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Formulation of Experimental Data Based model using SPSS (Linear Regression) for Stirrup Making Operation by Human Powered Flywheel Motor

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Abstract - ***The paper presents to formulate an experimental data based SPSS (linear regression analysis) model for stirrup making operation by using Human Powered flywheel motor. SPSS stands for Statistical Package for the Social Sciences and is a comprehensive system for analyzing data. The authors in their research paper published earlier have suggested the design of the experimentation for the formulation of such model. The experimentation has been carried out on a stirrup making operation by human power Flywheel motor. Mathematical models have been formulated, validated and optimized as per the suggested procedure. In this paper the SPSS (linear regression) model is formulated to generate the correct values of the output parameters corresponding to the various values of the input parameters. The regression coefficient between the observed values and the values of the response variables computed by the SPSS (linear regression) model justifies this as best fit model. The developed SPSS (linear regression) can now be used to select the best values of the various independent parameters for the designed stirrup making operation to match the features of the machine operator performing the task so as to maximize the Quantity of stirrup and minimize resistive torque. Thus the operator / worker selecting the best possible combinations of the input parameters by using this SPSS (linear regression) can now improve the number of bends for stirrup making of an experimental setup.***

Key Words: *HPFM, SPSS (linear regression) model, stirrup, bending of rod, Optimization, statistical analysis.*

1. INTRODUCTION

The abbreviation SPSS stands for Statistical Package for the Social Sciences and is a comprehensive system for analyzing data. This package of programs is available for both personal and mainframe (or multi-user) computers.

SPSS package consists of a set of software tools for data entry, data management, statistical analysis and presentation. SPSS integrates complex data and file management, statistical analysis and reporting functions [13]. SPSS can take data from almost any type of file and use them to generate tabulated reports, charts, and plots of distributions and trends, descriptive statistics, and complex statistical analyses. The theory of experimentation as suggested by Hilbert [2] is a good approach of representing the response of any phenomenon in terms of proper interaction of various inputs of the phenomenon. This approach finally establishes an experimental data based model for any phenomenon. As suggested in this article the experimentation has been carried out and the models are formulated. The concept of least-square multiple regression curves as suggested by Spiegel [2] has been used to develop the models. An entrepreneur arranging optimized inputs so as to get targeted responses. This objective is only achievable by formulation of such models. An entrepreneur of an industry or operator is always ultimately interested in arranging optimized inputs so as to get targeted responses[11]. This objective is only achievable by formulation of such models. Once models are formulated they are optimized using the optimization technique.

1.1 Overview of SPSS (linear regression analysis)

Statistical Package for the Social Sciences SPSS is tool to find out the model summary in which R, R square, ANOVA, Coefficients, Residuals Statistics, histogram and normal P-P plot of regression standardised residual that gives the idea about dependent and independent terms. In SPSS software we can create neural network diagram. Features of SPSS (i) It is easy to learn and use.(ii) It includes a full range of data management system and editing tools.(iii) It provides in-depth statistical capabilities (iv) It offers complete plotting, reporting and presentation features. SPSS makes statistical analysis accessible for the casual user and convenient for the experienced user. The data editor offers a simple and efficient spreadsheet-like facility for entering data and browsing the working data file. To invoke SPSS in the windows environment, select the appropriate SPSS icon. There are a number of different types of windows in SPSS.

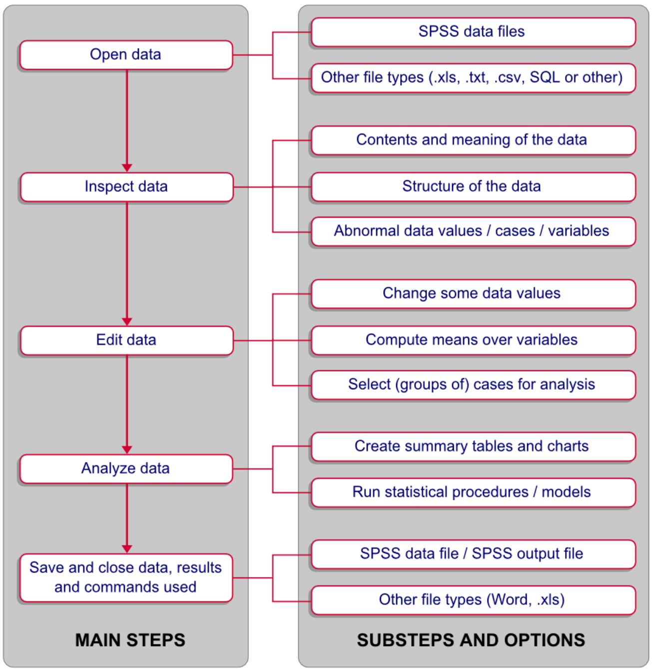

Fig – 1: SPSS project workflow

1.2 Research Scope and Approach

Scope of present research is to establish formulation of design data for stirrup making operation energized by human powered flywheel motor. With the help of this design data the specific unit for bar bending operation by HPFM can be designed. The utility of such a stirrup making unit will be for medium construction work, entrepreneurs and semiskilled people for bringing about low cost automation[12]. 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 stirrup making products and sell in open market, (2) alternatively to a low profiled entrepreneur who can execute the business in the market. 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 this economic problem.

2. Materials and Methods

2.1 Experimental approach

In the present research of stirrup making activity by HPFM is proposed to generate design data and performance validation based on methods of experimentation have been carried out. The approach of methodology of experimentation proposed by Hilbert Schank Jr. has been used for stirrup making operation as the nature of the phenomenon is complex.

The basic approach included in following steps:

1.Identification of independent, dependent and 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 model.

8. Reliability of the model.

9. Model optimization.

10. ANN Simulation of the experimental data.

This will lead to development of new models or proposing of process improvements in the field of stirrup making operations which will help to solve multiple manufacturers' problem. Different experiments are performed and real data was collected and analyzed by making use of statistical and mathematical tools. Based on this data, conclusions are drawn. The new findings of the work have been disseminated through publications in international journals, presentations in international & national conferences. The first six steps mentioned above constitute design of experimentation. The seventh step constitutes model formulation where as eighth and ninth steps are respectively reliability of model and optimization. The last step is ANN Simulation of model.

2.2 Identification of variables

The Independent and dependent variables for stirrup making activity by using human powered flywheel motor was identified and are as tabulated in Table No.1 Dimensional analysis was carried out to established dimensional equations, exhibiting relationships between dependent π terms and independent π terms using Buckingham π theorem.

2.3 Reduction of the Variables and Formation of Dimensional Equation

In stirrup making machine by using HPFM can be seen that there are large numbers of variables involved in this HPFM system. The technique of dimensional analysis has been used to reduce the number of variables into few dimensionless pi terms. The independent and the dependent pi terms as formulated are shown in the Table No.1. Thus there are fourteen independent pi terms and three dependent pi terms in this experimentation. Applying Buckingham π theorem, the dimensional equations for processing time, number of bends and resistive torque are formulated as under.

Dimensional equation as follows

Table -1: Variables related to stirrup making operation by HPFM

Sr	Variables	Unit	MLT	Dependent/ Independent
1	Tr = Resistive Torque	N-m	ML^2T^{-2}	Dépendent
2	tp = Processing Time	Sec	T	Dépendent
3	nb = No. of actual bend per cycle	--	$M^0L^0T^0$	Dépendent
4	Ef = Flywheel Energy	N-m	ML^2T^{-2}	Independent
5	ωf = Angular speed of flywheel	Rad /sec	T^{-1}	Independent
6	tf = Time to speed up the flywheel	Sec	T	Independent
7	ds = Diameter of stirrup	m	L	Independent
8	s = Size of stirrup	m^2	L^2	Independent
9	θ = Angle of bend	Degree	-	Independent
10	Hs = Hardness of stirrup	N/m^2	$ML^{-1}T^{-2}$	Independent
11	r = Distance betn pin & center	m	L	Independent
12	G = Gear Ratio	--	$M^0L^0T^0$	Independent
13	k = Stiffness of spring	N/m	MT^{-2}	Independent
14	dr = Diameter of Rotating Disc	m	L	Independent
15	tr = Thickness of Rotating Disc	m	L	Independent
16	g = Acceleration due to Gravity	m/s^2	LT^{-2}	Independent
17	Ls = Length of stirrup	m	L	Independent
18	Es= Modulus of Elasticity of stirrup	N/m^2	$ML^{-1}T^{-2}$	Independent

Processing time –tp

$$\left(t_p\sqrt{\frac{g}{L_s}}\right) = f_1\left\{\left(\frac{E_f}{L_s^{\,3}E_s}\right)(\omega_f.t_f)\left(\frac{K}{L_s.E_s}\right)\left(\frac{H_s}{E_s}\right)\left(\frac{d_s.r.d_r.t_r}{L_s^4}\right)\left(\frac{S}{L_s^{\,2}}\right)(\theta.G)\right\} \quad (1)$$

Number of bends – nb (2)

$$(n_b) = f_2\left\{\left(\frac{E_f}{L_s^{\,3}E_s}\right)(\omega_f.t_f)\left(\frac{K}{L_s.E_s}\right)\left(\frac{H_s}{E_s}\right)\left(\frac{d_s.r.d_r.t_r}{L_s^4}\right)\left(\frac{S}{L_s^{\,2}}\right)(\theta.G)\right\}$$

Resistive torque

$$\left(\frac{T_r}{L_s^{\,3}E_s}\right) = f_3\left\{\left(\frac{E_f}{L_s^{\,3}E_s}\right)(\omega_f.t_f)\left(\frac{K}{L_s.E_s}\right)\left(\frac{H_s}{E_s}\right)\left(\frac{d_s.r.d_r.t_r}{L_s^4}\right)\left(\frac{S}{L_s^{\,2}}\right)(\theta.G)\right\} \quad (3)$$

2.4 Test Planning

This comprises of deciding test envelope, test points, test sequence and experimental plan [4] for the deduced sets of independent pi term. It is necessary to decide the range of variation of the variable governed by the constraints of cost, time of fabrication and experimentation and computation accuracy the test envelopes are decided. On the basis of ranges of variation of the independent variable, the ranges of variation of independent dimensionless groups have been calculated. During experimentation, at a time, the value of one of the independent dimensionless group will be varied, keeping the values of rest of the independent dimensionless groups constant. Thus classical plan of experimentation is adopted. Test sequence is random as experimentation is reversible.

3. Design of Experimental Setup

It is very important 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 and independent variables. From these provisions one can deduce the dependent and independent pi-terms of the dimensional equation. The experimental set up is designed considering various physical aspects of its elements. For example, if it involves a gear, then it has to be designed applying the procedure of the gear design. In this experimentation there is a scope for design as far as oil seed presser is concerned from the strength considerations. The other dimensions of the stirrup making operation by HPFM are designed using previous mechanical design experience and practice under the presumption of process operation at constant feed condition. This is so because only that data is available. Experimental set up is designed for the above stated criteria, so that the pre decided test points can be set properly within the test envelope proposed in the experimental plan. The procedure of design of experimental set up, however cannot be totally followed in the field experimentation. This is so because in the field experimentation, we were carrying out the experimentation using the available ranges of the various independent variables to assess the value of the dependent variable.

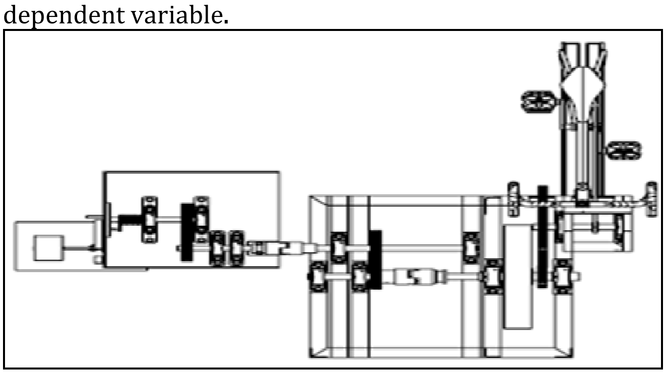

Fig – 2: Line diagram of stirrup making machine by HPFM

3.1 Collection and Purification of the Experimental Data

The experimentation is performed as per the experimental plan and the values of the independent and dependent pi terms for each test run . Proper precautions were taken during the test run and for any erroneous data for a test run the test are repeated.

3.2 Development of Experimental Data Based Model

Establishment of a quantitative relationship is to be done amongst the responses and the inputs. The inputs are varied experimentally and the corresponding responses are measured. Such relationships are known as models. The observed data of dependent parameters for the redesigned independent parameters of the system has been tabulated. In this case there are dependent and independent pi terms. It is necessary to correlate quantitatively various independent and dependent pi terms involved in this HPFM system. This correlation is nothing but a mathematical model as a design tool for experimental setup of such workstations. The optimum values of the independent pi terms can be decided by optimization of these models for maximum number of bends and resistive torque and minimum processing time. Formulation experimental data based models for stirrup making process by using human powered flywheel motor system has been established for responses of the system such as processing time (π 01), number of bends (π 02), resistive torque (π03)

The mathematical models are

$(t_p) =$

$$0.0005504273433.\sqrt{\frac{L_s}{g}}\left\{\begin{matrix}\left(\frac{E_f}{L_s{}^3E_s}\right)^{0.3195}(\omega_f.t_f)^{0.2209}\left(\frac{K}{L_s.E_s}\right)^{-1.0589}\\ \left(\frac{H_s}{E_s}\right)^{-4.4256}\left(\frac{d_s.r.d_r.t_r}{L_s^4}\right)^{0.1162}\left(\frac{S}{L_s{}^2}\right)^{-0.2425}(\theta.G)^{0.0444}\end{matrix}\right\}$$

$(n_b) =$

$$0.0000000259656979\left\{\begin{matrix}\left(\frac{E_f}{L_s{}^3E_s}\right)^{0.5355}(\omega_f.t_f)^{0.0831}\left(\frac{K}{L_s.E_s}\right)^{-1.9243}\left(\frac{H_s}{E_s}\right)^{8.9311}\\ \left(\frac{d_s.r.d_r.t_r}{L_s^4}\right)^{0.1377}\left(\frac{S}{L_s{}^2}\right)^{1.0505}(\theta.G)^{0.0986}\end{matrix}\right\}$$

$\left(T_{r\,Avg}\right) =$

$$10060046770000.L_s{}^3E_s\left\{\begin{matrix}\left(\frac{E_f}{L_s{}^3E_s}\right)^{0.1465}(\omega_f.t_f)^{-0.1309}\left(\frac{K}{L_s.E_s}\right)^{2.6796}\left(\frac{H_s}{E_s}\right)^{-7.06}\\ \left(\frac{d_s.r.d_r.t_r}{L_s^4}\right)^{-0.0268}\left(\frac{S}{L_s{}^2}\right)^{0.1835}(\theta.G)^{-1.5492}\end{matrix}\right\}$$

Thus corresponding to the three dependent pi terms we have formulated three models from the set of observed data.

4. Computations of the Predicted Values by SPSS (Linear regression analysis)

One of the main issues in this research is prediction of future results. The experimental data based modelling achieved through mathematical models for the dependent π terms. In such complex phenomenon involving non linear systems, it is also planned to develop a models using SPSS (Linear regression analysis). The output of this network can be evaluated by comparing it with observed data and the data calculated from the mathematical models. Linear regression is used to specify the nature of the relation between two variables. Another way of looking at it is, given the value of one variable (called the independent variable in SPSS), how can you predict the value of some other variable (called the dependent variable in SPSS)? Remember that you will want to perform a scatter plot and correlation before you perform the linear regression.

4.1 Procedure for Model Formulation in SPSS (Linear regression analysis):

Different software / tools have been developed to construct the linear regression command is found at Analyze | Regression | Linear (this is shorthand for clicking on the Analyze menu item at the top of the window, and then clicking on Regression from the drop down menu, and Linear from the popup menu.)

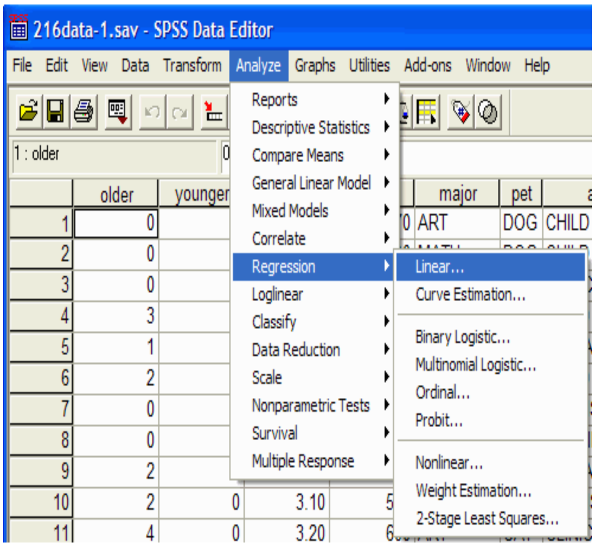

Fig – 3: Linear Regression dialog box

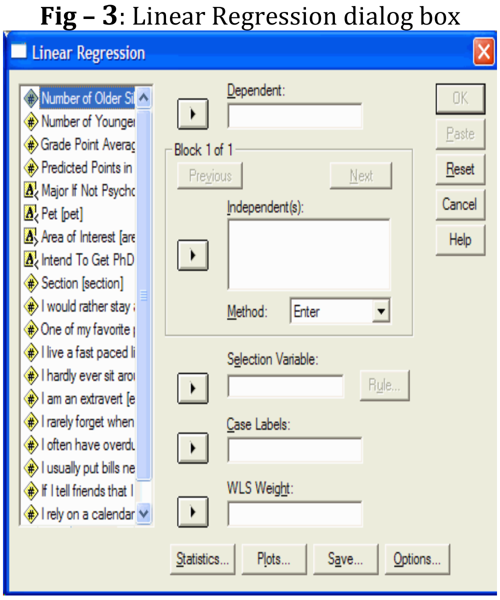

Fig – 4: dialog box for linear regression

Select the variable that you want to predict by clicking on it in the left hand pane of the Linear Regression dialog box. Then click on the top arrow button to move the variable into the Dependent box:

Select the single variable that you want the prediction based on by clicking on it is the left hand pane of the Linear Regression dialog box. (If you move more than one variable into the Independent box, then you will be performing multiple regressions. While this is a very useful statistical procedure, it is usually reserved for graduate classes.) Then click on the arrow button next to the Independent(s) box:

In this example, we are predicting the value of the "I'd rather stay at home than go out with my friends" variable given the value of the extravert variable. You can request SPSS to print descriptive statistics of the independent and dependent variables by clicking on the Statistics button. This will cause the Statistics Dialog box to appear.

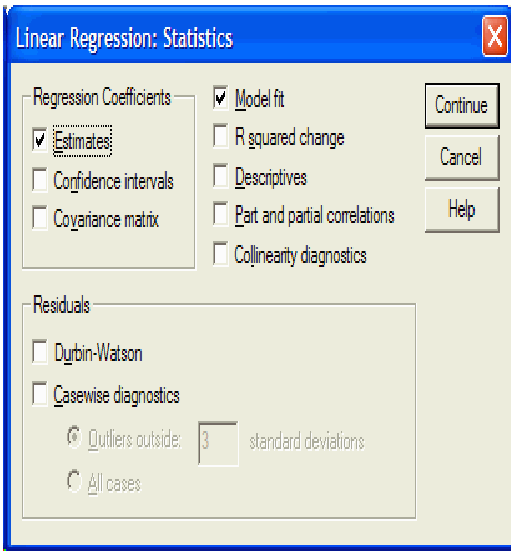

Fig. 5: linear regression statistics dialog box

Click in the box next to Descriptive to select it. Click on the Continue button. In the Linear Regression dialog box, click on OK to perform the regression. The SPSS Output Viewer will appear with the output:

4.2Description of SPSS (linear regression analysis) output

i) Variables Entered/Removed Table

The Variables Entered/Removed part of the output simply states which independent variables are part of the equation (extravert in this example) and what the dependent variable is ("I'd rather stay at home than go out with my friends" in this example.) Check this to make sure that this is what you want (that is, that you want to predict the "I'd rather stay at home than go out with my friends" score given the extravert score.)

ii) Model Summary Table

The Model Summary part of the output is most useful when you are performing multiple regression (which we are NOT doing.) Capital R is the multiple correlation coefficient that tells us how strongly the multiple independent variables are related to the dependent variable. In the simple bivariate case (what we are doing) R = | r | (multiple correlation equals the absolute value of the bivariate correlation.) R square is useful as it gives us the coefficient of determination

iii) ANOVA Table

The ANOVA part of the output is not very useful for our purposes. It basically tells us whether the regression equation is explaining a statistically significant portion of the variability in the dependent variable from variability in the independent variables.

iv) Coefficients Table

The Coefficients part of the output gives us the values that we need in order to write the regression equation. The regression equation will take the form: Predicted variable (dependent variable) = slope * independent variable + intercept.

The slope is how steep the line regression line is. A slope of 0 is a horizontal line, a slope of 1 is a diagonal line from the lower left to the upper right, and a vertical line has an infinite slope. The intercept is where the regression line strikes the Y axis when the independent variable has a value of 0.

v) Histogram- generates a histogram showing the distribution of an individual variable.

vi) Normal P-P plots- the cumulative proportions of a variable's distribution against the

4.3 Output result of processing time – tp (π01)

Table Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Pi 7, Pi 6, Pi 4, Pi 2, Pi 5, Pi 1, Pi 3		Enter

a. Dependent Variable: Pi 01 b. All requested variables entered

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.869	0.755	0.743	0.08538

a. Predictors: (Constant), Pi 7, Pi 6, Pi 4, Pi 2, Pi 5, Pi 1, Pi 3
b. Dependent Variable: Pi 01

ANOVA

Model 1	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.057	7	.437	59.0	.00b
Residual	.991	136	.007		
Total	4.049	143			

Dependent Variable: Pi 01 b. Predictors: (Constant), Pi 7, Pi 6, Pi 4, Pi 2, Pi 5, Pi 1, Pi 3

Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
1	B	Std. Error	Beta			Lower Bound	Upper Bound
Constant	3.674	2.367		1.552	.123	-1.006	8.35
Pi 1	.246	.072	.361	3.398	.001	.103	.389
Pi 2	.441	.074	.558	5.951	.000	.294	.587
Pi 3	-.180	.345	-.090	-.521	.603	-.862	.502
Pi 4	-3.881	2.676	-.073	-1.450	.149	-9.174	1.41
Pi 5	.100	.061	.142	1.626	.106	-.022	.221
Pi 6	.518	.915	.088	.566	.572	-1.291	2.32
Pi 7	.061	.034	.075	1.760	.081	-.007	.128

a. Dependent Variable: Pi 01

Equation of dependent Pi01 term

$$Y\ \ Pi\ 01 = 3.674 + 0.246\,\pi 1 + 0.441\,\pi 2 - 0.180\,\pi 3 - 3.881\,\pi 4 + 0.100\,\pi 5 + 0.518\,\pi 6 + 0.061\,\pi 7 \text{ --------(1)}$$

Residuals Statistics

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.3481	.8896	.5825	.14622	144
Residual	-.27151	.28695	.00000	.08327	144
Std. Predicted Value	-1.603	2.100	.000	1.000	144
Std. Residual	-3.180	3.361	.000	.975	144

a. Dependent Variable: Pi 01

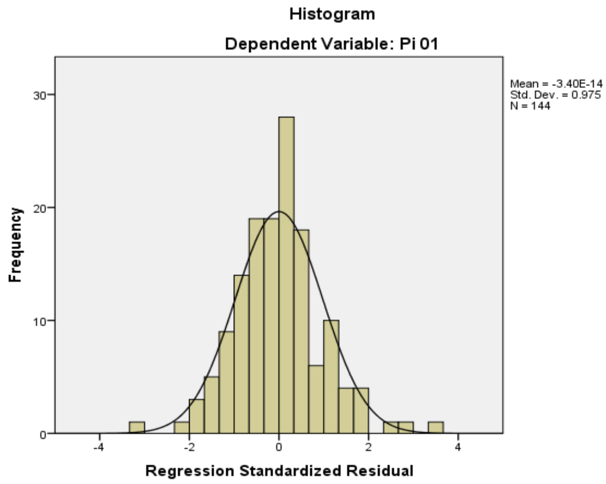

Fig -6: Histogram dependent variable Pi01

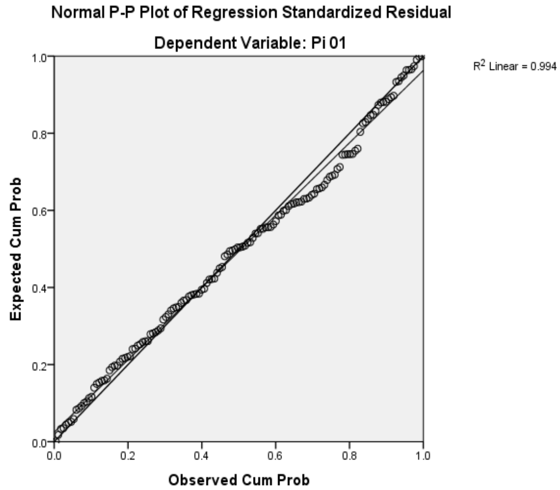

Fig -7: Normal P-P plot of Regression standardized residual (R^2 Linear = 0. 994)

Similarly output result find out for number of bends and resistive torque as follows.

4.4 Output result of Number of bends – nb (π02)

Equation for dependent Pi_{02} term

$$Y\ Pi_{02} = -4.358 + 0.444\,\pi 1 + 0.380\pi 2 - 0.409\,\pi 3 + 3.441\,\pi 4 + 0.078\,\pi 5 + 1.440\,\pi 6 + 0.094\,\pi 7 \text{ --------(2)}$$

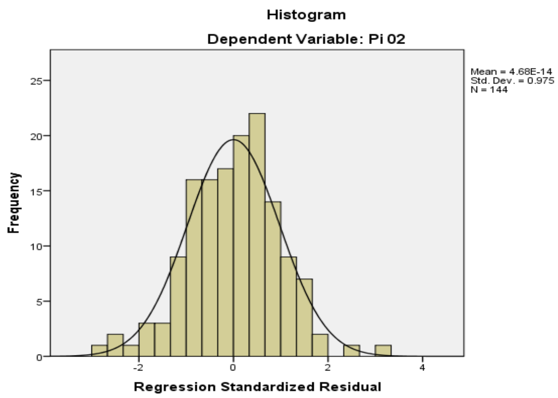

Fig -8: Histogram dependent variable Pi02

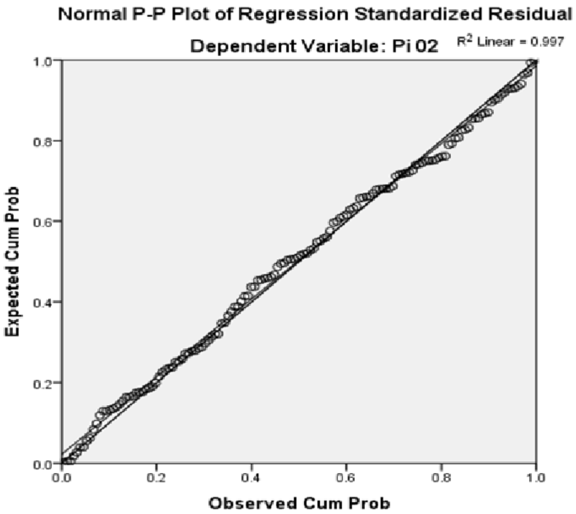

Fig -9: Normal P-P plot of Regression standardized residual (R^2 Linear = 0. 997)

4.5 Output result of Resistive torque–Tr_avg (π03)

Equation of dependent Pi03 term

Y Pi 03 = 3.055 + 0.161 π1 - 0.109 π2 + 1.093 π3 -1.965 π4 - 0.061 π5 - 0.998 π6 – 0.854 π7----------(3)

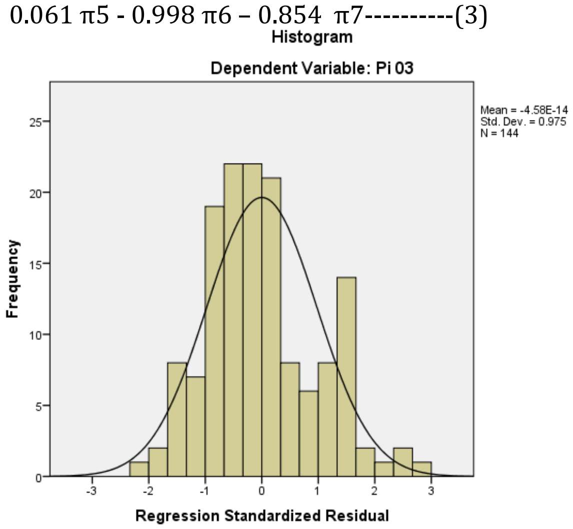

Fig -10: Histogram dependent variable Pi03

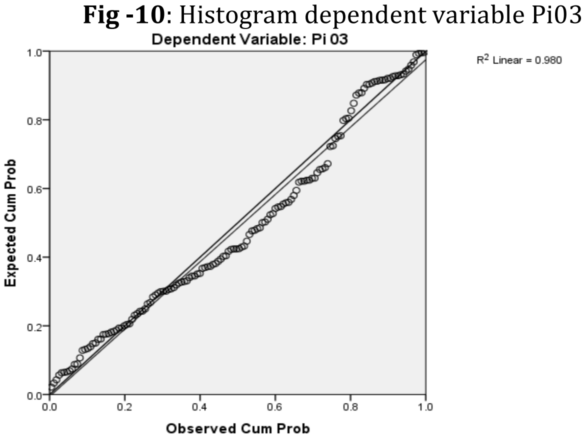

Fig -11: Normal P-P plot of Regression standardized residual (R^2 Linear = 0. 980)

Residual Variance and R-square

R-Square, also known as the Coefficient of determination is a commonly used statistic to evaluate model fit. R-square is 1 minus the ratio of residual variability. When the variability of the residual values around the regression line relative to the overall variability is small, the predictions from the regression equation are good. For example, if there is no relationship between the X and Y variables, then the ratio of the residual variability of the Y variable to the original variance is equal to1.0. Then R-square would be 0.If X and Y are perfectly related then there is no residual variance and the ratio of variance would be 0.0, making R-square=1.

Adjusted R square

The adjusted R-square compares the explanatory power of regression models that contain different numbers of predictors. The adjusted R-square is a modified version of R-square that has been adjusted for the number of predictors in the model. The adjusted R square increases only if the new term improves the model more than would be expected by chance It decreases when a predictor improves the model by less than expected by chance. The adjusted R-square can be negative , but its usually not. It is always lower than the R-square

CONCLUSION

1.The SPSS (Linear regression analysis) is study and SPSS model formed for three dependent response variable similarly find the value of R , R square , Adjusted R square and Standard error of the estimate for processing time , number of bends and resistive torque.

2. By using SPSS (Linear regression analysis) model find out the predicted value and equation for various dependent pi terms and also getting the Histogram dependent variable Pi term and Normal P-P plot of Regression standardized residual , The value of R^2 Linear = 0. 994 for processing time , R^2 Linear = 0. 997 for number of bends and R^2 Linear = 0. 980 resistive torque.

3. A new theory of stirrup making operation from the Human Powered flywheel motor machine is proposed. This hypothesis is validated by using SPSS (linear regression analysis) and formed model is compare with experimental data.

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BIOGRAPHIES

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