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Analysis&Optimization of Design Parameters of Mechanisms Using Ga

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ABSTRACT

The main objective of this study is to investigate of dynamic reaction forces of a crank mechanism. Therefore, this study consists of three major sections: (1) dynamic reactions investigation, (2) analysis of the mechanisms (3) optimization for static analysis. Analysis on slider crank mechanism is performed to calculate the reaction forces. This data is implemented for regression analysis for regression equation. These parameters are aimed to be optimized using GA. Because genetic algorithm is give good optimal values comparing to traditional optimization. This traditional optimization was done by using MATLAB.

KEYWORDS: *dynamic reactions, regression analysis, genetic algorithm (GA), MATLAB.*

I. INTRODUCTION

Here mechanism is a slider-crank mechanism. The slider-crank mechanism is one of the most useful mechanisms in modern technology since it appears in most of the internal combustion engines including automobiles, trucks and small engines. The slider-crank kinematic chain consists of four bodies linked with three cylindrical joints and one sliding or prismatic joint. It is used to change circular into reciprocating motion, or reciprocating into circular motion.

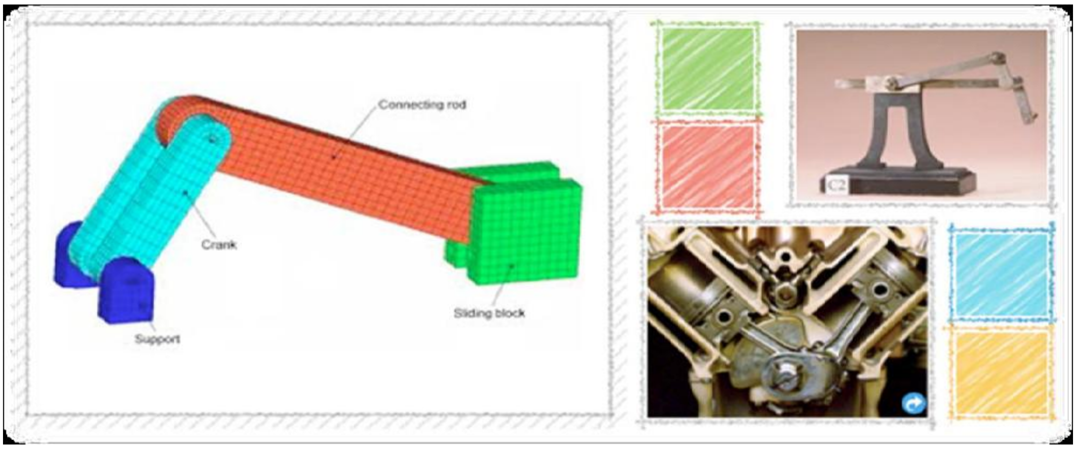


Figure 1: Slider Crank

The arm may be a bent portion of the shaft, or a separate arm attached to it. Attached to the end of Velocity analysis of slider crank mechanism the crank by a pivot is a rod, usually called a connecting rod. The end of the rod attached to the crank moves in a circular motion, while the other end is usually constrained to move in a linear sliding motion, in and out.

A mechanism is used to produce mechanical transformations in a machine. This transformation could be any of the following.

- It may convert one speed to another speed.
- It may convert one force to another force.

- It may convert one torque to another torque.
- It may convert force into torque.
- It may convert one angular motion to another angular motion.
- It may convert angular motion into linear motion.
- It may convert linear motion into angular motion.

1.1 STUDY OBJECTIVES :-

- Determine all loads acting on the links in a mechanism to allow stress and deflection analysis.
- Determine input torque(s) required to produce desired motion in a mechanism(input torque = torque supplied by input device)
- This present study in the design of machine elements includes the minimization of weight of the individual components in order to reduce the over all weight of the machine elements.
- It saves both cost and energy involved.
- The most important problem that confronts practical engineers is the mechanical design, a field of creativity.
- Mechanical design can be defined as the selection of materials and geometry, which satisfies the specified and implied functional requirements while remaining within the confines of inherently unavoidable limitations.

1.2MAT LAB :-

Here we can calculate the dynamic reactions of a slider crank mechanism by using MATLAB. MATLAB is an abbreviation for MATrix LABoratory. It is a matrix-based system for scientific calculations. we can solve numerical problems without necessarily having to write a long pro-gram. This course provides an introduction to MATLAB. It will provide the basics of MATLAB programming and applications (primarily) for macroeconomics and international finance. MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, we can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions are enable to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java. we can use MATLAB for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. More than a million engineers and scientists in industry and academia use MATLAB, the language of technical computing.

1..2.1Genetic algorithm :

The Genetic Algorithm and Direct Search Toolbox is a collection of functions that extend the capabilities of the Optimization Toolbox and the MATLAB® numeric computing environment. The Genetic Algorithm and Direct Search Toolbox includes routines for solving optimization problems using

•Genetic algorithm

•Direct search

These algorithms are enabling to solve a variety of optimization problems that lie outside the scope of the standard Optimization Toolbox. All the toolbox functions are MATLAB M-files, made up of MATLAB statements that implement specialized optimization algorithms. we can view the MATLAB code for these functions using the statement

type function _ name

we can extend the capabilities of the Genetic Algorithm and Direct Search Toolbox by writing our own M-files, or by using the toolbox in combination with other toolboxes, or with MATLAB or Simulink®.

Dynamic reaction forces on MATLAB :

```
%1lb=453.592grams
g=386.4;
wbd=5.5*453.592; %weight of the connecting rod
wp=6.3*453.592; %weight of the piston
mp=wp/g; %mass of the piston
mbd=wbd/g;
l=10; %length of the connecting rod
b=3.5; %crank radius
i_bar=(1/12)*mbd*l^2; %mass moment of inertia
```

```
omega_AB=1000*(2*pi)/60;
v_B=b*omega_AB;
theta=[0:10:180];
t=theta*pi/180;
beta=asin(b*sin(t)/l);
omega_BD=v_B*cos(t)./(l*cos(beta));
%acceleration
a_B=b*omega_AB^2;
alpha_BD=(l.*omega_BD.^2.*sin(beta)-a_B.*sin(t))./(l.*cos(beta));
a_D=a_B.*cos(t)+l.*omega_BD.^2.*cos(beta)+l.*alpha_BD.*sin(beta);
%
ax_bar=-0.5*a_B*sin(t);
ay_bar=0.5*a_B*cos(t)+0.5*a_D;
Dy=-mp*a_D;
Dx=-Dy.*tan(beta)+(i_bar*alpha_BD)./(l*cos(beta))-mbd*ax_bar./2+mbd*ay_bar.*tan(beta)./2;
Bx=mbd*ax_bar+Dx;
By=mbd*ay_bar-Dy;
%
%determine and plot values
z=[theta;Bx;By;Dx;Dy;ax_bar;ay_bar];
fprintf('theta   Bx     By     Dx     Dy     ax_bar    ay_bar\n')
fprintf('(deg)  (gr)   (gr)   (gr)   (gr)   (m/s^2)   (m/s^2)\n')
fprintf('\n')
fprintf('%5.0f  %5.0f  %5.0f  %5.0f   %5.0f   %5.0f    %5.0f\n',z);
fprintf('\n');
figure(1)
plot(theta,Bx,theta,By)
xlabel('theta(degrees)')
ylabel('dynamic reactions(gr)')
legend('Bx','By')
grid on
%
figure(2)
plot(theta,Dx,theta,Dy)
xlabel('theta(degrees)')
ylabel('dynamic reactions(gr)')
legend('Dx','Dy',2)
grid on
%
figure(3)
subplot(2,1,1);
plot(theta,ax_bar);
xlabel('theta(degrees)')
ylabel('x_acceleration(m/s^2)')
grid on
subplot(2,1,2);
plot(theta,ay_bar);
xlabel('theta(degrees)')
ylabel('y_acceleration(m/s^2)')
grid on
```

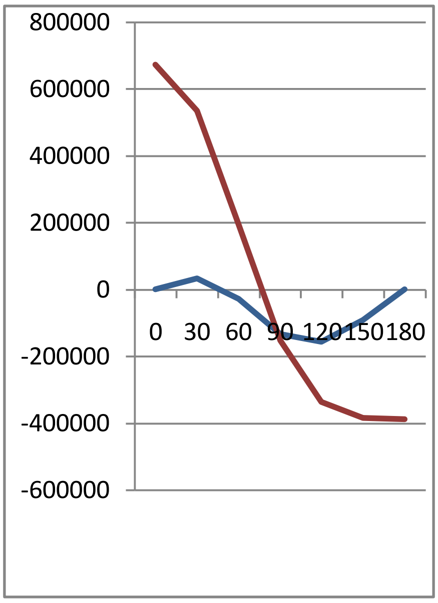
Out put:

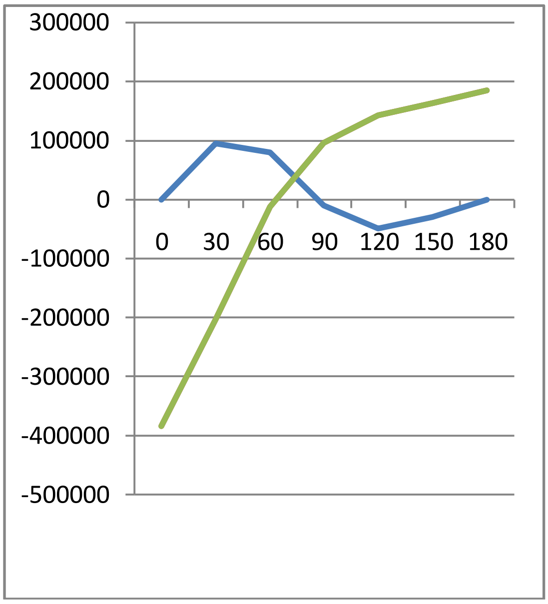
Theta (deg)	Bx (gr)	By (gr)	Dx (gr)	Dy (gr)	ax_bar (m/s^2)	ay_bar (m/s^2)
0	0	674377	0	-383202	0	0 45099

10	17488	658456	39003	-373429	-3332	44146
20	30081	611562	72458	-344676	-6564	41337
30	33591	536343	95543	-298668	-9595	36812
40	25255	437293	104899	-238340	-12336	30815
50	4419	320762	99335	-167850	-14701	23684
60	-27010	194739	80294	-92437	-16620	15845
70	-64614	68217	51818	-17987	-18034	7780
80	-102289	-49923	19733	49731	-18899	-30
90	-133761	-152351	-9856	106057	-19191	-7170
100	-154287	-234567	-32265	148312	-18899	-13360
110	-161754	-295461	-45322	176180	-18034	-18475
120	-156707	-336923	-49402	191416	-16620	-22537
130	-141470	-362729	-46554	197065	-14701	-25659
140	-118990	-377260	-39346	196549	-12336	-27989
150	-91942	-384522	-29989	192980	-9595	-29967
160	-62319	-387635	-19942	188794	-6564	-30798
170	-31414	-388714	-9899	185653	-3332	-31451
180	0	-388947	0	184505	0	-31665

Plots:

theta(deg) vs dynamic reaction(gr)





2.Response surface optimization of slider crank mechanism:-

Std	run	Factor 1 A:A	Response 1 R1	Response 2 R2	Response 3 R3	Response 4 R4
1	1	0	0	674377	0	-383202
2	2	10	17488	658456	39003	-373429
3	3	20	30081	611562	72458	-344676
4	4	30	33591	536343	95543	-298668
5	5	40	25255	437293	104899	-238340
6	6	50	4419	320762	99335	-167850
7	7	60	-27010	194739	80294	-92437
8	8	70	-64614	68217	51818	-17987
9	9	80	-102289	-49923	19733	49731
10	10	90	-133761	-152351	-9856	106057
11	11	100	-154287	-234567	-32265	148312
12	12	110	-161754	-295461	-45322	176180
13	13	120	-156707	-336923	-49402	191416

14	14	130	-141470	-362729	-46554	197065
15	15	140	-118990	-377260	-39346	196549
16	16	150	-91942	-384522	-29989	192980
17	17	160	-62319	-387635	-19942	188794
18	18	170	-31414	-388714	-9899	185653
19	19	180	0	-388947	0	184505

2.1 ANOVA table:

Response 1:

Source	Sum of Squares	df	Mean square	F value	p-value prob>F	
Model	9.037E+010	6	1.506E+010	7759.79	<0.0001	significant
A-A	1.888E+010	1	1.888E+010	9725.85	<0.0001	
A^2	4.921E+009	1	4.921E+009	2535.55	<0.0001	
A^3	3.638E+009	1	3.638E+009	1874.39	<0.0001	
A^4	1.022E+009	1	1.022E+009	526.47	<0.0001	
A^5	7.862E+008	1	7.862E+008	405.04	<0.0001	
A^6 RESIDUAL	4.082E+008 2.329E+007	1 12	4.082E+008 1.941E+006	210.32	<0.0001	
COR TOTAL	9.039E+010	18				

Obser vations:

I. The model F-value of 7759.79 implies the model is significant. There is only a 0.01% chance that a "model F-value" this large could due to noise.
II. Values of " prob>F " less than 0.0500 indicate model terms are significant.
III. In this case A,A^2,A^3,A^4,A^5,A^6 are significant model terms.
IV. Values greater than 0.1000 indicate the model terms are not significant.
V. If there are many insignificant model terms(not counting those required to support hierarchy), model reduction may improve the model.

R-Squared Results:

Std.Dev	1393.17	R-squared	0.9997
Mean	-59774.89	Adj R-squared	0.9996
C.V.%	2.33	Pred R-squared	0.9968

PRESS	2.903E+008	Adeq precision	232.752

The " pred R-squared"of 0.9968 is in reasonable agreement with the " adj R-squared" of 0.9996.
"adeq precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 232.752 indicates an adequate signal. This model can be used to navigate the design space.
Model equation of response1:-

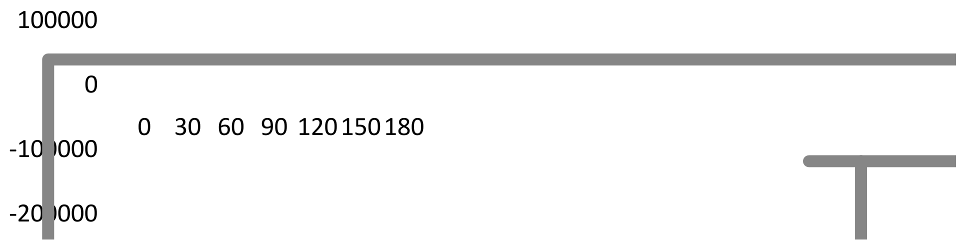
R1= +121.51151+748.60025*A+103.03328*A^2-4.26162*A^3+0.048831*A^4-2.25466E-004*A^5+3.74055E-007*A^6.

Proceed to diagnostics plots(the next icon in progression). Be sure to look at the:

1. Normal probability plot to the studentized residuals to check for normality of residuals.
2. Studentized residuals versus predicted values to check for constant error.
3. Externally studentized residuals to look for outliers, i.e., influential values.
4. Box-Cox plot for power transmissions

If all the model statistics and diagnostic plots are OK, finish up with the model graphs icon.

R1 vs A:A



Response 2:

Source	Sum of Squares	df	Mean square	F value	p-value prob>F	
Model	3.042E+012	6	5.069E+011	5.474E+005	<0.0001	significant
A-A	2.433E+011	1	2.433E+011	2.628E+011	<0.0001	
A^2	1.870E+010	1	1.870E+010	20199.67	<0.0001	
A^3	3.088E+009	1	3.088E+009	3334.99	<0.0001	
A^4	2.414E+009	1	2.414E+009	2606.43	<0.0001	
A^5	5.986E+007	1	5.986E+007	64.64	<0.0001	
A^6	5.380E+008	1	5.380E+008	581.06	<0.0001	
RESIDUAL	1.111E+007	12	9.260E+005			
COR TOTAL	3.042E+012	18				

Obser vations:

1. The model F-value of 547448.75 implies the model is significant. There is only a 0.01% chance that a model F-value" this large could due to noise.
2. values of " prob>F " less than 0.0500 indicate model terms are significant.
3 In this case A,A^2,A^3,A^4,A^5,A^6 are significant model terms.
4. Values greater than 0.1000 indicate the model terms are not significant.
5 If there are many insignificant model terms(not counting those required to support hierarchy), model reduction may improve the model.

R-Squared Results:

Std.Dev	962.28	R-squared	1.0000
Mean	7511.42	Adj R-squared	1.0000
C.V.%	12.81	Pred R-squared	1.000
PRESS	1.037E+008	Adeq precision	1822.836

The " pred R-squared"of 1.0000 is in reasonable agreement with the " adj R-squared" of 1.0000 "adeq precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of1822.836 indicates an adequate signal. This model can be used to navigate the design space.

Model equation of respone2:-

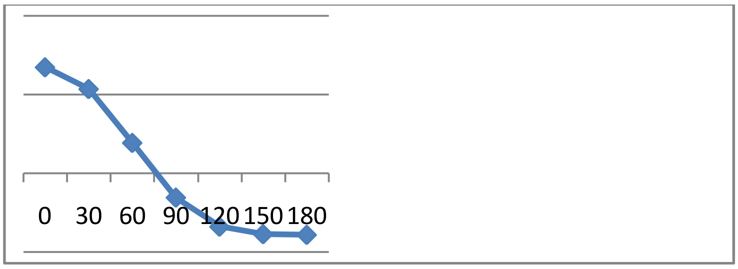
R2= +6.74815E+005-613.87632*A-95.42986*A^2-2.34427*A^3+0.044055*A^4-2.38374E-004*A^5+4.29437E-007*A^6.

Proceed to diagnostics plots(the next icon in progression). Be sure to look at the:

1. Normal probability plot to the studentized residuals to check for normality of residuals.
2. Studentized residuals versus predicted values to check for constant error.
3. Externally studentized residuals to look for outliers, i.e., influential values.
4. Box-Cox plot for power transmissions

If all the model statistics and diagnostic plots are OK, finish up with the model graphs icon.

R2 vs A:A



Response 3:

Source	Sum of Squares	df	Mean Square	F value	p-value prob>F	
Model	5.287E+010	6	8.812E+009	4544.83	<0.0001	significant
A-A	1.888E+010	1	1.888E+010	9736.05	<0.0001	

A^2	1.910E+009	1	1.910E+009	985.14	<0.0001	
A^3	3.638E+009	1	3.638E+009	1876.36	<0.0001	
A^4	8.906E+008	1	8.906E+008	459.35	<0.0001	
A^5	7.862E+008	1	7.862E+008	405.47	<0.0001	
A^6	3.986E+008	1	3.986E+008	205.57	<0.0001	
RESIDUAL	2.327E+007	12	1.939E+006			
COR TOTAL	5.289E+010	18				

Obser vations:

1. The model F-value of 4544.83 implies the model is significant. There is only a 0.01% chance that a “model F-value” this large could due to noise.
2. Values of “ prob>F ” less than 0.0500 indicate model terms are significant.
3. In this case A,A^2,A^3,A^4,A^5,A^6 are significant model terms.
4. Values greater than 0.1000 indicate the model terms are not significant.
5. If there are many insignificant model terms(not counting those required to support hierarchy), model reduction may improve the model.

R-Squared Results:

Std.Dev	1392.44	R-squared	0.9996
Mean	14763.58	Adj R-squared	0.9993
C.V.%	9.43	Pred R-squared	0.9945
PRESS	2.901E+008	Adeq precision	184.886

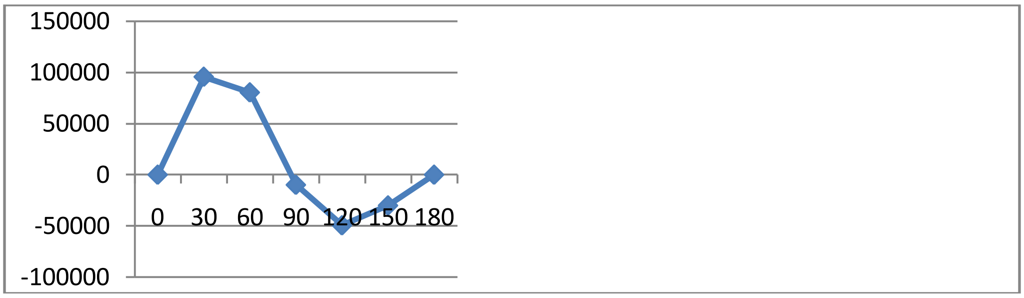
The “ pred R-squared”of 0.9945 is in reasonable agreement with the “ adj R-squared” of 0.9993.
“adeq precision” measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 184.886 indicates an adequate signal. This model can be used to navigate the design space.
Model equation of respone3:-

$$R3= 1021.12280+2911.61629*A+102.96956*A^2-4.36850*A^3+0.048767*A^4-2.23065E-004*A^5+3.69608E-007*A^6.$$

Proceed to diagnostics plots(the next icon in progression). Be sure to look at the:
1.Normal probability plot to the studentized residuals to check for normality of residuals.
2. studentized residuals versus predicted values to check for constant error.
3.Externally studentized residuals to look for outliers, i.e., influential values.
4.Box-Cox plot for power transmissions

If all the model statistics and diagnostic plots are OK, finish up with the model graphs icon.

R3 vs A:A



Response 4:

Source	Sum of Squares	df	Mean Square	F value	p-value prob>F	
Model	9.099E+011	6	1.516E+011	3.382E+005	<0.0001	significant
A-A	6.936E+010	1	6.936E+010	1.547E+005	<0.0001	
A^2	9.064E+009	1	9.064E+009	20212.43	<0.0001	
A^3	8.803E+008	1	8.803E+008	1962.89	<0.0001	
A^4	1.170E+009	1	1.170E+009	2608.12	<0.0001	
A^5	1.706E+007	1	1.706E+007	38.04	<0.0001	
A^6	2.608E+008	1	2.608E+008	581.45	<0.0001	
RESIDUAL	5.381E+006	12	4.485E+005			

Obser vations:

1. The model F-value of338154.65 implies the model is significant. There is only a 0.01% chance that a “model F-value” this large could due to noise.
2. Values of “ prob>F ” less than 0.0500 indicate model terms are significant.
3. In this case A,A^2,A^3,A^4,A^5,A^6 are significant model terms.
4. Values greater than 0.1000 indicate the model terms are not significant.
5. If there are many insignificant model terms(not counting those required to support hierarchy), model reduction may improve the model.

R-Squared Results:

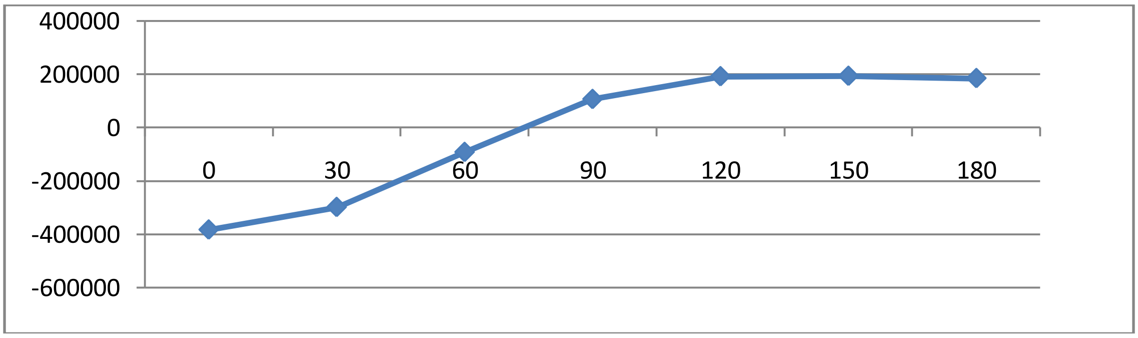
Std.Dev	669.67	R-squared	1.0000
Mean	-5228.79	Adj R-squared	1.0000
C.V.%	12.81	Pred R-squared	0.9999
PRESS	5.020E+007	Adeq precision	1429.511

The " pred R-squared"of 0.9999 is in reasonable agreement with the " adj R-squared" of 1.0000.
"adeq precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 1429.511 indicates an adequate signal. This model can be used to navigate the design space.
Model equation of respone1:-

R4=-3.83503E+005+424.21111*A+53.57290*A^2+1.62285*A^3-0.030196*A^4+1.64893E-004*A^5-2.98952E-007*A^6

Proceed to diagnostics plots(the next icon in progression). Be sure to look at the:
1.Normal probability plot to the studentized residuals to check for normality of residuals.
2.Studentized residuals versus predicted values to check for constant error.
3.Externally studentized residuals to look for outliers, i.e., influential values.
4.Box-Cox plot for power transmissions
If all the model statistics and diagnostic plots are OK, finish up with the model graphs icon.

R4 vs A:A



optimization of ga:
The above equations we can substitute MATLAB GA TOOL BOX .from these equations we can get function values.

```
function y = multi(x)
y(1)=1021.51151+748.60025*x+103.03328*x^2-4.26162*x^3+0.048831*x^4-2.25466e-004*x^5+3.74055e-007*x^6;
y(2)=6.74815e+005-613.87632*x-95.42986*x^2-2.34427*x^3+0.044055*x^4-2.38374e-004*x^5+4.29437e-007*x^6;
y(3)=1021.12280+2911.61629*x+102.96956*x^2-4.36850*x^3+0.048767*x^4-2.23065e-004*x^5+3.69608e-007*x^6;
y(4)=45120.14114-29.45313*x-6.47866*x^2-0.11183*x^3+2.14752e-003*x^4-1.1357e-005*x^5+2.02182e-008*x^6;
```

index	F1	F2	F3	F4	X1
1.0	1030.010049855302	674808.0295095751	1054.1389002259089	45119.80645920059	0.011334899168385 26
2.0	3902.1414740814184	672233.3296832528	10073.316120386307	44980.80958589086	2.854612491185239
3.0	6666.648025134849	669291.1189407776	17217.29226297474	44809.87601864121	4.884400935267964

4.0	13753.51897853 0545	659385.803384 3625	33698.28682758 919	44217.6049770 8893	9.262936403717731
5.0	7712.876010706 652	668051.906960 2515	19762.04229237 1087	44736.6350171 2435	5.580245386297689
6.0	15657.66439670 671	656040.114357 3725	37970.61293282 041	44015.9662240 23956	10.374399955568672
7.0	5387.727552646 778	670711.013621 3038	14006.13027983 8622	44893.0639376 19634	3.9882269438848876
8.0	17554.69403625 1265	652354.528369 2771	42220.02484493 131	43793.5813420 0431	11.48237864815935
9.0	2487.866063309 993	673559.506461 6316	5993.013496893 71	45054.9145250 8123	1.6209584805875714
10. 0	1030.010049855 302	674808.029509 5751	1054.138900225 9089	45119.8064592 0059	0.01133489916838526
11. 0	9375.899399967 24	665932.289871 1474	23699.13940182 108	44610.4958430 53366	6.6378561512343115
12. 0	1359.174821763 1664	674535.665531 3867	2281.220821239 2356	45106.3934545 1995	0.4264668284769069
13. 0	11868.02584851 2572	662388.188453 5601	29435.52447059 132	44398.1892400 7252	8.150745196936356
14. 0	19231.63099161 8444	648763.459435 4536	45989.58815874 372	43576.7721308 8078	12.471674419307638
15. 0	19231.63099161 8444	648763.459435 4536	45989.58815874 372	43576.7721308 8078	12.471674419307638

CONCLUSION

- In this study dynamic reactions investigation was successfully done by using MATLAB software.
- The obtained data have been statistically processed using Response Surface Method.
- The empirical models of output parameters are established and tested through the analysis of variance to validate the adequacy of the models.
- A response surface optimization is attempted using DESIGN EXPERT software for output responses in slider crank mechanism.
- The optimization of slider crank mechanism is done by using GA.

REFERENCES

a. MAT LAB R2009 SOFTWARE HELP .
b. SWILLSON.
c. GA TOOL BOX .
d. DESIGN EXPERT 8.0 HELP.
e. MAT LAB FOR MECHANICAL ENGINEERING TEXTBOOK.
f. WWW.MATLABTUTORIALS.COM.