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Model formulation and Analysis of Total Weight of Briquettes after mixing for Briquette making operation

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ABSTRACT
This paper presents model formulation with analysis of Total Weight of Briquettes after mixing for Briquette making operation. A briquette is a block of flammable material used as fuel to start and maintain a fire. Agro Waste or Biomass briquetting is the densification of loose material to produce compact solid composites of different sizes with the application of pressure. Briquetting of residues takes place with the application of pressure, heat and binding agent on the loose materials to produce the briquettes. The model is formulated for total weight of briquettes after mixing for briquette making operation along with optimization, sensitivity, reliability and ANN simulation.

Keywords – Briquettes, Biomass, Fuel, Sensitivity Analysis

I. INTRODUCTION

A briquette is a block of flammable material used as fuel to start and maintain a fire Low income households consume, on average 2.5 kg of firewood per day. Advantages of Agro Waste Briquettes. Following are the advantages of Agro Waste Briquette : An alternative way to save consumption and dependency on fire wood, These are easy to handle, transport and store, They are uniform in size and quality, The manufacturing process helps solve the residual disposal problem. The process assists the reduction of fuel wood and deforestation, Indoor air pollution is minimized. Briquettes are cheaper than coal, oil or lignite ,There is no sulfur in briquettes, There is no fly ash when burning briquettes, Briquettes have a consistent quality, have high burning efficiency, and are ideally sized for complete combustion ,The briquettes are expected to have consistent calorific values ranging from 3,000-4,500 K Cal / Kg depending on the type of agro-waste used.

Our annual requirement of energy is more than 160 Million tonnes of coal, in excess of 100 Million tonnes of petroleum products and around 250 Million tonnes of other traditional conventional energy to meet the ever growing demand of industrial, agricultural, domestic and commercial requirements. It is also estimated that by the year 2030 we will need around 400 million tonnes of oil imports and 800 million tonnes of coal import in addition to the local resources to sustain the projected 8% growth rate in the country. We will also need 150 million tons of firewood to meet our domestic demand.

II. METHODS AND MATERIAL

Design of an Experimental Set up

It is necessary to evolve physical design of an experimental set up having provision of setting test points, adjusting test sequence, executing proposed experimental plan, provision for necessary instrumentation for noting down the responses. The experimental set up is designed considering various physical aspects of the elements which are shown in figure 1.

Fig.1 Experimental setup of Agro Waste Briquettes making machine

The detailed procedure for the test run is as under:

1. Before starting of experimentation all ingredients were measured on weighing machine for proper selection of ingredients in proportion.
2. Selecting three combinations of ingredients/material (Agro Waste) in proportion.
3. Starting the briquette making operation at first gear ratio thirty two ie. At forty five rpm.
4. Feed the material through hoper and insert small quantity of water for proper mixing after some heat generated in extrusion die.
5. Recording the readings for all dependent variables such as angular speed, power consumption, temperature rise in extrusion

disc, weight of briquettes at outlet, processing torque and current drawn.

6. After completion of process samples of briquette are tested for quality measurement using proximate analysis to measure percentage moisture content, percentage ash content and calorific value of briquettes.
7. Similar procedure was repeated for different combinations of ingredients and processed at sixty six and thirty four rpm.

III. NEED OF FORMULATING GENERALIZED

Experimental Data Based Model

In view of forgoing it is obvious that one will have to decide what should be the minimum processing torque required, and power to be supplied to the system for getting appropriate sizes of briquettes in minimum time. By knowing this one can establish relation for briquettes making process. This would be possible if one can have a quantitative relationship amongst various dependent and independent variables of the system. This relationship would be known as the mathematical model of this briquettes processing operation. It is well known that such a model for the briquettes processing cannot be formulated applying logic. The only option with which one is left is to formulate an experimental data based model. Hence, in this investigation it is decided to formulate such an experimental data based model. All the independent variable are varied over a widest possible range, a response data is collected and an analytical relationship is established. Once such a relationship is established then the technique of optimization can be applied to deduce the values of independent variables at which the necessary responses can be minimized or maximized. In fact determination of such values of independent variables is always the puzzle for the operator because it is a complex phenomenon of interaction of various independent variables and dependant variables. The same is adopted in the present work.

Scope of the present Research

Scope of present research is to establish design data for briquette manufacturing process. With the help of this design data the specific unit for briquette manufacturing can be designed. The utility of such a briquette manufacturing unit will be for small industrialists, entrepreneurs and semiskilled people. Thus end result of this work will be useful: (1) partly as an aid to a low/ medium entrepreneurs and semiskilled people to start their business of briquette manufacturing products, (2) alternatively to a low profiled entrepreneur who can execute the business in the market and can use the design data through theory of experimentation done in this work which is not available for them. As the work is ultimately useful for a low profiled people from rural area of India, this scientific research effort is likely to be useful in lessening the severity of economic problem.

IV. III EXPECTED OUTCOME OF THE RESEARCH

The demand for fuel briquettes comes from the shortage of conventional fuels such as coal, oil, firewood etc. and their escalating prices. There is crying-need for an economical and renewable source of energy. The gap between demand and supply is very wide and the country has been facing a chronic coal shortage for several years. Briquetted fuel can be used by the industrial, commercial and domestic sectors. It is ideally suited for use in the following areas. Boilers / Hot water / Hot air Generators: (paper mills, chemical plants, food processing units, oil extraction units, Natural products processing units etc.) using fuel for steam / Hot water / Hot air generation and / or heating,Brick Kilns and Ceramic Units: for firing of furnaces, Residential and Commercial Heating: For winter heating in cold areas and in restaurants, canteens etc.

V. RESULT AND DISCUSSION

The data generated and collected during experimentation has been converted to interpretable form and this interpretable data has been analyzed to draw some logical results for useful discussions. Keeping this in view studies have been made under the following heads. Quantitative analysis of space curve and Performance of model

Analysis from indices of the models

The indices of the model are the indicator of how the phenomenon is getting affected because of the interaction of various independent pi terms in the models. The influence of indices of the various independent pi terms on each dependent pi term is shown in figure 9.17 to figure 9.24 and discussed below. The constants and indices of independent pi terms on dependent pi terms are given in Table 9.10.

Table 1 Constant and Indices of Response variable

Pi terms	Π_{01}	Π_{02}	Π_{03}	Π_{04}	Π_{05}	Π_{06}	Π_{07}	Π_{08}
K	1.159	2068.23	2322.20	5.86	9.46	1.9538	1.745	6839.11
Π_1	0.009	0.2076	0.3593	-0.04	0.12	-0.002	-0.063	0.1657
Π_2	0.148	-0.0615	-0.4152	0.49	1.11	0.024	-0.004	0.2278
Π_3	-0.0008	-0.0244	0.0158	-0.02	-0.05	0.221	- 0.0007	0.0052
Π_4	0.0653	0.0936	0.125	0.09	0.42	-0.04	-0.084	0.0665
Π_5	0.0049	-0.5798	-0.3586	0.005	-0.11	-0.1684	0.0083	-0.4107
Π_6	-0.0873	-0.165	0.9145	0.267	-0.65	0.2481	0.239	-0.4633

Analysis of Total Weight of Briquettes after mixing (WTo)

Π01= Mathematical Equation for Total Weight of Briquettes after mixing (WTo):

$$(\pi_{01}) = \left(\frac{W_{To}}{W}\right) = 1.1593 \left\{ \begin{array}{c} \left(\frac{\omega^{20}.d_{s D_{sc}} P_s.P_{d t_g D_{sh} L_{sh} L_s t_{sc} L_{cr}}}{g^{10}}\right)^{0.0098} \left(\frac{\omega^6.V_{cr}}{g^3}\right)^{0.1485} \\ \left(\frac{W_I W_{II}.W_{III}}{W^3}\right)^{-0.0008} \left(\frac{g^9.\rho_i.\rho_{ii}.\rho_{iii}}{W^3.\omega^{18}}\right)^{0.0653} \left(\frac{\omega^4.A_h}{g^2}\right)^{0.0049} (N.G)^{-0.0873} \end{array} \right\} \quad (1)$$

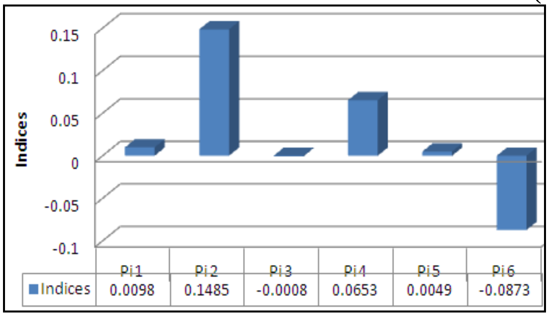

Fig.2 Indices of Model for dependant Pi term- π_{01}

The following primary conclusions appear from the above model i.e equation9.1 and figure9.17

1] The absolute index of π2is highest index of π01 viz. 0.1485. The factor 'π2'is related to Volume of crushing cylinder is the most influencing term in this model. The value of this index is positive indicating involvement of Volume of crushing cylinder has strong impact on Π01.

2] The absolute index of π5, is lowest index of π01 viz. 0.0049. The factor 'π5' is related Area of extrusion hole is the least influencing term in this model.

3] The negative index of π3, π6 is lowest index of π01 viz. -0.0008,-0.0873 respectively. The factor π3and π6 is related to Weight of Ingredients/materials and No of holes and Gear ratio respectively is the least influencing term in this model. The value of this index is negative indicating inversely varying.

3] The negative indices are indicating need for improvement. The negative indices of π01 are inversely varying with respect to π3 and π6 respectively.

4] From above it is clear that value of constant is equal to 1 for model π01, hence it has no magnification effect in the value computed from the product of the various terms of the model.

Sensitivity Analysis

The influence of the various independent π terms has been studied by analyzing the indices of the various π terms in the models. Through the technique of sensitivity analysis, the change in the value of a dependent π term caused due to an introduced change in the value of individual π term is evaluated. In this case, of change of ± 10 % is introduced in the individual independent π term independently (one at a time).Thus, total range of the introduced change is 20 %. The effect of this introduced change on the change in the value of the dependent π term is evaluated .The average values of the change in the dependent π term is due to the introduced change of 20 % in each independent π term. This is defined as sensitivity. The total % change in output for ±10% change in input is considered while calculating sensitivity. Figure 3 shows graphs of sensitivity analysis for dependent pi terms.

Effect of introduced change on the dependent pi term π01

When a total range of the change of ±10% is introduced in the value of independent pi term π2, a change of about 2.978% occurs in the value of π01 (computed from the model). The change brought in the value of π01 because of change in the values of the other independent pi term π3 is only 0.02%. Similarly the change of about 0.197%, 1.31%, 0.098% and 1.75% takes places because of change in the values of π1, π3, π4, π5 and π6 respectively.

It can be seen that highest change takes place because of the pi term π2, whereas the least change takes place due to the pi term π3. Thus, π2 is the most sensitive pi term and π3 is the least sensitive pi term. The sequence of the various pi terms in the descending order of sensitivity is π2, π6, π4, π1, π5 and π3.

From Sensitivity analysis of Π01 ie.Total Weight of Briquettes after mixing (WTo), Volume of crushingcylinder (π2) is most sensitive and Weight of Ingredients/materials (π3) is least sensitive for model Π01 and hence needs strong improvement.

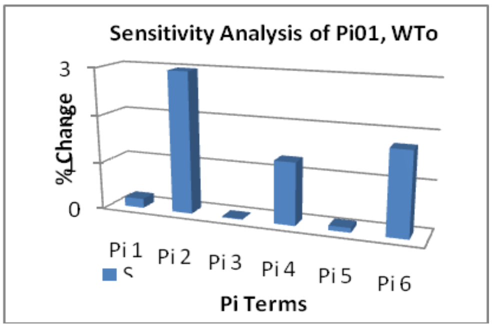

Fig.3 Sensitivity analysis of Π_{01} Total Weight of Briquettes after mixing (W_{To})

Estimation of Limiting Values of Response Variables

The ultimate objective of this work is to find out best set of variables, which will result in maximization/minimization of the response variables. In this section attempt is made to find out the limiting values of eight response variables viz.Total Weight of Briquettes after mixing (WTo), Time of mixing (tm), Power required for processing(P), Temperature Rise of Extrusion Die (ΔT), Processing Torque (Tp), Percentage (%) of moisture Content (PMC,) Percentage (%)of Ash Content (PAC) and Calorific Value (Cv). To achieve this, limiting values of independent π term viz. π1, π2, π3, π4, π5, π6, are put in the respective models. In the process of maximization, maximum value of independent π term is substituted in the model if the index of the term was positive and minimum value is put if the index of the term was negative. The limiting values of these response variables are compute for briquette making operation is as given in Table 2:

Table 2 Limiting Values of Response Variables

Max and Min. of Response π terms	**Briquette making operation**
	Total Weight of Briquettes after mixing (W_{To}) in Kg
Maximum	1.781689219
Minimum	0.375010277

VI. LIMITING VALUES OF TOTAL WEIGHT OF BRIQUETTES AFTER MIXING (WTO)):

The model for dependent pi term involving the termTotal Weight of Briquettes after mixing (WTo) is:

(π01) = 1.1593x (π1)-0.1291 x(π2)-0.4912 x(π3)-0.3039 x(π4)-0.0735 x(π5)-3.2531 x(π6)0.138

$$(\pi_{01}) = (W_{To}) = 1.1593.W\left\{\begin{matrix}\left(\frac{\omega^{20}.d_{s,}D_{sc.}P_s.P_{d.}t_dD_{sh}.L_{sh}.L_s.t_{sc}L_{cr}}{g^{10}}\right)^{0.0098}\left(\frac{\omega^6.V_{cr}}{g^3}\right)^{0.1485} \\ \left(\frac{W_I.W_{II}.W_{III}}{W^3}\right)^{-0.0008}\left(\frac{g^9\cdot\rho_i\cdot\rho_{ii}\cdot\rho_{iii}}{W^3.\omega^{18}}\right)^{0.0653}\left(\frac{\omega^4.A_h}{g^2}\right)^{0.0049}(N.G)^{-0.0873}\end{matrix}\right\} \quad (2)$$

(WTo)max = (π01) = 1.1593 x1.00631579x (0.000157)0.0098x(0.164107)0.1485x(0.00042)-0.0008x(2.44E+08)0.0653x(0.001866)0.0049x(254.1)-0.0873 =1.78168 Kg

$(WTo)_{min} = (\pi_{01}) = 1.1593 \text{ x}1.00631579\text{x} (2.72976E\text{-}10)^{0.0098}\text{x}(0.003067)^{0.1485}\text{x}(0.036)^{-0.0008}\text{x}(848.7761)^{0.0653}\text{x}(0.000131)^{0.0049}\text{x}(192)^{-0.0873}$ =0.375010 Kg

Table 3. Comparison Values of dependent pi terms computed by experimentation, mathematical model and ANN for all dependant Pi 01 terms

SN	**W_{TO} Model**	**W_{TO} Expem**	**W_{TO} (ANN)**	**Error betn Expm & Model**	**Error betn Expm & ANN**
1	0.862	0.734	0.714	0.127	0.02
2	0.862	0.811	0.713	0.05	0.098
3	0.862	0.89	0.782	0.029	0.108
4	0.862	0.749	0.837	0.113	0.088
5	0.862	0.796	0.724	0.066	0.072
6	0.758	0.605	0.713	0.154	0.108
7	0.758	0.671	0.783	0.087	0.112
8	0.758	0.706	0.783	0.053	0.077
9	0.758	0.783	0.736	0.025	0.047
10	0.758	0.686	0.738	0.072	0.052

Table 4 Comparison between Mathematical Model, Experimental and ANN values for Mean value, coefficient of determination -R^2, Error, % Error, Mean Square Error (MSE) , Root Mean Square Error (RMSE)

π terms	**Response Variable**	**Mean**			**Value of R^2**	
		Math. Model	**Expe.**	**ANN**	**General Model**	**ANN**
Π_{01}	Total Weight of Briquettes after mixing (W_{To})	0.806	0.809	0.804	0.275	0.929

VII. CONCLUSIONS

In the present work all the details of proposed machine has been found considering all the design parameters. The present machine is robust in construction. It can be operated by single unskilled operator. It requires less space, less fabrication cost and relatively less power. This machine is very useful in rural as well as in urban areas because good quality briquettes have very high demand in market. So, small manufactures can start their own business of manufacturing small size briquettes by purchasing this machine. Due to this machine, employment may be increased in terms of becoming entrepreneur, machine mechanic, and machine operator.

From the interaction made with manufacturers of briquettes processing machines, literature cited and cursory survey conducted in Vidarbha region of the state of Maharashtra (INDIA) following conclusions have been drawn:

i)The design data, economic viability and feasibility, low cost of fabrication will help them to start small scale industry.

ii) The machining properties (viz. processing time, processing torque, and processing energy) of briquettes are established through Theory of experimentation [36], which was unknown in previously mentioned literature along with quality measures of briquettes.

The data in the present work is collected by performing actual experimentation. Due to this, the finding of the present study truly represents the degree of interaction of various independent variables. This has been made possible only by the approach adopted in this investigation. The standard error of estimate of the predicted / computed values of the dependent variables is fount to be very low. This gives authenticity to the developed mathematical models and ANN.

From sensitivity analysis of briquette making operation, it is analyzed that–

For total Weight of Briquettes after mixing (WTo) , No of holes and Gear ratio is most sensitive and Weight of Ingredients/materials is least sensitive for model π01 and hence needs strong improvement. So, No of holes and Gear ratio is predominant over Weight of Ingredients/materials.

REFERENCES

Journal Papers:

[1]. Channankaiah Murali G., Goutham P., I. Hasan Enamul, Anbarasan P. , “Performance Study of Briquettes from Agricultural Waste for Wood Stove with Catalytic Combustor”, *International Journal of ChemTech Research Coden (USA): Ijcrgg Issn:* 0974-4290 Vol.8, No.1, pp 30-36, 2015.

[2]. Oyelaran O. A., Bolaji B. O., Waheed M. A, Adekunle M. F. “Characterization of Briquettes Produced from Groundnut Shell and Waste Paper Admixture”, *Iranica Journal of Energy and Environment* 6(1): 34-38, 2015.

[3]. Chinyere D. C., Asoegwu S. N., Nwandikom G. I.“An Evaluation of Briquettes from Sawdust and Corn Starch Binder” *The International Journal Of Science & Technoledge*, Vol 2 Issue 7 July, 2014, 149-157.

[4]. Pholoso Malatji, Ntshengedzeni Sampson Mamphweli, Martina Meincken“The technical pre-feasibility to use briquettes made from wood and agricultural waste for gasification in a downdraft gasifier for electricity generation”*Journal of Energy in Southern Africa*Vol 22 No 4 November 2011,2-7.

[5]. Yousif A. Abakr, Ahmed E. Abasaeed,“ Experimental Evaluation Of A Conical-Screw Briquetting Machine For The Briquetting Of Carbonized Cotton Stalks In Sudan “,*Journal of Engineering Science and Technology* Vol. 1, No. 2 (2006) 212-220.

[6]. Sharma P.K., SeniorScientist, “Development and Evaluation of Agro-Wastes/Residues Briquetting Machine”, *Agricultural Engineering Today,* Year : 2005, Volume : 29, Issue : 5&6, 60-63.

[7]. Osarenmwinda, J O; Ihenyen O.I,“The Preliminary Design and Fabrication of a Manually Operated Briquetting Machine”, *Journal. Appl. Sci. Environ. Manage*. June, 2012,Vol. 16 (2) 209 – 211.

[8]. Sakhale C.N. et al., “Formulation and Comparison of Experimental based Mathematical Model with Artificial Neural Network Simulation and RSM (Response Surface Methodology) Model for Optimal Performance of Sliver Cutting Operation of Bamboo”, *Elsevier Journal- Index-9 Procedia Materials Science* 6 (2014) 1710 – 1724.

[9]. Tamilvanan A, “Preparation of Biomass Briquettes using Various Agro- Residues and Waste Papers”,Journal of Biofuels, Vol. 4 Issue 2, July-December 2013 pp. 47-55.

[10]. Davies Rotimi M., “Some Physical and Mechanical Characteristics of Briquettes of White Afara (Terminalia superba) Sawdust and Organic Binders” International Journal of Scientific Research in Agricultural Sciences, 2(3), 2015, 55-60.

Books:

[11]. Hilbert Schenck Junier, *Theory of Engineering Experimentation*, Mc Graw Hill, New York.

[12]. Rao, S.S., *Optimization Theory & Application*, Wiley Eastern Ltd., 2nd Ed., 1984

Proceedings Papers:

[13]. Jaimul M., Sriring N., and Chaiklangmuang S., Effect of sodium hydroxide treatment on biomass binder preparation for lignite briquette, *14 th Chemical Engineering and Applied Chemistry,* Bangkok, Thailand, 1-3 December 2004