DESIGN AND DEVELOPMENT OF AGGLOMERATOR FOR WASTE PLASTIC AND FORMULATION OF MATHEMATICAL MODEL FOR IT

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***Abstract*— Plastic agglomerator is a machine which reduces large volume of plastic to smaller volume or it can also be defined as reduction of plastic volume in a machine called as agglomerator. Present agglomerator machine available in industries are costly, complex and hard in design and fabrication having electric motor of more than 20 hp. It requires bulky quantity of raw material to consume which is not possible in small industries. Hence, the basic theme behind this research is to improve these disadvantages for small industries. The agglomerator presently available is based on practice and past experience of the employer in his working field and also, its efficiency declines at a greater rate after a period of time. However, high literature search has indicated that no design data is available for such system. In view of appendance of developing the technology of recycling of waste plastics, it is very necessary to generate design data for such system. By surveying the present machines and comparing their present limitations, new model will be fabricated so that designs data can be obtained to formulate experimental data based model for this process. The design of model will be so simple that it can be adopted easily by small industries. Easy technology will help to reduce plastic pollution problem. The present work reports the design and fabrication of Agglomerator which is used as recycling of plastic products. It also includes experimental work to be executed for establishing approximate generalized empirical model for Agglomerator, on the basis of experimental data chosen, using methodology of engineering experimentation. It includes formulation of mathematical model and its analysis.**

Keywords-Agglomerator, Waste Plastics, Plastic Bag Pollution, Mathematical Formulation, Environmental Pollution

I. INTRODUCTION

Presently, plastic waste which have got some face value is sold to scrape dealer who sales it to next subordinate dealer who has facility to sort them according to their end uses which are then crushed to smaller pieces to sell them to different end user industries. In this way, plastic which is having some face value is utilized again by recycling it. But plastic waste in the surrounding is increasing day by day, causing environmental pollution. Lack of knowledge, lack of awareness amongst the people etc. are few major reasons of increasing plastic flooding.

Plastics waste scattered all round in surrounding has some face value but they are not in that position to use it in the existing machines which are so costly. The raw material required for this costlier machinery should be of average face value. Hence requirement to fabricate a Machine which is economical and easily adoptable by ordinary person to encourage consumption of waste polythene waste which is the hidden motive of this research work [1][2].

A. Limitation of present available plastic agglomerature machines

1. Designed for heavy electric power consumption so that they can be used in big industrial set up. Hence, not much useful for small town/villages where electric power is itself a big problem [3][4].

2. Present agglomerator is generally designed to agglo plastic material, which is having some good face value and present in large volume.

3. High literature search has indicated that no design data is available for such system.

In view of appendance developing the technology of recycling of waste plastics, it is very necessary to generate design data for such system.

While constructing of the machine, the main aspects which are broadly taken care are that this machine model should be simple in design and it could be re-fabricated in small industries aiming to reduce pollution. Ultimately to save of greenish volume of forest this is direct or hidden theme of this research.

B. Aims and objective of the project.

The agglomerator presently available is based on practice and past experience of the employer. However, high literature search has indicated that no design data is available for such system. In view of appendance developing the technology of recycling of waste plastics, it is very necessary to generate design data for such system. This is the aim of this research.

By looking into the present machines and comparing their present limitations new model will be fabricated so that designs data can be obtained to formulate experimental data based model for this process. Models design will be so simple that it can be adopted to use to reduce plastic pollution problem. This technology will be helpful for utilization of Indian plastic waste.

II. CONSTRUCTION AND WORKING OF THE SYSTEM

Model design will be simple which can be adopted to use by a small industries in a simple way. This machine will be helpful for utilization of Indian plastic waste available in open atmosphere.

"Fig.1" shows the different views of Agglomerator having 50 mm angle, iron plate, shafting, hollow cylinder for bearing Housing, hollow cylinder of 0.51 m, bearings etc

Figure 1. Different views of Agglomerator

A. Experimentation, working of the system and measurement of process variables

Plastic material to be processed is initially taken by measurement of volume which is measured by weighing machine.

1) Process Material is weighed on an electronic weight machine. Later on, it is fed in machine through the open inlet mouth from top of the machine. (Stage 1, refer "Fig. 2")

2) After starting the machine, material starts revolving and heats up due to rotation body frictional movement. Time is measured by stop watch or electronic watch (Stage 2, refer "Fig. 2")

3) When material starts shrinking in volume, again material is poured partly which shrinks its volume time to time; the procedure is repeated .Care should be taken while re-feeding the material. Increase in power should be within the power of electric motor used. In our present experimentation, a motor of 10 H.P. power is used which is having maximum current rating of 10 to 12 ampere. (Stage 3, refer "Fig. 3")

4) Different stages are as shown in Fig. 3 while getting reduces in volume of process material and forming of agglo.

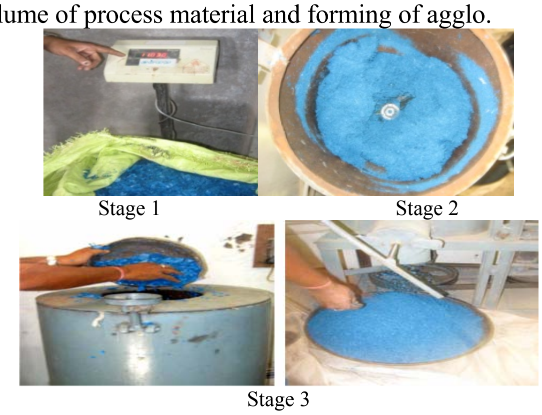

Figure 2. :Different stages of processing of plastic

Figure 3. Different stages while getting reduces in volume of process material

The raw material is not fed completely at once in a machine but rather, partly in intervals. When a volume of material reduces due to heating of material, raw plastic is fed again in some quantity which reduces its volume after mixing to initial heated volume. Initial volume or batch of material can be fed up to maximum volume of vessel then before getting material to agglo condition, material gets reduced to some volume. The same process is repeated again .Time required to complete one process depends on the speed of rotating shaft which also depends on electric motor horsepower rating. This speed can be increased or decreased with velocity ratio between motor and blade shaft .Volume and mass of rotating material also depends upon width, length of blade, angle of rotating blade. Less the clearance between blade and vessel more will be the output but there are more chances of getting tight material lock during agglo formation. Hence precaution should not be taken to care clearance not to get material locked nor so free to increase batch time, thus process time also depend upon present condition of material and density to be processed.

Rotating angle of the blade should be same for every process i.e 45 deg because processing time and electric energy consumption start increasing above 45 degree (from 45 to 90) and machine may get locked with tripping of electric motor.

Also while performing this whole process care should be taken that power consumption should be within one range, it can be checked by providing electric ampere meter on line

Hence measurement of processing time and energy consumed is done for different shaft speed with different blade width and length along with blade diameter(refer "Fig. 4"). The experimentation table is obtained.

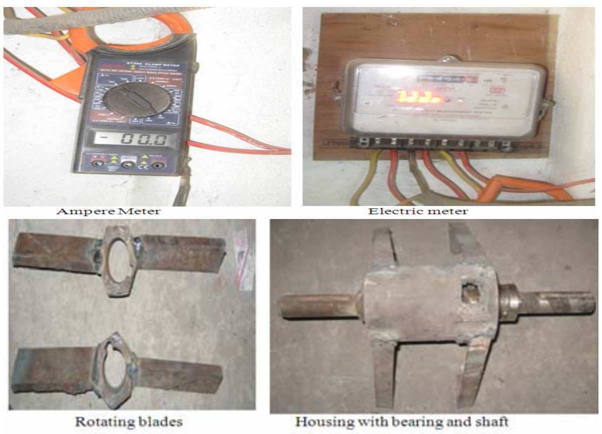

Figure 4. Measuring devices and blades used during experimentation

B. *Experimental Approach (Quantitative)*

A theoretical approach can be adopted in this case. If known logic can be applied correlating the various dependent and independent parameters of the system. Though qualitatively, the relationships between the dependent and independent parameters are known, based on the available literature, the generalized quantitative relationships are not known sometimes. Hence formulating the quantitative relationship based on the logic is not possible in the case of complex phenomenon. Because of no possibility of formulation of theoretical model (logic based), one is left with the only alternative of formulating experimental data based model. Hence, it is proposed to formulate such a model in the present investigation.

The approach adopted for formulating generalized experimental model suggested by Hilbert Schenck Jr. [5] .This is stepwise detailed as below:

1. Identification of independent, dependent and independent extraneous variables
2. Reduction of independent variables adopting dimensional analysis
3. Test planning comprising of determination of test envelope, test points, test sequence and experimentation plan
4. Physical design of an experimental set up
5. Execution of experimentation
6. Purification of experimentation data
7. Formulation of the model
8. Model optimization
9. Reliability of the model

The first six steps mentioned above constitute the design of experimentation. The seventh step constitutes of model formulation where as eighth and ninth steps are optimization and reliability of model respectively.

III. IDENTIFICATION OF VARIABLES

The term variables are used in a very general sense to apply any physical quantity that undergoes change. If a physical quantity can be changed independent of the other quantities, then it is an independent variable. If a physical quantity changes in response to the variation of one or more number of variables, then it is termed as dependent or response variable. The variables affecting the effectiveness of the phenomenon under consideration are speed, cutter dimensions, cross section of material to be processed, cutting, angle, feed, power etc. The dependent or the response variables in this case are :-

1) Q, Mass of Process material at outlet, kg, M
2) t , Processing time = sec= T
3) E , processing Energy , E, (N-mm/sec) = ML^2T^{-2}

The various independent variables involved in the process of Agglomerator are identified as under:

1. Volume of process material = q = $mm^3 = L^3$
2. Density of material = ρ = N/ mm3 = ML^{-3}
3. Thickness of processing material = μ = mm =L
4. Speed of blade shaft, ω =rpm= T^{-1}
5. Velocity ratio between motor and blades shaft = G = constant
6. Diameter of blade and shaft, d = mm = L
7. Acceleration due to gravity = g = mm/s2= LT^{-2}
8. Width of blade = b=mm = L
9. Length of blade = L = mm =L
10. Clearance of blade and vessel, C = mm =L
11. Cutting angle of blade in θ = rad
12. Internal diameter of operating of vessel = D = mm = L
13. Thickness of blade = t= mm = L

A. *Reduction of independent variables / dimensional analysis*

Deducing the dimensional equation for a phenomenon reduces the number of independent variables in the experiments. The exact mathematical form of this dimensional equation is the targeted model. This is achieved by applying Buckingham's π theorem [1].When we apply this theorem to a system involving n independent variables, (n minus number of primary dimensions viz. L, M, T, ∏) i.e. (n-4) numbers of π terms are formed. When n is large, even by applying this theorem number of π terms will not be reduced significantly than number of all independent variables. Thus, much reduction in number of variables is not achieved. It is evident that, if we take the product of the terms it will also be dimensionless number and hence a π term. This property is used to achieve further reduction in number of independent π terms.

B. Test planning:

This comprises of deciding the test envelope, test points, test sequence and experimentation plan for deduced set of dimensional equations [6]. Table I shows Test envelope, test points for agglomerator operations respectively.

C. Experimentation:

Experimentation approach starts initializes using thick gauge 125 micron (0.125 mm) to minor gauge of 30 micron (0.03 mm). Based on this approaches it is planned to perform experimentation in plastic agglomerator having diameter 457.2mm and height 500mm having electric motor of 10 H.P. While performing experimentation, strict precaution should be taken that current consuming should not exceed more than 15 ampere. It should range from 12 A to 15 A. Experimentation is carried for two speed of blades` (1)822 RPM & (2)1028 RPM. Two width of blades `b`(1)50.8 mm& (2)63.5mm are used for this experimentation. Similarly different length of blades `l` used (1)355.6 &(2) 381 mm having clearance between blades end and vessel wall `c`(1)76.2mm & (2) 101.6mm and different gauges used for experimentation (1)0.125mm, (2)0.075mm, (3)0.06mm, (4)0.05mm, (5)0.03mm.Experiment is carried off for Quantity for 49.05N, 68.67N, 88.29N, 107.91N and 127.53N. Experimentation starts with recyclable waste of 125 micron LDPE waste and found that energy consumed `E` and time used `t` for different batches `Q` are found and from that energy consumed and time used per N is calculated .Thus one complete process of experimentation is completed in one diameter of agglomerator 450mm .

Experimentation in 2nd model of agglomerator can now be carried having diameter 500mm.Repeat the procedure was performed for Model 1. But the only difference is that, in this process material having gauge of 0.075 mm is not used. Table II shows sample observation of the experimentation.

D. Model formulation:

It is necessary to correlate quantitatively various independent and dependent terms involved as this formulation [7], [8],[9]. This correlation is nothing but a mathematical model as a design tool for such situation. The mathematical model for sliver cutting operations is as given below:

π_{01} : Mathematical equation for processing mass (Q)

$$Q = (\rho \times \upsilon) \times 0.46248 \times \left(\frac{q}{\rho \times \upsilon}\right)^{1.0023} \times \left(\frac{d \times b \times L \times c \times d \times D \times t}{\upsilon^{1/2187}}\right)^{0.001} \times \left(\frac{g}{\upsilon^{1/3} \times \omega^{2}}\right)^{-0.0532} \times (G)^{0.1011} \times (\theta)^{-0.0011} \;...... \; Eqn.(1)$$

π_{02}: Mathematical equation for processing time (t)

$$t = \left(\frac{1.9792\text{ E} - 24}{\omega}\right) \times \left(\frac{q}{\rho \times \upsilon}\right)^{0.2476} \times \left(\frac{d \times b \times L \times c \times d \times D \times t}{\upsilon^{1/2187}}\right)^{0.0992} \times \left(\frac{g}{\upsilon^{1/3} \times \omega^{2}}\right)^{-4.9953} \times (G)^{9.7234} \times (\theta)^{-0.0328} \;....... \; Eqn.(2)$$

π_{03} : Mathematical equation for processing Energy (E)

$$\text{E} = (254624.4)(\rho \upsilon^{5/3} \omega^{2}) \times \left(\frac{q}{\rho \times \upsilon}\right)^{0.6725} \times \left(\frac{d \times b \times L \times c \times d \times D \times t}{\upsilon^{1/2187}}\right)^{-0.0756} \times \left(\frac{g}{\upsilon^{1/3} \times \omega^{2}}\right)^{1.0877} \times (G)^{-0.4659} \times (\theta)^{-0.0657} \;...... \; Eqn.(3)$$

IV. 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 [9]. 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 due to the introduced change of ± 10 % in each independent π term. This defines sensitivity. The total % change in output for ±10% change in input is shown in Table III.

V. ESTIMATION OF LIMITING VALUES OF RESPONSE VARIABLES

In this section attempt has been made to find out the limiting value of three response variables viz. quantity of processing mass at outlet, processing time and processing energy of processing operations each. To achieve this, limiting values of independent pi terms viz. π_1, π_2, π_3, π_4 and π_5 are put in the respective models. In the process of maximization, maximum value of independent pi term is put in the model if the index of the term is positive and minimum value if the index of the term is negative. In the process of minimization, minimum value of independent pi term is put in the model if the index of the term is positive and maximum value is put if the index of the term is negative. The limiting values of three response variables are computed as given below for Agglomerator operation. Table IV shows limiting values of response variables.

VI. OPTIMIZATION OF THE MODELS

Three mathematical models have been developed for the phenomenon. The ultimate objective of this work is not merely developing the models but to find out best set of independent variables, which will result in maximization / minimization of the objective functions[10][11]. In this case there are three different models corresponding to the Processing mass (Q), Processing Time required (T), Processing Energy required (E) for Agglomerator operation. There are thus three objective functions corresponding to these models. The objective functions for processing mass, time and energy required for processing of Agglomerator need to be minimized. The models have non linear form; hence it is to be converted into a linear form for the optimization purpose. This can be achieved by taking the log of both the sides of the model, we get

$$\log(\pi_{01}) = \log(0.46248) + \log(\rho\upsilon) + 1.0023\log\left(\frac{q}{\rho\times\upsilon}\right) + 0.001\log\left(\frac{d\times b\times L\times c\times d\times D\times t}{\upsilon^{1/2187}}\right) - 0.0532\log\left(\frac{g}{\upsilon^{1/3}\omega^2}\right) + 0.1011\log(G) - 0.0011\log(\theta)....Eqn.(4)$$

$$Z = \log(0.46248) + \log(1.63E+03) + 1.0023\times\log(\pi_1) + 0.001\times\log(\pi_2) - 0.0532\times\log(\pi_3) + 0.1011\times\log(\pi_4) - 0.0011\times\log(\pi_5).....Eqn.(5)$$

Z(Mass: π_{01}max)

$$= -0.3349 + 3.21218 + 1.0023\times X_1 + 0.001\times X_2 - 0.0532\times X_3 + 0.1011\times X_4 - 0.0011\times X_5 ......Eqn.(6)$$

Z(Time: π_{02min})

$$= -23.7035 - 1.97637 + 0.2476 X_1 - 0.0992 X_2 - 4.9953 X_3 + 9.7134 X_4 - 0.03284 X_5 ...Eqn.(7)$$

Z(Energy: π_{03min})=

$$5.4059 + 12.6848 + 0.6746 X_1 - 0.0756 X_2 + 1.0877 X_3 - 0.4659 X_4 - 0.0657 X_5 ...Eqn.(8)$$

Subject to the following constraints

$$1\times X_1 + 0\times X_2 + 0\times X_3 + 0\times X_4 + 0\times X_5 \le 8.61E-02$$
$$1\times X_1 + 0\times X_2 + 0\times X_3 + 0\times X_4 + 0\times X_5 \ge 3.31E-02$$
$$0\times X_1 + 1\times X_2 + 0\times X_3 + 0\times X_4 + 0\times X_5 \le 2.11E+13$$
$$0\times X_1 + 1\times X_2 + 0\times X_3 + 0\times X_4 + 0\times X_5 \ge 2.38E+12$$
$$0\times X_1 + 0\times X_2 + 1\times X_3 + 0\times X_4 + 0\times X_5 \ge 2.42E-06$$
$$0\times X_1 + 0\times X_2 + 1\times X_3 + 0\times X_4 + 0\times X_5 \ge 1.46E-06$$
$$0\times X_1 + 0\times X_2 + 0\times X_3 + 1\times X_4 + 0\times X_5 \le 1.75$$
$$0\times X_1 + 0\times X_2 + 0\times X_3 + 1\times X_4 + 0\times X_5 \ge 1.4$$
$$0\times X_1 + 0\times X_2 + 0\times X_3 + 0\times X_4 + 1\times X_5 \le 2.20E+02$$
$$0\times X_1 + 0\times X_2 + 0\times X_3 + 0\times X_4 + 1\times X_5 \ge 7.85E-01$$

……Eqn.(9)

On solving the above problem by using MS solver we get values of X_1,X_2,X_3,X_4,X_5 and Z. Thus $\Pi_{11\ min}$ = Antilog of Z and corresponding to this value of the Π_{11min} the values of the independent π terms are obtained by taking the antilog of X_1,X_2,X_3,X_4,X_5 and Z. Similar procedure is adopted to optimize the models for Π_{12min} and Π_{13min} and the optimized values of $\Pi_{11\ min}$, $\Pi_{12\ min}$ and $\Pi_{13\ min}$ are tabulated in the Table V.

VII. ESTABLISHMENT OF RELIABILITY OF MODEL

Reliability of model is established using relation Reliability =100-% mean error and Mean error = $\left(\frac{\sum xi \times fi}{\sum xi}\right)$ where, xi is % error and fi is frequency of occurrence [12]. System Reliability (R_T) is given by relation= $1-\prod_{i=1}^{n}(1-R_i)$ =1-[(1- R_{iQ})*(1-Ri_{tp})*(1-Ri_E)], where R_i is the reliability of individual model i.e., mass, time and energy. Therefore total reliability of Sliver cutting equal 1-[(1-0.998045) (1-0.953636)(1-0.684318)= 0.989568 = 98.9568 %

VIII. RESULTS AND DISCUSSION

I] The indices of the model indicates that how the phenomenon is getting affected because of the interaction of various independent terms in the models. The Table VI shows Constant and Indices of the Response variables. The sequence of influence of indices of the various independent terms on each dependent term is as shown in Table VII.

II] Analysis of Sliver cutting operation models for dependent term Π_{11}, Π_{12}, Π_{13}

The following primary conclusions appear to be justified from the above model (Eqn.1, 2 and3).

1] The absolute index of π_1, π_4 and $\pi_1$is highest index of Π_{01}, Π_{02} and Π_{03} respectively viz. 1.0023, 9.7134 and 1.0877. The factor 'π_1', 'π_4'and π_3' is related to quantity of mass before processing, Gear ratio of the machine and Speed of acceleration of machine is the most influencing term in this model. The value of this index is positive indicating involvement of quantity of mass before processing, Gear ratio of the machine and Speed of acceleration has strong impact on Π_{01}, Π_{02}, and Π_{03} respectively and is directly varying with respect to Π_{01}, Π_{02}, and Π_{03} respectively.

2] The absolute index of π_2, π_1 and π_3 is lowest index of Π_{01}, Π_{02} and Π_{03} respectively viz. 0.0992, 0.6746, 0.6726. The factor 'π_2', and 'π_1' is related to dimension of machine and mass of processing material is the least influencing term in this model. Low value of absolute index indicates the dimension of machine and mass of processing material needs improvement.

3] The indices of dependent terms are as shown in Table VI. The negative indices are indicates need for improvement. The negative indices indicate that π_{01} varies inversely with respect to π_3 and π_5. The negative indices indicate that π_{02} vary inversely with respect π_3 and π_5. The negative indices indicate that π_{03} vary inversely with to respect π_2, π_4 and π_5.

4] From Eqn.1, 2 and 3, the curve fitting constant of the model Π_{01}, Π_{02} and Π_{03} are 0.46248, $1.97X10^{-24}$ and 254624.4 respectively. From above it is clear that value of constant is more than 1 for model Π_{02} and Π_{03}, hence it has high magnification effect in the value computed from the product of the various terms of the model. Value of constant is less than 1 for Π_{01}; hence it has least magnification effect in the value computed from the product of the various terms of the model.

5] From Sensitivity analysis it is clear that the π_1 is the most sensitive pi term and π_2 and π_5 are the least sensitive pi term for model Π_{01}. π_4 is the most sensitive pi term and π_5 is the least sensitive pi term for model Π_{02}. π_1 is the most sensitive pi term and π_5 are the least sensitive pi term model Π_{03}. Hence, for least sensitive pi term needs strong improvement.

IX. CONCLUSIONS

Present plastic Agglomerator are designed for heavy electric power consumption so they can be used in big industrial set up hence not much useful for small town/villages where electric power is itself a big issue. Present agglomerator is generally designed to agglo plastic material, which is having some good face value and can handle large volume of plastic.

The major aspect of designing and fabricating the machine is to come up with a simple design so that it can prove helpful to small village areas, which lag behind because of lack of technical knowledge, workshop facilities and Electric Supply Problem Also reducing pollution as conservation of greenish volume of forest is direct or hidden theme of this research.

A. *Advantages of Developed Machine*

Due to simplicity of machine, same model of machine can be easily fabricated again in small industries. Hence multiplication of model will be easily achieved. Hence, it can be helpful to increase number of industries for recycling the plastic waste and this can be advantageous to increase the employment.

B. *Effect on Market*

Due to the ease of technology and handling of this machine, this machine is expected to be adopted by majority of people. This machine will prove helpful in reducing plastic pollution problem and hence waste volume in surrounding is reduced to small volume. The comparison of machine available With Proposed /Fabricated Plastic Agglomerator is shown in Table VIII.

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TABLE I. TEST ENVELOPE, TEST POINTS FOR AGGLOMERATOR OPERATION

Pi terms	**Equation**	**Test envelope**	**Test points**	**Independent variables with its own range**
π_1	Volume of process material $\left(\frac{q}{\rho \upsilon}\right)$	(3.31E-02 to 8.61E-02)	3.31E-02, 3.71E-02, 3.88E-02, 4.44E-02, 4.64E-02, 4.78E-02, 4.98E-02, 5.71E-02, 5.96E-02, 6.09E-02, 6.98E-02, 7.29E-02, 8.61E-02	Q N: 49.05, 68.67, 88.29, 109.91, 127.53 ρ N/mm³: 9.418E-06, 9.025E-06 v mm³: 1.64E+08, 1.96E+08
π_2	Machine dimension $\left(\frac{d \times b \times L \times c \times d \times D \times c}{\upsilon^{1/2187}}\right)$	(2.38E+12 to 21.1E+12)	2.38E+12, 2.53E+12, 2.97E+12, 3.17 E+12, 3.96 E+12, 4.22 E+12, 4.75 E+12, 4.92 E+12, 5.07 E+12, 5.28 E+12, 5.94 E+12, 6.34 E+12, 6.60 E+12, 7.43 E+12, 7.92 E+12, 9.90 E+12, 10.6 E+12, 12.4 E+12, 13.2 E+12 21.1 E+12	d mm: 355.6, 381 b mm: 50.8, 63.5 L mm: 285.6, 311 c mm: 76.2, 101.6, 132.2, 119, 144.4 D mm: 457.2, 500 t mm: 0.03, 0.05, 0.06, 0.075, 0.125 V mm³: 1.64E+08, 1.96E+08
π_3	Speed $\left(\frac{g}{\upsilon^{1/3}\omega^2}\right)$	(1.46E06 to 2.42E-06)	1.46E-06, 1.55E-06, 2.28E-06, 2.42E-06	v mm³: 1.64E+08, 1.96E+08 ω rpm: 86.07964, 107.6519 g=9810 mm/s2 (constant)
π_4	Gear ratio (G)	1.4 to 1.75	1.4 1.75	1.4 1.75
π_5	Cutting angle of blade (θ)	0.785398	0.785398	0.785398 (constant)

TABLE II. OBSERVATION SAMPLES FOR MODEL 1

Processing Recyclable waste material (L.D.P.E.) Gauge 125 micron

SN	Blade speed RPM	Blade width \`b\`	Blade length \`L\`	Clearance of blade \`C\`	Mass of processing material\`q\`(N)	Processing time(t) (sec)	Energy(E) (N-mm)	Processing time / N	Processing energy / N
1.1(1)	1028	50	355.6	101.6	49.05 N	0.96E+03	3.96E+09	19.57	80.73E+06
(2)	1028	50	355.6	101.6	68.67 N	0.84E+03	5.04E+09	12.23	73.39E+06
(3)	1028	50	355.6	101.6	88.29 N	1.02E+03	6.12E+09	11.55	69.31E+06
(4)	1028	50	355.6	101.6	107.91 N	0.9E+03	7.56E+09	8.34	70.05E+06
1.2(1)	1028	50	381\`	76.2\`	49.05 N	0.84E+03	3.6E+09	17.12	73.39E+06
(2)	1028	50	381\`	76.2	68.67 N	0.84E+03	5.04E+09	12.23	73.39E+06
(3)	1028	50	381\`	76.2\`\`	88.29 N	0.96E+03	6.12E+09	10.87	69.31E+06
(4)	1028	50	381\`	76.2\`\`	107.91 N	1.14E+03	7.92E+09	10.56	73.39E+06
1.3(1)	1028	**63.5**	381 \`	76.2\`	49.05 N	0.84E+03	3.96E+09	17.12	80.73E+06
(2)	1028	63.5	381\`	76.2	68.67 N	0.9E+03	5.4E+09	13.10	78.63E+06
(3)	1028	63.5	381\`	76.2	88.29 N	0.9E+03	6.84E+09	10.19	77.47E+06
(4)	1028	63.5	381\`	76.2	107.91 N	1.08E+03	8.28E+09	10.00	76.73E+06

TABLE III. SENSITIVITY ANALYSIS OF RESPONSE VARIABLES

Sensitivity Analysis for Agglomerator operation					EQUATION		
Pi 1	**Pi 2**	**Pi 3**	**Pi 4**	**Pi 5**	**Mass**	**Time**	**Energy**
5.36E-02	7.71E+12	1.97E-06	1.59E+00	1.1E+02	8.866E+01	1.31E+03	6.69E+09
4.82E-02	7.71E+12	1.97E-06	1.59E+00	1.1E+02	7.78E+01	1.27E+03	5.95E+09
5.9E-02	7.71E+12	1.97E-06	1.59E+00	1.1E+02	9.52E+01	1.34E+03	7.41E+09
				Change%	**19.6255**	**5.3435%**	**22.8236%**
5.36E-02	**7.71E+12**	1.97E-06	1.59E+00	1.1E+02	8.66E+01	1.31E+03	6.69E+09
5.36E-02	**6.94E+12**	1.97E-06	1.59E+00	1.1E+02	8.66E+01	1.32E+03	6.74E+09
5.36E-02	**8.48E+12**	1.97E-06	1.59E+00	1.1E+02	8.66E+01	1.30E+03	6.64E+09
				Change%	**0.0000%**	**1.5267%**	**1.4947%**
5.36E-02	7.71E+12	**1.97E-06**	1.59E+00	1.1E+02	8.66E+01	1.31E+03	6.69E+09
5.36E-02	7.71E+12	**1.77E-06**	1.59E+00	1.1E+02	8.71E+01	2.23E+03	5.96E+09
5.36E-02	7.71E+12	**2.17E-06**	1.59E+00	1.1E+02	8.61E+01	0.818E+03	7.41E+09
				Change%	**1.1547%**	**10.7786%**	**21.6741%**
5.36E-02	7.71E+12	1.97E-06	**1.59E+00**	1.1E+02	8.66E+01	1.31E+03	6.69E+09
5.36E-02	7.71E+12	1.97E-06	**1.4318**	1.1E+02	8.57E+01	0.47E+03	7.03E+09
5.36E-02	7.71E+12	1.97E-06	**1.7499**	1.1E+02	8.74E+01	3.30E+03	6.40E+09
				Change%	**1.9630%**	**21.6053%**	**9.4170%**
5.36E-02	7.71E+12	1.97E-06	1.59E+00	**1.1E+02**	8.66E+01	1.31E+03	6.69E+09
5.36E-02	7.71E+12	1.97E-06	1.59E+00	**99.2568**	8.66E+01	1.31E+03	6.74E+09
5.36E-02	7.71E+12	1.97E-06	1.59E+00	**121.3139**	8.66E+01	1.30E+03	6.65E+09
				Change%	**0.0000%**	**0.7633%**	**1.3452%**

TABLE IV. LIMITING VALUES OF RESPONSE VARIABLES

Max and Min. of Response π terms	Agglomerator operation		
	mass at outlet Q (Π_{01})	processing time t (Π_{02})	processing Energy E (Π_{03})
Maximum	53.8 N	1.19E+03 sec	5.58E+09 N-mm
Minimum	139 N	2.02E+03 sec	9.74E+09 N-mm

TABLE V. OPTIMIZED VALUES OF RESPONSE VARIABLES FOR AGGLOMERATOR OPERATION

	Mass: π_{01max}		**Time: π_{02min}**		**Energy: π_{03min}**	
	Log values of π terms	**Antilog values of π terms**	**Log values of π terms**	**Antilog values of π terms**	**Log values of π terms**	**Antilog values of π terms**
Z	1.717058638	5.128610E+01	2.028866038	1.068725E+02	9.470343595	2.951209E+09
X_1	-1.48017200	3.31E-02	-1.48017200	8.61E-02	-1.48017200	3.31E-02
X_2	12.37657696	2.38E+12	13.32428246	2.11E+13	13.32428246	2.11E+13
X_3	-5.61618463	2.42E-06	-5.61618463	2.42E-06	-5.83564714	2.42E-06
X_4	0.146128036	1.4	0.146128036	1.4	0.243038049	1.75
X_5	2.342422681	2.20E+02	2.342422681	2.20E+02	2.342422681	2.20E+02

TABLE VI. CONSTANT AND INDICES OF RESPONSE VARIABLE

	Agglomerator operation		
	Quantity of mass at outlet	**Processing time**	**Processing Energy**
k	-0.3349	-23.7035	5.4059
a	1.0023	0.2476	0.6726
b	0.001	-0.0992	-0.0756
c	-0.0532	-4.9953	1.0877
d	0.1011	9.7134	-0.4659
e	-0.0011	-0.0328	-0.0657

TABLE VII. SEQUENCE OF INFLUENCE OF INDEPENDENT PI TERMS ON DEPENDENT PI TERMS

Agglomerator operation					
Dependent Pi terms	**Sequence of independent pi terms according to intensity of influence**				
Quantity of Processing mass π_{01}	π_1 (Quantity of mass)	π_4 (Gear ratio)	π_3 (Speed of Acceleration)	π_2 (Machine dimension)	π_5 (Cutting angle)
Processing time π_{02}	π_4 (Gear ratio)	π_3 (Speed of Acceleration)	π_1 (Quantity of mass)	π_2 (Machine dimension)	π_5 (Cutting angle)
Processing energy π_{03}	π_1 (Quantity of mass)	π_3 (Speed of Acceleration)	π_4 (Gear ratio)	π_2 (Machine dimension)	π_5 (Cutting angle)

TABLE VIII. COMPARISON OF MACHINE AVAILABLE WITH PROPOSED /FABRICATED PLASTIC AGGLOMERATOR

Parameters	**Present Plastic Agglomerator**	**Proposed/Fabricated Plastic Agglomerator**
Machine area	More than approximate .75m x 1.25m	Exact 0.5m x 1m only
Cost	Start from 1.5 lakh to 5 lakh approximately	0.5 lakh *(Very low cost).*