ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Title: Analysis some factors to create models in designing evacuating fans

Course:
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Abstract: This project is to create some models which can help the manufacturers in designing the evacuating fans. In flour manufacturing industries, the four is removed from one to another place through the runnels or tube. It is evacuated by evacuating fan. Multiple regression was used in this study

Analysis Some Factors to Create Models in Designing Evacuating Fans

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EMP-P9406

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Project : Analysis some factors
to create models in
designing evacuating
fans
Research Methology in EM.
Instructor : Dick Deckro
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Introduction and Purpose of Study

In flour manufacturing industries, the flour is removed from one to another place through the tunnels or tube. It is evacuated by evacuating fan which is located at the end of the tunnels or some joints of them. In order to evacuate the flour, the fan must have enough power to generate powerful wind to carry the flour through out tunnels. There are many factors which effect on the appearance of fan such as size of the tunnels. The bigger the tunnels, the more powerful the motor . In designing evacuating fans, the manufacturers need a couple information from the users. They would like to know size of the tunnels, flow rate of the wind which carries the flour, and the pressure of the wind in the tunnels especially at the output holes of the fan.

So far, designing evacuating fan in Thailand is based on manufacturers' experience. No equations or any model helps them in designing. They must use their knowledge and experiences they have collected for many years.

Therefore, the principle purpose of this study is to create some models which can help the manufacturers in designing the evacuating fans.

Carrying Out the Research

As said in, the manufacturers need to know the value of there factors in order to design the evacuating fans; the size of the tunnels, flow rate and pressure of the wind. They use three factors to create three characteristics of the fans; power of the motors, rotary speed, and number of propellers.

Getting the data

The data used in this study is from one evacuating fan manufacturer in Thailand. There are 68 sets of data. Each set contains six variables : power of motor; number of propeller; rotary speed; flow rate; size of tunnel; and wind pressure. Those 68 set of data are from the company's data base file. All of them are the characteristics of real evacuating fans which already built. Actually, the company need to keep this data as a precedence to build new evacuating fans.

Type of multivariate analysis used in the study.

In this research there are three step used in carrying out it:

- conduct multiple regression with number of propellers, as a dependent variable, and size of tunnels, flow rate, and pressure of winds as independent variables;
- conduct multiple regression with power of motor, as a dependent variable, and number of propellers, size of tunnels, flow rate, and pressure of winds, as independent variables;
- conduct multiple regression with rotary speed, as a dependent variable, and power of motors, number of propellers, size of tunnels, flow rate, and pressure of winds, as independent variables.

The reason to use these three steps to carrying out the research is simulation the same way as the company to design the evacuating fan in order to decrease percentages of errors.

Conducting multiple regression Analysis

First of all, the manufacturers determine the number of propellers from those three factors. Therefore, in this research, those three factors will be treated as independent variables to determine the number of propellers. I conduct multiple regression to create a model which represents the relationship between dependent variable and these independent variables.

The next step is to determine the power of the fan motor. I will use these three factors and the number of propellers to find the result. Similarly to the first step, multiple regression analysis is conducted to find the relation ship between dependent variables and independent variables.

Until now, we know two of the unknown variables. The remaining is the rotary speed. Multiple regression analysis is still used in the last step. I treated those three and two gotten characteristics as independent variables to find the appropriate model to determine the values of the rotary speed.

The model used in conducting multiple regression

Due to unknowing the real format of relationship between both dependent and independent variables, more complex relationship analysis is conducted instead of using common linear relationship. The reason is to decrease the effect from more than one time square variables. The model used in the analysis is shown in the following form.

$$y = a(x1^{b1})(x2^{b2})...(xn^{bn})$$

Take natural logarithm

$$\ln y = \ln a + b1 \ln x1 + b2 \ln x2 + ... + bn \ln xn$$

Suppose that

$$Y = \ln y$$

$$X1n = \ln xn$$

$$A = \ln a$$

Therefore

$$Y = A + b1\,X11 + b2\,X12 + ... + bn\,X1n$$

With this model, more than 1 time square will become coefficients of the variables which could be solved by multiple regression analysis.

Result of Analysis

The model getting from regression the first step is

$$X12 = 1.141775 + (1.77532\,X16) + (0.664782\,X15)$$

R Square = 0.71067 which represent 71% of changing in X12 is as a result of changing in X15, X16.

F = 162.11 which represents the statistical significance of the equation

T X16 = 8.434 and sig T = 0 . These two values represent the statistical significance of X16 to the equation.

T X15 = 19.627 and sig T = 0 . These two values represent the statistical significance of X15 to the equation.

The model getting from regression the second step is

X11 = -7.224771 + 1.137583*X12 + 0.785659*X16 + 0.508779*X14

R Square = 0.97047 which represent 97% of changing in X12 is as a result of changing in X12, X16, and X14.

F = 701.14 which represents the statistical significance of the equation

T X12 = 7.103 and sig T = 0 . These two values represent the statistical significance of X12 to the equation.

T X16 = 20.282 and sig T = 0 . These two values represent the statistical significance of X16 to the equation.

T X14 = 10.218 and sig T = 0. These two values represent the statistical significance of X14 to the equation.

The model getting from regression the second step is

X11 = -7.224771 + 1.137583*X12 + 0.785659*X16 + 0.508779*X14

R Square = 0.97047 which represent 97% of changing in X12 is as a result of changing in X12, X16, and X14.

F = 701.14 which represents the statistical significance of the equation

T X12 = 7.103 and sig T = 0 . These two values represent the statistical significance of X12 to the equation.

T X16 = -10.929 and sig T = 0 . These two values represent the statistical significance of X16 to the equation.

All of the equation getting from multiple regression analysis are changed to the power form.

$$\mathbf{X1 = 0.000728 * X2^{1.1375583} * X6^{0.785659} * X4^{0.508779}}$$
$$\mathbf{X2 = 3.131323 * X6^{1.77532} * X5^{0.664782}}$$
$$\mathbf{X3 = 7083.129 * X5^{-0.689441} * X1^{0.180716}}$$

ID	X1	X2	X3	X4	X5	X6
1	7.5	28	1445	5000	15	4
2	10	28	1440	3000	15	8
3	10	32	1440	14000	24	2
4	40	42	1472	18000	26	8
5	60	48	1480	35000	32	8
6	20	32	1450	9000	18	10
7	3	22	1420	5000	14	2.5
8	20	42	1460	22000	28	3
9	15	32	1450	17000	26	3
10	3	20	1420	2600	15	4
11	1	16	1410	1750	10	1
12	50	42	1460	27000	26	8
13	30	26	1440	9000	16	28
14	40	42	1472	20000	26	8
15	15	36	1450	10000	20	6
16	125	56	1485	60000	38	8
17	20	32	1460	10000	13	12
18	20	28	1455	7500	18	9
19	25	30	1455	12000	19	9
20	30	30	1470	10000	18	14
21	5	24	1450	6000	15	4
22	5	24	1425	6500	15	3.5
23	40	36	1472	12500	22	12
24	100	52	1475	56000	34	7
25	25	32	1450	9000	20	10
26	5	18	1425	1600	8	11
27	7.5	26	1445	8000	16	4
28	15	42	1450	20000	28	3
29	10	26	1440	9000	16	5
30	15	28	1450	14000	22	5
31	1	16	1410	1500	10	2
32	50	42	1475	7500	14	17
33	30	36	1460	18000	22	10
34	5	24	1425	5000	15	5
35	10	20	1440	3500	12	10
36	7.5	26	1440	7500	16	5
37	100	48	1485	36000	36	12
38	60	48	1480	32000	32	8
39	100	48	1475	45000	32	11
40	25	36	1450	16000	24	6
41	15	24	1450	6200	14	11
42	50	36	1475	17500	22	14
43	20	28	1460	10000	18	10
44	10	24	1450	6000	16	10
45	30	36	1465	21000	24	5
46	30	36	1460	18000	22	10
47	2	18	1420	3000	12	2

48	5.5	20	1440	2000	8	10
49	15	28	1450	12500	20	4.5
50	40	42	1472	20000	26	8
51	7.5	18	2900	3000	8	10
52	20	26	2910	2000	9	24
53	20	28	2920	2900	12	26
54	7.5	18	2920	2500	9	10
55	5.5	16	2900	2000	8	7
56	15	26	2900	1000	7	26
57	1	12	2820	400	5	7
58	40	36	2960	1750	10	50
59	30	28	2920	3500	10	30
60	100	40	2973	10000	20	32
61	15	20	2930	3500	12	15
62	20	28	2920	1750	7	36
63	15	20	2930	5000	10	14
64	15	28	2930	850	8	30
65	5	16	2885	1500	7	7
66	50	36	2960	10000	16	18
67	10	20	2920	3000	10	15
68	3	16	2845	1250	7	4
ID	X11	X12	X13	X14	X15	X16
1	2.014903	3.332205	7.275865	8.517193	2.70805	1.386294
2	2.302585	3.332205	7.272398	8.006368	2.70805	2.079442
3	2.302585	3.465736	7.272398	9.546813	3.178054	0.693147
4	3.688879	3.73767	7.294377	9.798127	3.258097	2.079442
5	4.094345	3.871201	7.299797	10.4631	3.465736	2.079442
6	2.995732	3.465736	7.279319	9.10498	2.890372	2.302585
7	1.098612	3.091042	7.258412	8.517193	2.639057	0.916291
8	2.995732	3.73767	7.286192	9.998798	3.332205	1.098612
9	2.70805	3.465736	7.279319	9.740969	3.258097	1.098612
10	1.098612	2.995732	7.258412	7.863267	2.70805	1.386294
11	0	2.772589	7.251345	7.467371	2.302585	0
12	3.912023	3.73767	7.286192	10.20359	3.258097	2.079442
13	3.401197	3.258097	7.272398	9.10498	2.772589	3.332205
14	3.688879	3.73767	7.294377	9.903488	3.258097	2.079442
15	2.70805	3.583519	7.279319	9.21034	2.995732	1.791759
16	4.828314	4.025352	7.30317	11.0021	3.637586	2.079442
17	2.995732	3.465736	7.286192	9.21034	2.564949	2.484907
18	2.995732	3.332205	7.282761	8.922658	2.890372	2.197225
19	3.218876	3.401197	7.282761	9.392662	2.944439	2.197225
20	3.401197	3.401197	7.293018	9.21034	2.890372	2.639057
21	1.609438	3.178054	7.279319	8.699515	2.70805	1.386294
22	1.609438	3.178054	7.261927	8.779557	2.70805	1.252763
23	3.688879	3.583519	7.294377	9.433484	3.091042	2.484907
24	4.60517	3.951244	7.296413	10.93311	3.526361	1.94591

25	3.218876	3.465736	7.279319	9.10498	2.995732	2.302585
26	1.609438	2.890372	7.261927	7.377759	2.079442	2.397895
27	2.014903	3.258097	7.275865	8.987197	2.772589	1.386294
28	2.70805	3.73767	7.279319	9.903488	3.332205	1.098612
29	2.302585	3.258097	7.272398	9.10498	2.772589	1.609438
30	2.70805	3.332205	7.279319	9.546813	3.091042	1.609438
31	0	2.772589	7.251345	7.31322	2.302585	0.693147
32	3.912023	3.73767	7.296413	8.922658	2.639057	2.833213
33	3.401197	3.583519	7.286192	9.798127	3.091042	2.302585
34	1.609438	3.178054	7.261927	8.517193	2.70805	1.609438
35	2.302585	2.995732	7.272398	8.160518	2.484907	2.302585
36	2.014903	3.258097	7.272398	8.922658	2.772589	1.609438
37	4.60517	3.871201	7.30317	10.49127	3.583519	2.484907
38	4.094345	3.871201	7.299797	10.37349	3.465736	2.079442
39	4.60517	3.871201	7.296413	10.71442	3.465736	2.397895
40	3.218876	3.583519	7.279319	9.680344	3.178054	1.791759
41	2.70805	3.178054	7.279319	8.732305	2.639057	2.397895
42	3.912023	3.583519	7.296413	9.769956	3.091042	2.639057
43	2.995732	3.332205	7.286192	9.21034	2.890372	2.302585
44	2.302585	3.178054	7.279319	8.699515	2.772589	2.302585
45	3.401197	3.583519	7.289611	9.952278	3.178054	1.609438
46	3.401197	3.583519	7.286192	9.798127	3.091042	2.302585
47	0.693147	2.890372	7.258412	8.006368	2.484907	0.693147
48	1.704748	2.995732	7.272398	7.600902	2.079442	2.302585
49	2.70805	3.332205	7.279319	9.433484	2.995732	1.504077
50	3.688879	3.73767	7.294377	9.903488	3.258097	2.079442
51	2.014903	2.890372	7.972466	8.006368	2.079442	2.302585
52	2.995732	3.258097	7.975908	7.600902	2.197225	3.178054
53	2.995732	3.332205	7.979339	7.972466	2.484907	3.258097
54	2.014903	2.890372	7.979339	7.824046	2.197225	2.302585
55	1.704748	2.772589	7.972466	7.600902	2.079442	1.94591
56	2.70805	3.258097	7.972466	6.907755	1.94591	3.258097
57	0	2.484907	7.944492	5.991465	1.609438	1.94591
58	3.688879	3.583519	7.992945	7.467371	2.302585	3.912023
59	3.401197	3.332205	7.979339	8.160518	2.302585	3.401197
60	4.60517	3.688879	7.997327	9.21034	2.995732	3.465736
61	2.70805	2.995732	7.982758	8.160518	2.484907	2.70805
62	2.995732	3.332205	7.979339	7.467371	1.94591	3.583519
63	2.70805	2.995732	7.982758	8.517193	2.302585	2.639057
64	2.70805	3.332205	7.982758	6.745236	2.079442	3.401197
65	1.609438	2.772589	7.96728	7.31322	1.94591	1.94591
66	3.912023	3.583519	7.992945	9.21034	2.772589	2.890372
67	2.302585	2.995732	7.979339	8.006368	2.302585	2.70805
68	1.098612	2.772589	7.953318	7.130899	1.94591	1.386294

REGRESSION X11 WITH X12 X14 X15 X16

```
DATA LIST FREE / ID X1 TO X6 X11 TO X16.
VARIABLE LABELS
 ID  'ID'
/X1  'POWER OF MOTOR (HP)'
/X2  'NUMBER OF PROPELLER'
/X3  'ROTARY SPEED (RPM)'
/X4  'FLOW RATE (CFM)'
/X5  'SIZE OF TUNNEL (SQ CM)'
/X6  'PRESSURE OF WIND (SP)'
/X11 'LN OF MOTOR POWER'
/X12 'LN OF NUMBER OF PROPELLER'
/X13 'LN OF ROTARY SPEED'
/X14 'LN OF FLOR RATE'
/X15 'LN OF TUNNEL SIZE'
/X16 'LN OF WIND PRESSURE'.
BEGIN DATA.
END DATA.
   68 cases are written to the compressed active file.

This procedure was completed at  0:21:30
REGRESSION
/VARIABLES (COLLECT)
/DEPENDENT X11
/METHOD STEPWISE X12 X14 X15 X16
/CASEWISE ALL DEPENDENT PRED.
-----------------------------------------------------------------------------
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     * * * *  M U L T I P L E   R E G R E S S I O N  * * * *


Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..  X11   LN OF MOTOR POWER

Block Number  1.  Method:  Stepwise    Criteria  PIN  .0500   POUT  .1000
  X12     X14     X15     X16
-----------------------------------------------------------------------------
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     * * * *  M U L T I P L E   R E G R E S S I O N  * * * *

Equation Number 1    Dependent Variable..  X11   LN OF MOTOR POWER


Variable(s) Entered on Step Number
  1..   X12      LN OF NUMBER OF PROPELLER


Multiple R          .88268
R Square            .77913
Adjusted R Square   .77579
Standard Error      .52668
```

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	64.58234	64.58234
Residual	66	18.30781	.27739

F = 232.82055 Signif F = .0000

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X11 LN OF MOTOR POWER

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
X12	2.856615	.187215	.882684	15.258	.0000
(Constant)	-6.819276	.629408		-10.834	.0000

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
X14	-.073157	-.083731	.289333	-.677	.5005
X15	-.296939	-.340309	.290099	-2.918	.0048
X16	.386314	.805124	.959352	10.944	.0000

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X11 LN OF MOTOR POWER

Variable(s) Entered on Step Number
2.. X16 LN OF WIND PRESSURE

Multiple R .96037
R Square .92230
Adjusted R Square .91991
Standard Error .31477

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	76.44990	38.22495
Residual	65	6.44025	.09908

F = 385.79603 Signif F = .0000

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X11 LN OF MOTOR POWER

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
X12	2.604555	.114235	.804799	22.800	.0000
X16	.557077	.050901	.386314	10.944	.0000
(Constant)	-7.155482	.377419		-18.959	.0000

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
X14	.499793	.787372	.188392	10.218	.0000
X15	.445986	.594099	.137872	5.909	.0000

Variable(s) Entered on Step Number
3.. X14 LN OF FLOR RATE

Multiple R .98513
R Square .97047
Adjusted R Square .96909
Standard Error .19556

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	3	80.44256	26.81419
Residual	64	2.44759	.03824

F = 701.14191 Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T

X12	1.137583	.160156	.351509	7.103	.0000
X16	.785659	.038737	.544828	20.282	.0000
X14	.508779	.049794	.499793	10.218	.0000
(Constant)	-7.224771	.234580		-30.799	.0000

------------ Variables not in the Equation ------------

Variable	Beta In	Partial	Min Toler	T	Sig T
X15	-.072040	-.093675	.049927	-.747	.4580

End Block Number 1 PIN = .050 Limits reached.

**** MULTIPLE REGRESSION ****

Casewise Plot of Standardized Residual

*: Selected M: Missing

```
         -3.0          0.0          3.0
 Case #   O:..............:..............:O      X11      *PRED
     1    .            .*             .     2.01     1.9884
     2    .            .*             .     2.30     2.2731
     3    .            .   *          .     2.30     2.1196
     4    .            .*             .     3.69     3.6460
     5    .           *.              .     4.09     4.1362
     6    .         *  .              .     3.00     3.1593
     7    .       *    .              .     1.10     1.3448
     8    .            *              .     3.00     2.9775
     9    .            .  *           .     2.71     2.5369
    10    .         *  .              .     1.10     1.2729
    11    .            .    *         .      .00     -.2715
    12    .            . *            .     3.91     3.8522
 Case #   O:..............:..............:O      X11      *PRED
         -3.0          0.0          3.0
```


Casewise Plot of Standardized Residual

*: Selected M: Missing

```
         -3.0          0.0          3.0
 Case #   O:..............:..............:O      X11      *PRED
    13    .       *    .              .     3.40     3.7320
    14    .            *              .     3.69     3.6996
    15    .        *   .              .     2.71     2.9455
    16    .            .    *         .     4.83     4.5858
```

```
  17   .     *      .         .    3.00     3.3561
  18   .            .  *      .    3.00     2.8318
  19   .            . *       .    3.22     3.1494
  20   .            *         .    3.40     3.4038
  21   .      *     .         .    1.61     1.9058
  22   .       *    .         .    1.61     1.8416
  23   .            . *       .    3.69     3.6036
  24   .            .    *    .    4.61     4.3615
  25   .            . *       .    3.22     3.1593
  26   .          * .         .    1.61     1.7008
Case #   O:..............:..............:O     X11      *PRED
       -3.0          0.0          3.0
-------------------------------------------------------------------------
```


Casewise Plot of Standardized Residual

*: Selected M: Missing

```
       -3.0          0.0          3.0
Case #   O:..............:..............:O     X11      *PRED
  27   .          * .         .    2.01     2.1432
  28   .       *    .         .    2.71     2.9290
  29   .          * .         .    2.30     2.3785
  30   .            .*        .    2.71     2.6876
  31   .        *   .         .     .00      .1947
  32   .            .  *      .    3.91     3.7927
  33   .       *    .         .    3.40     3.6459
  34   .    *       .         .    1.61     1.9884
  35   .            .  *      .    2.30     2.1441
  36   .      *     .         .    2.01     2.2857
  37   .            .  *      .    4.61     4.4691
  38   .            *         .    4.09     4.0906
  39   .            . *       .    4.61     4.5142
  40   .            .*        .    3.22     3.1846
Case #   O:..............:..............:O     X11      *PRED
       -3.0          0.0          3.0
-------------------------------------------------------------------------
```


Casewise Plot of Standardized Residual

*: Selected M: Missing

```
       -3.0          0.0          3.0
Case #   O:..............:..............:O     X11      *PRED
  41   .            *         .    2.71     2.7173
  42   .            *         .    3.91     3.8959
  43   .          * .         .    3.00     3.0610
  44   .     *      .         .    2.30     2.6257
  45   .            .    *    .    3.40     3.1798
  46   .       *    .         .    3.40     3.6459
  47   .            *         .     .69      .6813
```

```
   48  .        * .          .   1.70    1.8593
   49  .          . *        .   2.71    2.5471
   50  .          *          .   3.69    3.6996
   51  .          .*         .   2.01    1.9458
   52  .          . *        .   3.00    2.8456
   53  .       *  .          .   3.00    3.1819
   54  .          . *        .   2.01    1.8530
 Case #  O:..............:..............:O    X11     *PRED
      -3.0          0.0          3.0
```


Casewise Plot of Standardized Residual

*: Selected M: Missing

```
      -3.0          0.0          3.0
 Case #  O:..............:..............:O    X11     *PRED
   55  .          .     *    .   1.70    1.3253
   56  .          . *        .   2.71    2.5559
   57  .       *  .          .    .00     .1792
   58  .         *.          .   3.69    3.7245
   59  .          *          .   3.40    3.3900
   60  .          .   *      .   4.61    4.3805
   61  .          .   *      .   2.71    2.4626
   62  .       *  .          .   3.00    3.1806
   63  .          . *        .   2.71    2.5899
   64  .          .*         .   2.71    2.6699
   65  .          .     *    .   1.61    1.1789
   66  .          . *        .   3.91    3.8087
   67  .         *.          .   2.30    2.3842
   68  .          .      *   .   1.10     .6465
 Case #  O:..............:..............:O    X11     *PRED
      -3.0          0.0          3.0
```


**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X11 LN OF MOTOR POWER

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
*PRED	-.2715	4.5858	2.7349	1.0957	68
*RESID	-.3789	.4521	.0000	.1911	68
*ZPRED	-2.7437	1.6891	.0000	1.0000	68
*ZRESID	-1.9377	2.3120	.0000	.9774	68

Total Cases = 68

This procedure was completed at 0:21:51

SET/LISTING 'B:J2.RUN'.
•

REGRESSION X12 WITH X14 X15 X16

```
DATA LIST FREE / ID X1 TO X6 X11 TO X16.
VARIABLE LABELS
 ID  'ID'
/X1  'POWER OF MOTOR (HP)'
/X2  'NUMBER OF PROPELLER'
/X3  'ROTARY SPEED (RPM)'
/X4  'FLOW RATE (CFM)'
/X5  'SIZE OF TUNNEL (SQ CM)'
/X6  'PRESSURE OF WIND (SP)'
/X11 'LN OF MOTOR POWER'
/X12 'LN OF NUMBER OF PROPELLER'
/X13 'LN OF ROTARY SPEED'
/X14 'LN OF FLOR RATE'
/X15 'LN OF TUNNEL SIZE'
/X16 'LN OF WIND PRESSURE'.
BEGIN DATA.
END DATA.
   68 cases are written to the compressed active file.

This procedure was completed at  0:23:18
REGRESSION
/VARIABLES (COLLECT)
/DEPENDENT X12
/METHOD STEPWISE X14 X15 X16
/CASEWISE ALL DEPENDENT PRED.
------------------------------------------------------------------------------
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     * * * *  M U L T I P L E   R E G R E S S I O N  * * * *


Listwise Deletion of Missing Data

Equation Number 1   Dependent Variable..  X12   LN OF NUMBER OF PROPELLER

Block Number  1.  Method:  Stepwise    Criteria  PIN  .0500   POUT  .1000
  X14     X15     X16
------------------------------------------------------------------------------
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     * * * *  M U L T I P L E   R E G R E S S I O N  * * * *

Equation Number 1   Dependent Variable..  X12   LN OF NUMBER OF PROPELLER


Variable(s) Entered on Step Number
  1..   X14      LN OF FLOR RATE


Multiple R          .84301
R Square            .71067
Adjusted R Square   .70628
Standard Error      .18627
```

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	5.62441	5.62441
Residual	66	2.28985	.03469

F = 162.11114 Signif F = .0000

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X12 LN OF NUMBER OF PROPELLER

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
X14	.265171	.020827	.843011	12.732	.0000
(Constant)	1.003488	.185254		5.417	.0000

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
X15	.423676	.215867	.075111	1.782	.0794
X16	.320617	.590656	.981962	5.901	.0000

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X12 LN OF NUMBER OF PROPELLER

Variable(s) Entered on Step Number
2.. X16 LN OF WIND PRESSURE

Multiple R .90089
R Square .81161
Adjusted R Square .80581
Standard Error .15145

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	6.42328	3.21164
Residual	65	1.49098	.02294

F = 140.01287 Signif F = .0000

**** MULTIPLE REGRESSION ****

Equation Number 1   Dependent Variable.. X12   LN OF NUMBER OF PROPELLER

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
X14	.278716	.017089	.886071	16.310	.0000
X16	.142861	.024208	.320617	5.901	.0000
(Constant)	.581490	.166742		3.487	.0009

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
X15	.858932	.516324	.068075	4.823	.0000

Variable(s) Entered on Step Number
3..   X15   LN OF TUNNEL SIZE

Multiple R   .92835
R Square   .86183
Adjusted R Square   .85536
Standard Error   .13071

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	3	6.82076	2.27359
Residual	64	1.09350	.01709

F =   133.06771   Signif F = .0000

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
X14	.021953	.055240	.069791	.397	.6924

X16	.175257	.021946	.393322	7.986	.0000
X15	.615878	.127690	.858932	4.823	.0000
(Constant)	1.087174	.178050		6.106	.0000

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X12 LN OF NUMBER OF PROPELLER

Variable(s) Removed on Step Number
4.. X14 LN OF FLOR RATE

Multiple R	.92817
R Square	.86149
Adjusted R Square	.85723
Standard Error	.12986

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	6.81806	3.40903
Residual	65	1.09620	.01686

F = 202.14130 Signif F = .0000

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X12 LN OF NUMBER OF PROPELLER

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
X16	.177532	.021049	.398426	8.434	.0000
X15	.664782	.033871	.927135	19.627	.0000
(Constant)	1.141775	.112515		10.148	.0000

------------ Variables not in the Equation ------------

Variable	Beta In	Partial	Min Toler	T	Sig T
X14	.069791	.049615	.068075	.397	.6924

End Block Number 1 PIN = .050 Limits reached.

**** MULTIPLE REGRESSION ****

Equation Number 1   Dependent Variable.. X12   LN OF NUMBER OF PROPELLER

Casewise Plot of Standardized Residual

*: Selected   M: Missing

```
        -3.0           0.0          3.0
Case #  O:.............:.............:O     X12     *PRED
   1    .              .     *        .   3.33    3.1881
   2    .              .*             .   3.33    3.3112
   3    .              .  *           .   3.47    3.3775
   4    .              . *            .   3.74    3.6769
   5    .              . *            .   3.87    3.8149
   6    .              *              .   3.47    3.4720
   7    .              .*             .   3.09    3.0588
   8    .              .      *       .   3.74    3.5520
   9    .             *.              .   3.47    3.5027
  10    .        *     .              .   3.00    3.1881
Case #  O:.............:.............:O     X12     *PRED
        -3.0           0.0          3.0
```

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Casewise Plot of Standardized Residual

*: Selected   M: Missing

```
        -3.0           0.0          3.0
Case #  O:.............:.............:O     X12     *PRED
  11    .              .  *           .   2.77    2.6725
  12    .              . *            .   3.74    3.6769
  13    .   *          .              .   3.26    3.5765
  14    .              . *            .   3.74    3.6769
  15    .              .   *          .   3.58    3.4514
  16    .              .  *           .   4.03    3.9291
  17    .              .     *        .   3.47    3.2881
  18    .         *    .              .   3.33    3.4533
  19    .           *  .              .   3.40    3.4893
  20    .         *    .              .   3.40    3.5318
  21    .              *              .   3.18    3.1881
  22    .              .*             .   3.18    3.1644
  23    .            * .              .   3.58    3.6378
  24    .              .   *          .   3.95    3.8315
Case #  O:.............:.............:O     X12     *PRED
        -3.0           0.0          3.0
```

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Casewise Plot of Standardized Residual

*: Selected   M: Missing

```
      -3.0             0.0             3.0
Case #  O:..............:..............:O   X12    *PRED
  25    .            *  .               .   3.47   3.5421
  26    .             * .               .   2.89   2.9499
  27    .               .*              .   3.26   3.2311
  28    .               .      *        .   3.74   3.5520
  29    .               *               .   3.26   3.2707
  30    .         *     .               .   3.33   3.4824
  31    .              *.               .   2.77   2.7955
  32    .               .           *   .   3.74   3.3992
  33    .              *.               .   3.58   3.6054
  34    .             * .               .   3.18   3.2278
  35    .       *       .               .   3.00   3.2025
  36    .               *               .   3.26   3.2707
  37    .           *   .               .   3.87   3.9652
  38    .               . *             .   3.87   3.8149
Case #  O:..............:..............:O   X12    *PRED
      -3.0             0.0             3.0
------------------------------------------------------------------------------
```

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Casewise Plot of Standardized Residual

*: Selected M: Missing

```
      -3.0             0.0             3.0
Case #  O:..............:..............:O   X12    *PRED
  39    .               *               .   3.87   3.8714
  40    .               *               .   3.58   3.5726
  41    .         *     .               .   3.18   3.3219
  42    .            *  .               .   3.58   3.6652
  43    .          *    .               .   3.33   3.4720
  44    .       *       .               .   3.18   3.3937
  45    .               . *             .   3.58   3.5402
  46    .              *.               .   3.58   3.6054
  47    .              *.               .   2.89   2.9168
  48    .               . *             .   3.00   2.9329
  49    .            *  .               .   3.33   3.4003
  50    .               . *             .   3.74   3.6769
  51    .             * .               .   2.89   2.9329
  52    .               .   *           .   3.26   3.1667
Case #  O:..............:..............:O   X12    *PRED
      -3.0             0.0             3.0
------------------------------------------------------------------------------
```

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Casewise Plot of Standardized Residual

*: Selected M: Missing

```
      -3.0             0.0             3.0
Case #  O:..............:..............:O   X12    *PRED
```

```
  53  .        * .         .   3.33    3.3721
  54  .       *  .         .   2.89    3.0112
  55  .        * .         .   2.77    2.8696
  56  .          .    *    .   3.26    3.0138
  57  .        * .         .   2.48    2.5572
  58  .          .    *    .   3.58    3.3670
  59  .          . *       .   3.33    3.2763
  60  .         *.         .   3.69    3.7486
  61  .  *       .         .   3.00    3.2745
  62  .          .     *   .   3.33    3.0716
  63  .      *   .         .   3.00    3.1410
  64  .          .    *    .   3.33    3.1280
  65  .          *         .   2.77    2.7808
  66  .          . *       .   3.58    3.4981
Case #  O:..............:..............:O    X12     *PRED
     -3.0           0.0          3.0
```

Casewise Plot of Standardized Residual

*: Selected M: Missing

```
     -3.0           0.0          3.0
Case #  O:..............:..............:O    X12     *PRED
  67  .       *  .         .   3.00    3.1533
  68  .          . *       .   2.77    2.6815
Case #  O:..............:..............:O    X12     *PRED
     -3.0           0.0          3.0
```

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X12 LN OF NUMBER OF PROPELLER

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
*PRED	2.5572	3.9652	3.3446	.3190	68
*RESID	-.3184	.3385	.0000	.1279	68
*ZPRED	-2.4684	1.9454	.0000	1.0000	68
*ZRESID	-2.4519	2.6067	.0000	.9850	68

Total Cases = 68

This procedure was completed at 0:23:38

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**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X13 LN OF ROTARY SPEED

------------------ Variables in the Equation ------------------

Variable	B	SE B	Beta	T	Sig T
X15	-.689441	.063086	-1.066644	-10.929	.0000
X11	.180716	.027186	.648787	6.647	.0000
(Constant)	8.865471	.138370		64.071	.0000

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
X12	-.234798	-.125127	.099812	-1.009	.3168
X14	-.300213	-.124727	.060664	-1.006	.3184
X16	-.267192	-.156524	.071689	-1.268	.2095

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**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X13 LN OF ROTARY SPEED

End Block Number 1 PIN = .050 Limits reached.

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**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. X13 LN OF ROTARY SPEED

Casewise Plot of Standardized Residual

*: Selected M: Missing

```
        -3.0        0.0        3.0
 Case #  O:..........:..........:O     X13     *PRED
    1    .         * .          .     7.28    7.3626
    2    .        *  .          .     7.27    7.4145
    3    .           .  *       .     7.27    7.0905
    4    .           *          .     7.29    7.2858
    5    .           . *        .     7.30    7.2160
    6    .        *  .          .     7.28    7.4141
    7    .           *          .     7.26    7.2445
    8    .           .  *       .     7.29    7.1095
```

Confirmation the equation

For the power of motor, even though we get its value from the equation, we need to change that value to the common value which can be easy to find in the
market. For example, 7.303926 from first set of data is translated to 7.5 Hp which can easily buy in the market.

Also, the number of propellers are changed to the closest even number because the number of propellers can only be built in even number.

Supposed that we can not use any error which is more than 10 %.

To confirmation the equation, by applied 68 set of data in

$\mathbf{X1 = 0.000728 * X2^{1.1375583} * X6^{0.785659} * X4^{0.508779}}$, the result indicates 50 useable values.

$\mathbf{X2 = 3.131323 * X6^{1.77532} * X5^{0.664782}}$, the result indicates 38 useable values.

$\mathbf{X3 = 7083.129 * X5^{-0.689441} * X1^{0.180716}}$, the result indicates 36 useable values.