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Optimizing the Proportion of Cow Hooves, Bamboo and Arabic Gum Materials Composite for the Production of Automobile Brake Linings

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ABSTRACT

In this paper, optimizing the proportion of cow hooves, bamboo and Arabic gum materials composite for the production of automobile brake linings was successfully achieved. Researchers gathered the cow hooves and dried bamboo wood; cleaned, washed, sun dried and grounded them to size to reduce impurity and its moisture content. Manual weighing balance was used to weigh materials into variable masses and was used to model the wear rate response polynomial model using matlab and 3D surface interactions. The matrix for the three variables were chosen and varied at 3 levels (0.1, 1.3, 2.2g/rev-m) for wear rate response prediction with reference to brake operational temperature of 25℃, 500℃ and 700℃ respectively. Results suggested that the best maximum real root of the polynomial model created was 2.1026g/rev-m and this represented the optimal wear rate for the brake lining material mixture. It was also; observed that the optimal values for material mix for the production of automobile brake linings was 0.12g of cow hooves, 0.22g of bamboo and 0.34g of Arabic gum. Researchers recommended based on the study; optimal material mix should be used in brake linings production to reduce functional wear rate and thermal stability of the automobile brake pads, this research could also be done in future using different levels of matrix input ratio of composite materials and other advanced software for generalization.

Keywords: *Optimization, Cow hooves, Bamboo, Wear rate, Matlab*

1.0 INTRODUCTION

Researchers have shown that the already existing automobile brake linings made of asbestos and its additives, have carcinogenic health challenges associated to them, the non renewable nature of asbestos and the equivalent filler materials necessitated the need for eco-friendly, non-hazardous, renewable fillers and additives to replace asbestos and binders. It is on this note the researchers aimed to study optimizing the proportion of cow hooves, bamboo and Arabic gum materials composite for the production of automobile brake linings.

According to Ibezim et al (2024) as cited in Olagunju et al (2024) explained that composite material is a multiphase material, formed by two or more materials with reinforcing element like fibers, fillers with binders such as resins, gums or polymers. The current study strategizes to use cow hooves, bamboo and Arabic gum as material composite and find an optimal ratio that could improve performance and reliability in production of automobile brake linings. Cow hooves is located at the toe of animal cow, the weight of the animal is normally borne by both the sole and the edge of the hoof wall. Also, it helps to dissipate the energy impact as the hooves strike the ground or surface, thereby protecting the tissues and bones. Bamboo, a greenish plant that could be easily seen in Africa and bamboo fibre, due to its softness, mechanical properties, durability and good frictional behavior provides an edge to be used in automobile brake linings design and production. Arabic gum would function as a binder for the fillers and is locally available in Nigeria. It has the ability to withstand high frictional temperature up to 700℃ dissipated during vehicle braking.

2.0 METHODOLOGY

Researchers gathered the cow hooves and dried bamboo plant, cleaned, washed, sun dried and grounded them to size to reduce impurity and its moisture content. The grounded particles were sieved using standard sieve to achieve finer grains. Manual weighing balance was used to weigh materials into variable masses and was used to establish or determine optimal levels using MATLAB software and 3D surface graphical interactions.

3.0 OPTIMIZATION OF THE MATERIAL MIXTURE

Optimal ratio of the material mixture was determined through optimization of the measured masses. Here, W *is* a dependent variable or predicted response known as wear rate of brake linings in grams/rev-m; *X1, X2 and X3* are independent variables; representing cow hooves in grams, bamboo in grams and Arabic gum in grams respectively. The matrix for the three variables were chosen and varied at 3 levels (0.1 1.3 2.2g/rev-m) for wear rate response prediction. This is done with operational temperature references of 25℃, 500℃ and 700℃ respectively.

MATLAB (R2015a) was used to generate regression model and 3D graphical analysis of surface interaction to establish the optimal values to be used for production.

4.0 RESULTS

```
>> % Optimal value of cow hooves, bamboo, and arabic gum is modeled below;

>> % W = dependent response, wear rate in g/rev-m;

>> % X1 = independent variable, cow hooves in grams;

>> % X2 = independent variable, bamboo in grams;

>> % X3 = independent variable, arabic gum in grams;

>> % X1 = M;

>> %X2 = N

>> %X3 = O;

>> W = [0.1 1.3 2.2];

>> M = [0.35 0.20 0.1];

>> N = [0.1 0.35 0.20];

>> O = [0.20 0.10 0.35];

>> % the expected model for the three variables are;

>> W = X1 + X2 + X3;

Undefined function or variable 'X1'.

Did you mean:

>> W = ex1 + X2 + X3;

Attempt to execute SCRIPT ex1 as a function:

C:\Program Files\MATLAB\MATLAB Production

Server\R2015a\toolbox\robust\rctobsolete\mutools\subs\ex1.m

>> mdl = fitlm(M,W)

mdl =

Linear regression model:

    y ~ 1 + x1

Estimated Coefficients:

               Estimate      SE        tStat      pValue
               ________    ________    ______    ________

    (Intercept)   3.0132    0.065579   45.947    0.013853

    x1           -8.3684     0.27348    -30.6    0.020797

Number of observations: 3, Error degrees of freedom: 1

Root Mean Squared Error: 0.0487
```

R-squared: 0.999, Adjusted R-Squared 0.998

F-statistic vs. constant model: 936, p-value = 0.0208

```
>> tbl = anova(mdl)

tbl =

             SumSq      DF     MeanSq       F       pValue
           _________    __   _________   ______   ________

    x1        2.2176     1      2.2176   936.33   0.020797
    Error  0.0023684     1   0.0023684

>> mdl = fitlm(N,W)

mdl =

Linear regression model:

    y ~ 1 + x1

Estimated Coefficients:

                   Estimate      SE      tStat      pValue
                   ________    ______   _______   _______

    (Intercept)    0.34474     1.7706    0.1947   0.87758
    x1              3.9474      7.384   0.53458   0.68746

Number of observations: 3, Error degrees of freedom: 1

Root Mean Squared Error: 1.31

R-squared: 0.222,  Adjusted R-Squared -0.555

F-statistic vs. constant model: 0.286, p-value = 0.687

>> tbl = anova(mdl)

tbl =

             SumSq     DF    MeanSq       F        pValue
           _______     __   _______   _______   _______

    x1     0.49342      1   0.49342   0.28578   0.68746
    Error   1.7266      1    1.7266

>> mdl = fitlm(O,W)

mdl =

Linear regression model:

    y ~ 1 + x1

Estimated Coefficients:

                   Estimate      SE      tStat      pValue
                   ________    ______   _______   _______

    (Intercept)    0.24211      1.705   0.14199    0.9102
    x1              4.4211     7.1105   0.62176   0.64587

Number of observations: 3, Error degrees of freedom: 1

Root Mean Squared Error: 1.27

R-squared: 0.279, Adjusted R-Squared -0.442

F-statistic vs. constant model: 0.387, p-value = 0.646

>> tbl = anova(mdl)
```

```
tbl =

          SumSq    DF   MeanSq      F      pValue
         _______   __   _______  _______  _______

  x1     0.61895   1    0.61895  0.38659  0.64587

  Error   1.6011   1     1.6011

>>end
```

The response linear regression model for the three materials required for production of brake linings is shown below.

$W = 3.0132 - 8.3684X_1 + 3.9474X_2 + 0.34474 + 4.4211X_3 + 0.24211$ g/rev-m.. (4.0)

Where;

W = dependent response, wear rate in g/rev-m;

X1 = independent variable, cow hooves in grams;

X2 = independent variable, bamboo in grams;

X3 = independent variable, Arabic gum in grams.

>> % TO OBTAIN THE ROOT OF THE POLYNOMIAL IS BELOW;

```
>> P = [3.0132 -8.3684 3.9474 0.34474 4.4211 0.24211];

>> sqrt(P)

ans =

  Columns 1 through 4

   1.7359 + 0.0000i   0.0000 + 2.8928i   1.9868 + 0.0000i   0.5871 + 0.0000i

  Columns 5 through 6

   2.1026 + 0.0000i   0.4920 + 0.0000i
```

The best maximum real root of the polynomial is 2.1026 g/rev-m and this represents the optimal wear rate for the material mixture.

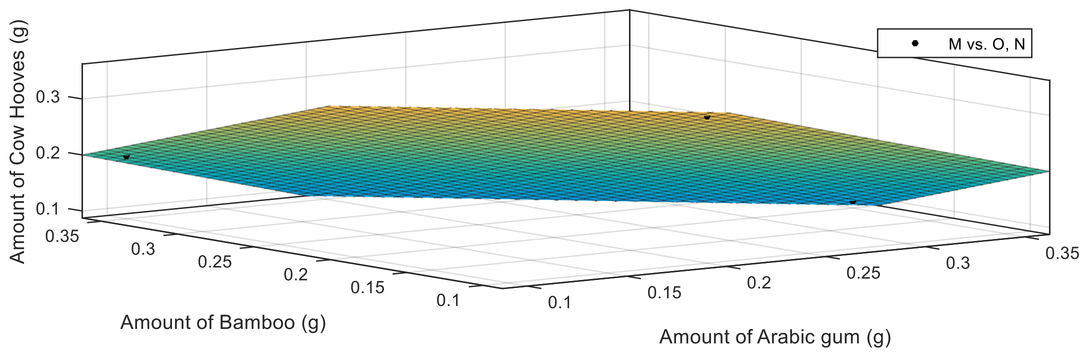

Fig 1.0: 3D Surface Interaction of Materials

LINEAR MODEL POLY11

f(x,y) = p00 + p10*x + p01*y

Coefficients:

p00 = 0.65

p10 = -1

p01 = -1

Goodness of fit:

SSE: 5.239e-32

R-square: 1

Adjusted R-square: NaN

RMSE: NaN

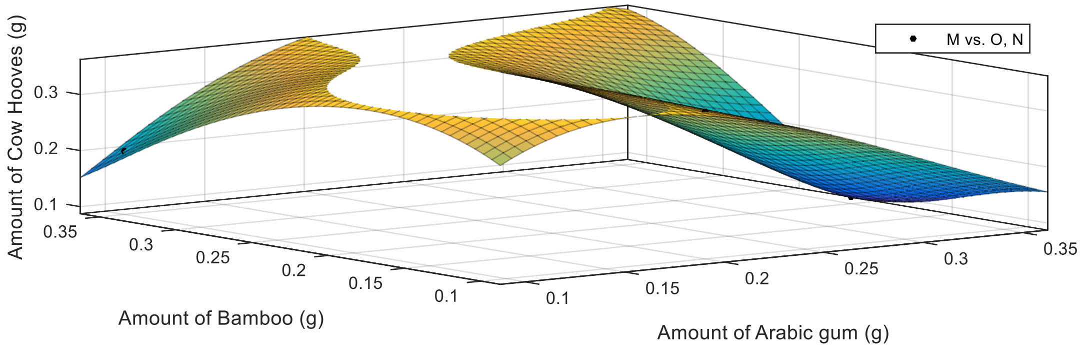

Fig 2.0: 3D Surface Interaction of Materials

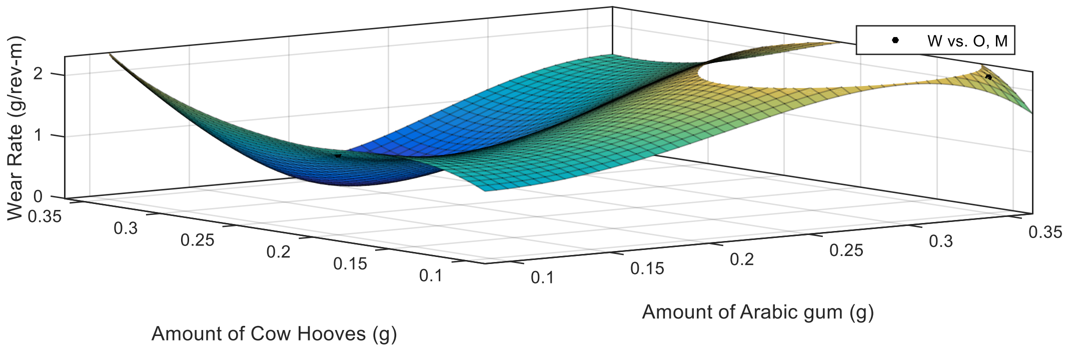

Fig 3.0: 3D Surface Interaction of Materials with Wear Rate

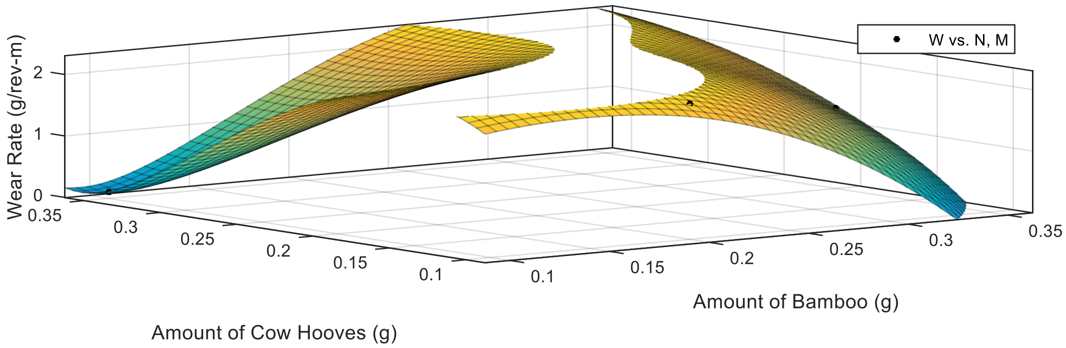

Fig 4.0: 3D Surface Interaction of Materials with Wear Rate

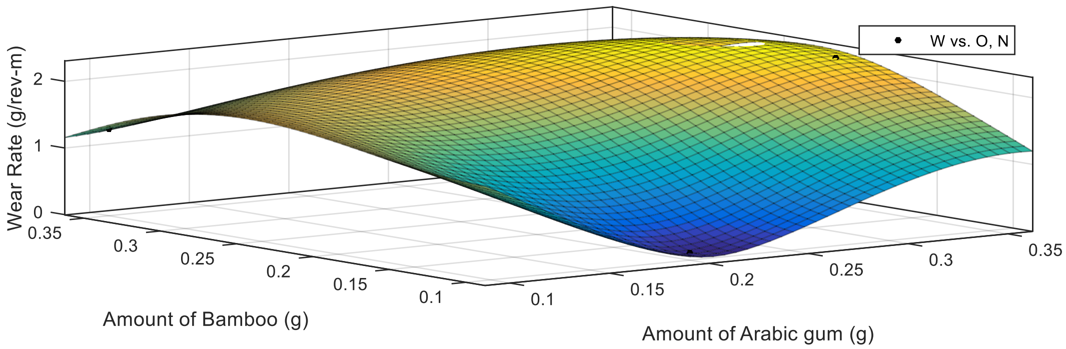

Fig 5.0: 3D Surface Interaction of Materials with Wear Rate

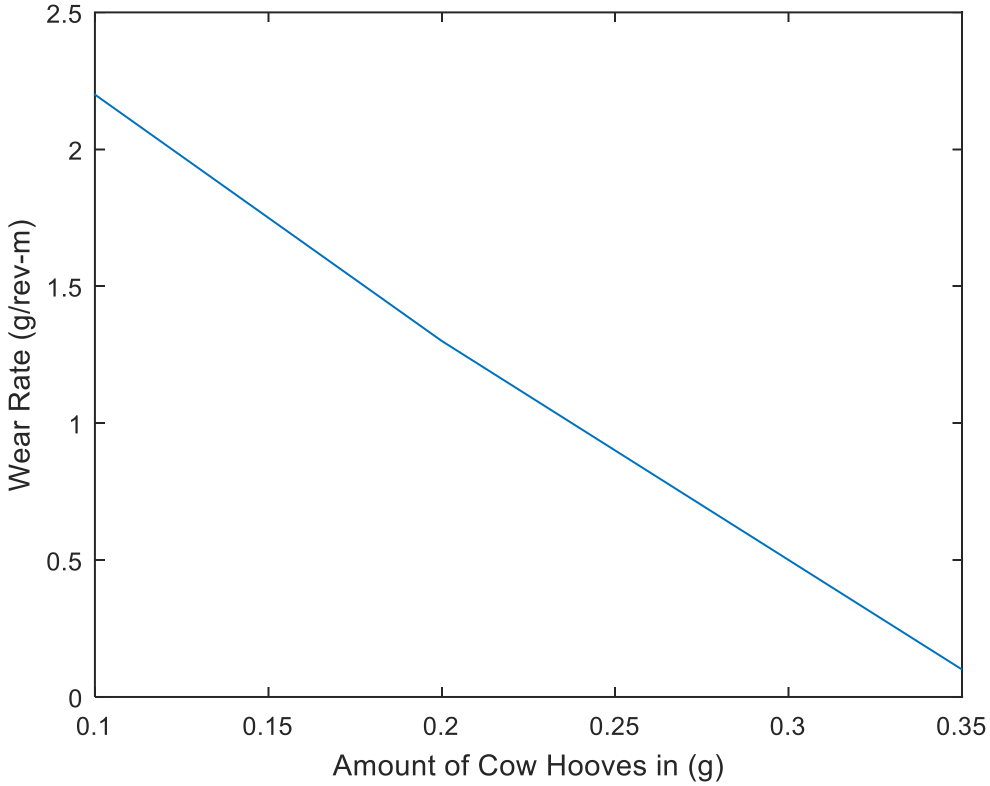

Fig 6.0: Graph of Wear Rate against Amount of Cow Hooves

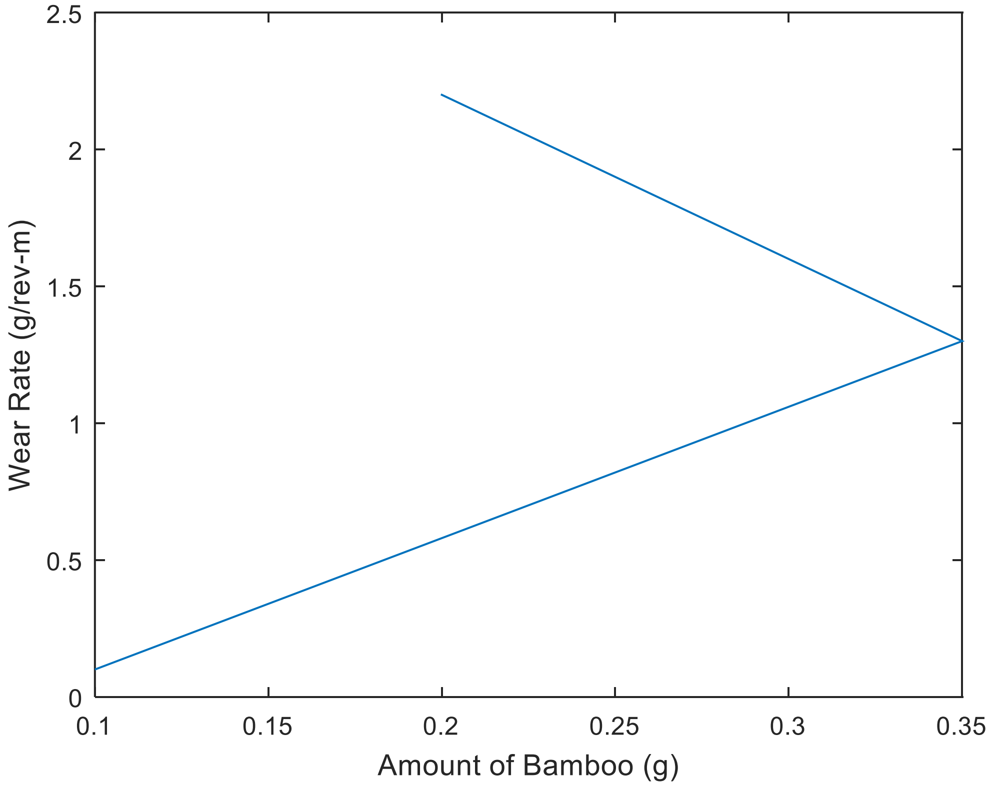

Fig 7.0: Graph of Wear Rate against Amount of Bamboo

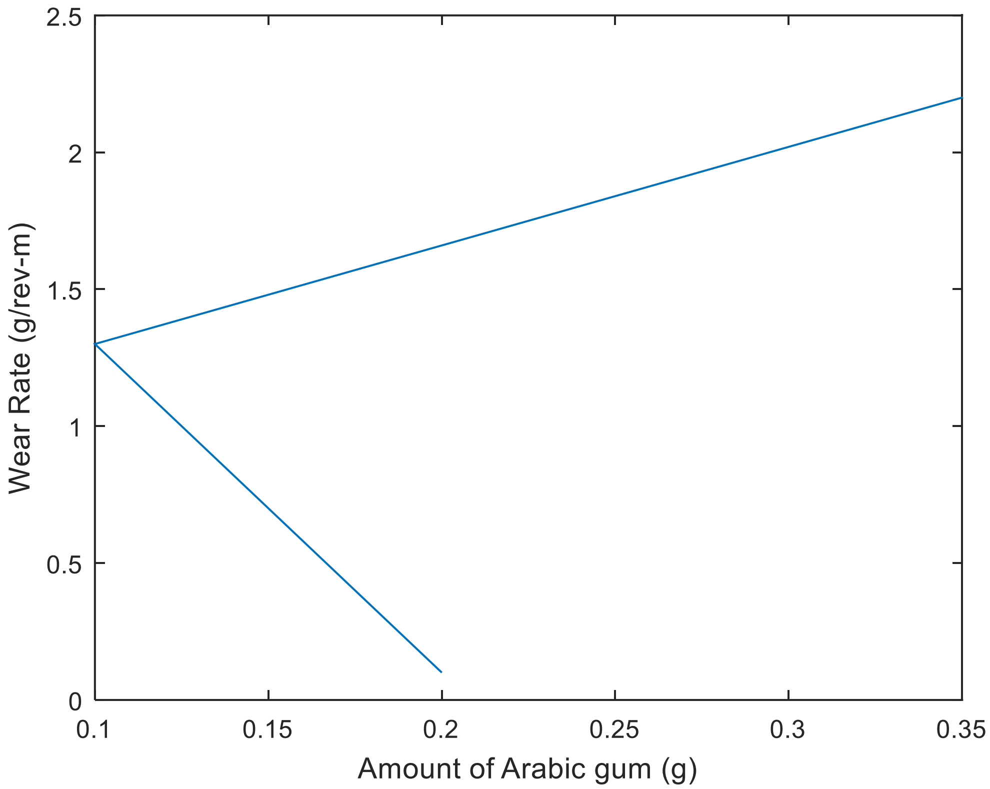

Fig 8.0: Graph of Wear Rate against Amount of Arabic gum

MATLAB CODES FOR THE GRAPHS ABOVE

```
function createfigure1(X1, Y1)

%CREATEFIGURE1(X1, Y1)

%  X1:  vector of x data

%  Y1:  vector of y data

%  MATLAB on 27-May-2024 14:51:23

% Create figure

figure1 = figure;

% Create axes

axes1 = axes('Parent',figure1);

box(axes1,'on');

hold(axes1,'on');

% Create plot

plot(X1,Y1);

% Create xlabel

xlabel({'Amount of Arabic gum (g)'});

% Create ylabel

ylabel({'Wear Rate (g/rev-m)'});
```

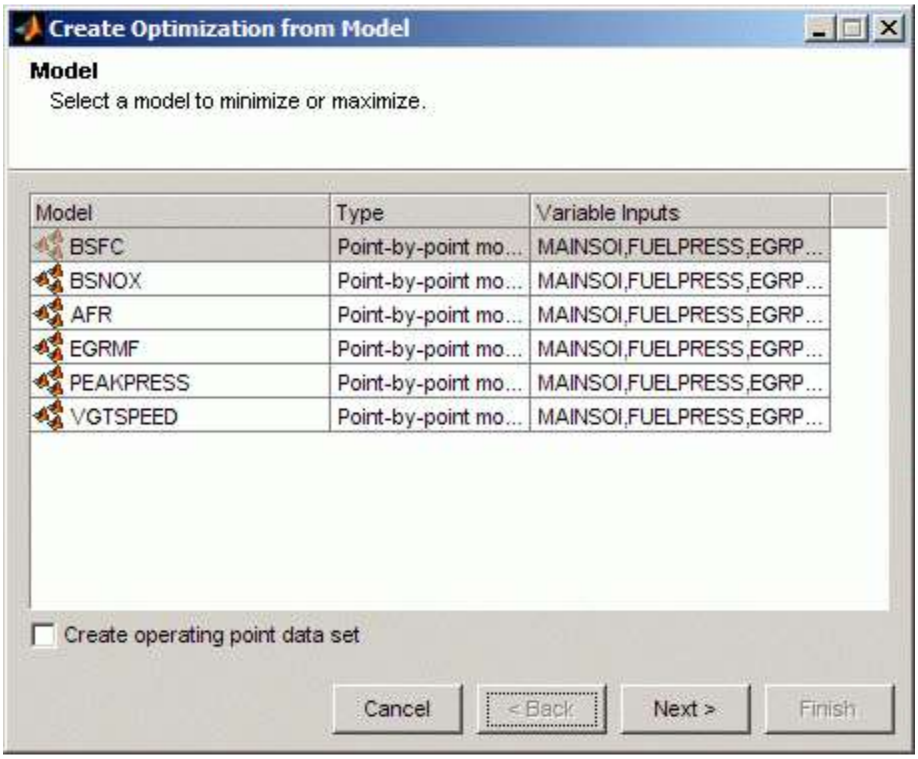

Fig 9.0: Optimization box for polynomial model

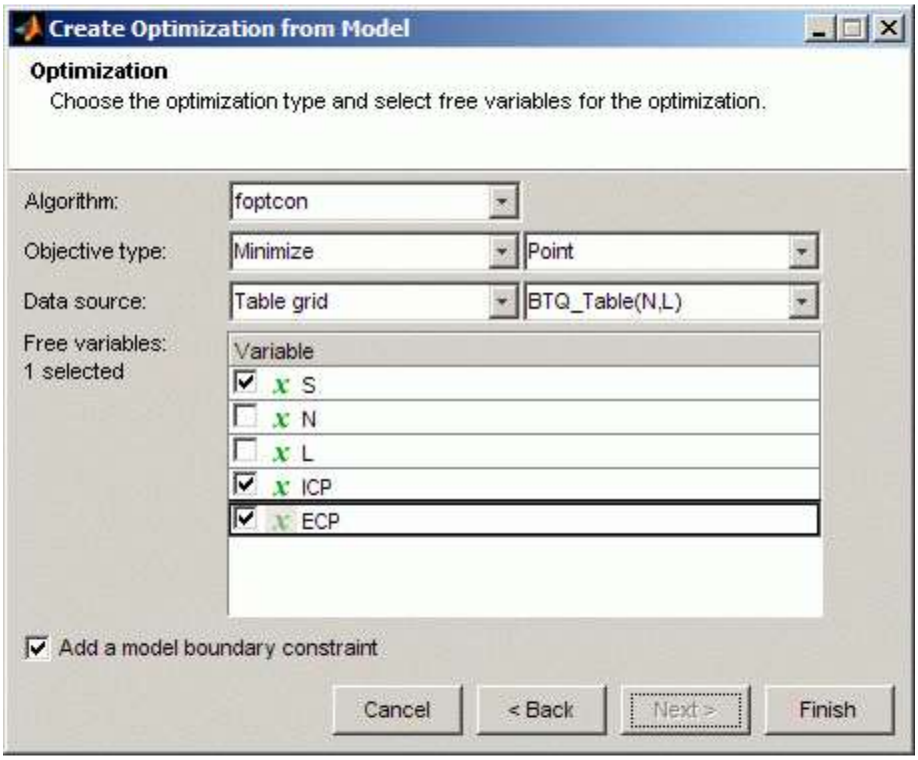

Fig 10.0: Optimization box for polynomial model

The results from the study showed that the best maximum real root of the polynomial was 2.1026g/rev-m and this represented the optimal wear rate of brake linings for the material mixture under the stated condition. According to **fig 1.0 to fig 8.0**, the 3D surface interactions and optimization of the model for the three materials required for production of the automobile brake linings or pad suggested that the optimal values for material mix is 0.12g of cow hooves, 0.22g of bamboo and 0.34g of Arabic gum respectively. This gave optimal wear rate of 2.1026g/rev-m, as suggested by the best root of the polynomial model. In addition, the linear model poly11generated with MATLAB confirms the correctness of the linear model equation for the wear rate response created by modeling.

5.0 CONCLUSION

The results of the study showed that the use of composite material, cow hooves, bamboo and Arabic gum for the production of automobile brake linings would require optimal materials mixture of 0.12g, 0.22g and 0.34g respectively for cow hooves, bamboo and Arabic gum as material composite with optimal wear rate of 2.1026g/rev-m, based on the stated conditions. Hence, cow hooves, bamboo and Arabic gum as composite material should be used in automotive brake linings design and production to cut cost and improve operational performance. The following recommendations were suggested based on the study; optimal material mix should be used in brake linings production to reduce functional wear rate and thermal stability of the automobile brake pads, this research could also be done in future using different levels of matrix input ratio of composite materials and other advanced software for generalization.

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