil   | Coconut oil      | Sunflower oil    | Castor oil       |
| B Percentage of | 5%               | 10%              | 15%              |
| Concentration   |                  |                  |                  |
| C Stirrer speed | 5000             | 10000            | 15000            |

The type of oil for different levels was chosen based on the oil’s heat transfer efficiency [23-24]. Percentage of oil concentration is selected based on the economic point of view therefore it is arbitrarily chosen as 5 %, 10% and 15% and similarly the fixed Speed levels are 5000, 10000 and 15000 RPM. For solar thermal applications the heat transfer fluids having higher thermal conductivity, High density and low viscosity were recommended [25, 26]. The thermal conductivity and density of the bio fluids has been used with “the larger-the-better,” characteristic which is calculated as follows:

\[
x_{(i)(p)} = \frac{|y_i(p) - \min_y_i(p)|}{\max_y_i(p) - \min_y_i(p)}
\]

(1)

The Viscosity of the bio fluids has been considered as “the smaller-the-better,” characteristic which is calculated as follows:

\[
x_{(i)(p)} = \frac{\max_y_i(p) - y_i(p)}{\max_y_i(p) - \min_y_i(p)}
\]

(2)

Here \(y_i(p)\) is the reference order (original), \(x_i(p)\) = the comparison order, \(i = 1, 2, \ldots, m, p = 1, 2, \ldots, n\), where \(n\) is number of experiments and retorts along with \(k\).

where \(\max_y_i(p)\) are the maximum computed of \(y_i(p)\) and \(\min y_i(p)\) are the minimum computed values of \(y_i(p)\), respectively.

The grey relational coefficient \(\phi(p)\) can be calculated as follows:

\[
\phi(p) = \frac{\Delta_m + \Delta_{0}}{\Delta_{0} + \Delta_{\phi}}
\]

(3)

\[
\Delta_0 = ||x_i(p) - x_i(0)||
\]

(4)

Where \(\Delta_0\) = difference value which is absolute.

\(\Delta_{\phi} = \) maximum value of differences of all compared series (absolute)
\( \Delta_{\text{min}} = \text{minimum value of differences of all compared series (absolute)} \)

The main aim of distinguishing coefficient \( \epsilon (0 \leq \epsilon \leq 1) \) is to slightly modify the dominant effect of \( \Delta_{\text{max}} \) whenever it is higher. Hence in our present work, a value of 0.5 is set for \( \epsilon \). The value of \( y_0 \) (grey relational grade) can be determined as follows:

\[
y_0 = \sum_{j=1}^{n} \delta_j \phi \left( \frac{r_j}{y_j} \right) \quad \sum \delta = 1 \quad \text{Eq (5)}
\]

where \( \delta \) is the weighting factor.

\( y_0 \) is the nominal value of the equivalent response.

While converting the multiple grey relation grades, a high weightage is assigned for thermal conductivity rather than for density and viscosity because thermal conductivity directly influences the efficiency of solar thermal applications. The set of following weightage values for different responses for made: Thermal Conductivity = 0.5, Density = 0.2, and Viscosity = 0.3. In orthogonal array, more than one parameter can be varied at a time hence it makes more suitable for the present study. Based on the design variables and levels chosen, L9 orthogonal array carries out the data which is shown in Table 3.

**Table 3. Array (L9) of the experimental results.**

| Trails | Input Process Parameters | Output Responses | S/N Ratio |
| --- | --- | --- | --- |
|  | Type of oil | Percentage | Speed (rpm) | Thermal Conductivity (W/mK) | Density (Kg/m³) | Absolute Viscosity (Centipoise) | Thermal Conductivity | Density | Absolute Viscosity |
| 1 | Coconut Oil | 5% | 5000 | 0.525 | 998 | 1.0382 | -5.59681 | 59.98 | 0.3 |
| 2 | 10% | 10000 | 0.506 | 1015 | 1.0032 | -5.91699 | 60.12 | 0.0 |
| 3 | 15% | 15000 | 0.326 | 1024 | 0.9883 | -9.73565 | 60.206 | 0.1 |
| 4 | Sunflower | 5% | 10000 | 0.687 | 990 | 0.9963 | -3.26087 | 59.00 |
| oil   |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|
| 5     | 10%   | 0.606 | 1.0132| -4.35055| 60.  |
|       | 15000 | 1005  | 04    | 0.1   | 14   |
| 6     | 15%   | 0.82  | 1.0482| -1.72372| 60.  |
|       | 5000  | 1020  | 17    | 0.4   | 09   |
| 7     | Castor oil | 5%    | 0.459 | 1.0482 | -6.76375| 60.  |
|       | 15000 | 1005  | 04    | 0.4   | 09   |
| 8     | 10%   | 0.533 | 1.0082| -5.46546| 60.  |
|       | 5000  | 1018  | 15    | 0.0   | 71   |
| 9     | 15%   | 0.404 | 1.0032| -7.87237| 60.  |
|       | 10000 | 1050  | 42    | 0.0   | 28   |

2.5 Results and Discussions

2.5.1 Determination of optimal Preparation parameters to provide maximum Thermal Conductivity by Taguchi method

To find the Optimum thermal conductivity, the loss function value is modified into a signal to noise ratio (S/N Ratio). S/N ratios are the log functions of the predicted results which would be the as main aim of the optimization problem. Then Larger-the-Better (LTB) characteristic for S/N Ratio is used to calculate deviation of quality function from the expected value. The S/N ratio for Thermal conductivity is calculated using the equation 6,

\[
\frac{S}{N} = -10 \log_{10}\left(\frac{1}{N} \sum_{i=1}^{N} \left(\frac{1}{y_i^2}\right)\right)
\]

Eq (6)

Where I denotes the number of measurements indicates the trial number and Ni reflects the number of trials for the experiment
It is necessary to produce the biofluids with maximum thermal conductivity for best performance. From table 3, It is observed that the maximum thermal conductivity (0.82 W/mK) is obtained for the parameter of Type of oil = sunflower oil, Percentage of Concentration= 15% and Stirrer speed= 5000 in the 6th trial. Second and third highest thermal conductivity is also obtained from the same Sunflower oil. Hence the selection of oil plays a vital role in influencing thermal conductivity. On arranging the oil in the order of thermal conductivity, it is seen that Sunflower oil > Castor oil > Coconut oil. Hence it is evident that, other parameters such as % of concentration and Stirrer speed comes into play only after the type of oil. Minimum thermal conductivity (0.326 W/mK) is obtained for the parameter of Type oil=Coconut oil, Percentage of Concentration = 15% and Stirrer speed =15000 in the 3rd trial. Now by applying the Taguchi method to evaluate the best possible solution based on the thermal conductivity values. The plot for the SN ratio obtained (figure 6), larger the S/N ratio, larger is the influence of the parameter in the performance. From the graph, it is observed that the Sunflower oil, with 5% of concentration in 5000 RPM gives the optimal solution for best performance.

2.5.2 Determination of optimal Preparation parameters to provide maximum Density by Taguchi method

To find the Optimum Bio fluid preparation parameters for maximum density, S/N ratio is normalized according to Larger the Better. S/N Ratio is calculated and it is shown in figure 7. Similar to thermal conductivity, the biofluids with high density is analyzed in the trials from table 3.

From table 3, It is observed that the maximum Density (1050 Kg/m$^3$) is obtained for the parameter of Type of oil=Castor oil, Percentage of Concentration=15% and Stirrer speed= 10000rpm in the 9th trial. Now Taguchi method is applied to evaluate the best possible solution based on the density values. Second and third highest density is also obtained from the same 15% of the concentration. On arranging the percentage of concentration
in terms of density, it is seen that 15% > 10% > 5%. Hence the percentage of concentration plays a vital role in influencing density. Hence it is evident that, other parameters such as type of oil and Stirrer speed comes into play only after the percentage of concentration. Minimum density (990 kg/m$^3$) is obtained for the parameter of Type oil=Sunflower oil, Percentage of Concentration = 5% and Stirrer speed =10000 in the 4$^{rd}$ trial. Now by applying the Taguchi method to evaluate the best possible solution based on the density values. The plot for the S/N ratio obtained (figure 7), is larger the S/N ratio, larger is the influence of the parameter in the performance. From the graph, it is observed that the Castor oil, with 15% of concentration in 10000 RPM gives the optimal solution for best performance.

2.5.3 Determination of optimal Preparation parameters to provide Minimum Viscosity by Taguchi method

To find the Optimum Bio fluid preparation parameters for Minimum Viscosity, smaller, the Better S/N Ratio is calculated and it is shown in figure 9.

$$\frac{S}{N} = \log_{10} \sum_{n}^{N} \frac{y_{r}^{2}}{n}$$

![Figure 9 S/N Ratio Plot for Each Parameter at Different levels for Optimum Viscosity](image)

For best performance, the biofluids with low viscosity are analyzed. It is observed that the Minimum Viscosity (0.9883 Centepoise) is obtained in the 3rd run for the parameter; Type of oil=Coconut oil, Percentage of Concentration =15% and Stirrer speed = 15000 rpm. Unlike thermal conductivity and density, no parameter directly dominates in viscosity evaluation. Now by applying the Taguchi method to evaluate the best possible solution based on the viscosity values. The plot for the S/N ratio obtained (figure 8), larger the S/N ratio, larger is the influence of the parameter in the performance. From the graph, it is observed that the Coconut oil, with 10% of concentration in 10000 RPM gives the optimal solution for best performance.

2.5.4 Taguchi Grey analysis

In order to optimize the process parameters for combined optimized outputs, then regulation of the experimental data for determining grey relational grade. Different optimal combinations for various optimal cases are carried out. The S/N ratio for the overall grey relational grade is calculated. Table 4 shows the grey relational coefficients, grey relational grades, and S/N ratios of each run and ranks the runs based on grey relational grade. R.No,6, has the greatest response among all cases showing the Type of oil for level 2, Percentage of contribution for level 3, Stirrer speed for level 1 (Sunflower oil ,15% concentration at a stirrer speed of 5000 rpm).This is found to have a good output response during the L9 orthogonal array experiments and is believed to be almost precise to the optimal value.
| Trail | Output Responses | Grey relational coefficient | S/N ratio | Rank |
|-------|------------------|-----------------------------|----------|------|
|       | Thermal Conductivity | Density | Absolute Viscosity | Thermal Conductivity | Density | Absolute Viscosity | Grey relational grade |   |
|       | W/mK | Kg/ m³ | (Centipoises) | 0.5 | 0.2 | 0.3 |                  |       |
| 1     | 0.525 | 998 | 1.0382 | 0.456 | 0.366 | 0.375 | 0.41 | - | 8 |
|       |       |     |       |       |       |       | 7.66 |   |     |
| 2     | 0.506 | 1015 | 1.0032 | 0.440 | 0.462 | 0.668 | 0.51 | - | 5 |
|       |       |     |       |       |       |       | 5.80 |   |     |
| 3     | 0.326 | 1024 | 0.9883 | 0.333 | 0.536 | 1.000 | 0.57 | - | 4 |
|       |       |     |       |       |       |       | 4.82 |   |     |
| 4     | 0.687 | 990 | 0.9963 | 0.650 | 0.333 | 0.789 | 0.63 | - | 2 |
|       |       |     |       |       |       |       | 4.03 |   |     |
| 5     | 0.606 | 1005 | 1.0132 | 0.536 | 0.400 | 0.546 | 0.51 | - | 6 |
|       |       |     |       |       |       |       | 5.81 |   |     |
| 6     | 0.82  | 1020 | 1.0482 | 1.000 | 0.500 | 0.333 | 0.70 | - | 1 |
|       |       |     |       |       |       |       | 3.09 |   |     |
| 7     | 0.459 | 1005 | 1.0482 | 0.406 | 0.400 | 0.333 | 0.38 | - | 9 |
|       |       |     |       |       |       |       | 8.33 |   |     |
| 8     | 0.533 | 1018 | 1.0082 | 0.463 | 0.484 | 0.601 | 0.51 | - | 7 |
|       |       |     |       |       |       |       | 5.87 |   |     |
| 9     | 0.404 | 1050 | 1.0032 | 0.373 | 1.000 | 0.668 | 0.59 | - | 3 |
|       |       |     |       |       |       |       | 4.63 |   |     |
To predict the significance of process parameters, the total irregularity of grey relational grades must be distinguished by calculating the mean sum of squares (SS). SS can be found by using:

\[
SS = \sum \left( y_i - y_m \right)^2
\]

Where \( y_i \) is the mean response for the \( i \)th experiment and \( y_m \) is the grand mean of the response. Depending on the DOF and SS, value of mean sum of squares is computed. Table 5 lists the S/N ratio responses and the significance of the process parameters on overall performance. All three input parameters factors, Type of oil: 67.80%, stirrer speed: 13.84% and Percentage of concentration: 18.36% significantly contribute to increased performance as shown in Table 5. Moreover, the optimum process parametric setting is A2B3C1, in which Type of Oil = sunflower oil, Percentage of concentration = 15% and stirrer speed = 5000 rpm. Grey Analysis has been made for the above three tests. It has been noticed that the proportions Sunflower oil+ 15%+ 15000 RPM gives the Optimum output.

### Table 5. Analysis of Variance (ANOVA) Table

| Level | Type of Oil | % of Concentration | Stirrer Speed |
|-------|-------------|-------------------|---------------|
| 1     | 0.5081      | 0.5428            | 0.5959        |
| 2     | 0.653       | 0.5072            | 0.534         |
| 3     | 0.489       | 0.6               | 0.5202        |
| Delta | 0.164       | 0.0927            | 0.0757        |
| Rank  |             |                   |               |
| Optimum level | A2 | B3 | C1 |
| SS    | 0.048       | 0.013             | 0.0098        |
| DOF   | 2           | 2                 | 2             |

The optimal sample has been prepared for the proportions of Sunflower oil+ 15%+ 5000 rpm

### 3. CONCLUSION

A statistical approach of design of experiments by Taguchi techniques was used to minimize the number of experiments and for getting optimal results. The influence of processing parameters for the thermal conductivity properties location was analyzed. The optimum parameters were obtained from Design of Experiments using L9 array. Thermal Conductivity, Density, Viscosity of various proportions of liquids were observed. From the properties of the bio fluids the Taguchi Analysis has been made.

Key results are summarized as follows;

The results are identified for maximum thermal conductivity, maximum density and minimum viscosity.

1. Maximum thermal conductivity of 0.82 mK is obtained for Type of oil=Sunflower oil, Percentage of concentration= 15% and Stirrer speed =5000 RPM. The optimal thermal conductivity is identified in Type of oil=Sunflower oil, Percentage of concentration= 15% and Stirrer speed =5000 RPM.
2. Maximum density of 1050 kg/m\(^3\) is obtained for Type of oil=Castor oil, Percentage of concentration = 15% and Stirrer speed =10000 RPM. The optimal density is identified in Type of oil=Castor oil, Percentage of concentration=15% and Stirrer speed =10000 RPM.
3. Minimum viscosity of 0.9883 centipoise is obtained for Type of oil=Coconut oil, Percentage of concentration = 15% and Stirrer speed =15000 RPM. The optimal viscosity is identified in Type of oil=Castor oil, Percentage of concentration= 10% and Stirrer speed =10000 RPM.
4. The best possible solutions are identified by the Grey Analysis and optimal combination was determined as Sunflower oil with 15% concentration at 5000 rpm.

### Nomenclature

Rpm- Revolution per minute
S/N Ratio – Signal to Noise ratio
SS – Sum of Squares
DOF – Degree of Freedom

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