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Linear Regression Modelling of Actual and Designed Angles of a Four Bar Linkage using MATLAB.

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ABSTRACT

The study, linear regression modeling of actual and designed angles of a four bar linkage through MATLAB approach was successfully carried out. The researchers considered actual and designed angles data gotten through Simulink modeling and simulation in the MATLAB command window. The linear regression modeling was achieved using designed angles of +30, +30, -23 and 0 degrees with the corresponding actual position angles of -92.4196, -223.375, 0, +101.66 degrees. The correlation coefficient of -0.7022 and p-value coefficient of 0.2978 from data analysis indicated that there is negative and significant relationship between actual angle and designed positions angles; however, the linear graph showed some region of positive relationship. MATLAB analysis also computed the linear regression model between actual and designed positions angles. The root mean squared error was observed to be 121 with standard error of 65. 234. The P-value 0.2978 and degrees of freedom 2 of the linear regression model generated are consistent with the P-value and degrees of freedom of ANOVA model, that proves correctness of the model. The researchers made the following recommendations: To avoid failure of machines and mechanisms and to minimize operational noise, actual position angles of links must be computed before linkage configuration is carried out, this research can also be done in future using other advanced software for generalization.

Keywords *---- MATLAB, regression model, actual angle, linear modeling, designed angle, simulink, ANOVA.*

INTRODUCTION

Background of the Study

Plecnik and McCarthy (as cited in Ugwuegbu and Ewurum, 2022) opined that traditionally, linkage synthesis is divided into three types, motion generation, function generation, and path generation. Each of the synthesis types has been extensively researched and has many applications in various engineering fields, but, in many situations, configuration angle of the links receives little attention of the researchers. Four-bar- linkages are usually designed to take an input and produce a different output, altering motion, velocity, acceleration, and applying mechanical advantage.

Gupta (2014) stated that the relationship between the actual configuration angles and specified configuration angles of a mechanical four-bar-linkage has been a problem in the design and creation of mechanisms. Four bar linkage is the foundation of machine design, analysis and creation and can produce rotational, translational and oscillation motions through the movement of prime mover. A linkage is called a mechanism if two or more links are movable with respect to a fixed link.

Linear regression modeling here is a linear approach for modeling the relationship between a scalar response (actual position angles) and one explanatory variable (specified position angles).

There are no doubts that there is need to determine the relationship between actual position angles and specified position angles of a four bar linkage to improve mechanism task precision. Hence, the paper aimed at studying linear regression modeling of actual and designed angles of a four bar linkage through MATLAB approach.

Statement of Problem

In order to minimize sudden failure of linkages, machine noise and improve links ability to perform task, there is a need to establish the relationship between actual links position angles and specified/designed links position angles.

According to .McCarthy and Soh (as cited in Ugwuegbu and Ewurum, 2022) stated that four-bar-linkage is a series of four rigid links connected with joints (revolute joints) to form a closed chain. Each link has two joints, and the joints have various degrees of freedom to allow relative motion. Four-bar-linkage play a key role in industrial machines, robotics, conveyors, diesel engines, automatic machines and therefore, demands accurate configuration

angles if the machines must perform satisfactorily. They further added that a four bar linkage would fail if the designed position angles deviates from the actual links position angles. A four-bar linkage mechanism, formed by four links connected in a closed chain with revolute joints, each obtained by grounding a different link, provides a great number of configuration angle problems that will affect machine precision. It is on this note that the paper aims at determining the linear regression model of actual position angles and designed position angles of a four bar linkage through MATLAB approach.

Purpose of the Study

The general purpose of the study is to determine the linear regression model of actual position angles and designed or specified position angles of a four bar linkage through matlab approach.

Significance of the Study

The result of this study will be beneficial to industrial machine designers/production engineers in the following ways:

1) Production engineers can improve machine safety; reduce noise and avoid sudden failure of mechanisms by choosing and computing actual angles with the aid of the formula.
2) The knowledge of the linear regression model can be used to improve the design life of mechanisms.

Scope of the Study

This research will focus on establishing the linear regression model between the actual position angles and designed position angles of a four bar linkage through matlab approach. So, all efforts will be directed towards the general objectives. The data used here, was gotten through simulink modeling of a four bar linkage and simulation approach and is beyond the scope of this paper. The researchers are members of Federal Polytechnic Nekede, within South East of Nigeria. Results may be subject to variations within other parts of the World.

Literature Review

Plecnik and McCarthy (as cited in Ugwuegbu and Ewurum, 2022) evaluated numerical synthesis of six bar linkage for mechanical computation and they opined that, four-bar-linkage synthesis is to determine link dimensions of the linkage that achieves prescribed task positions. Traditionally, linkage synthesis is divided into three types, motion generation, function generation, and path generation. Jain and Gupta (2011) experimented four bar linkage and they concluded that it is made up of four links, three movable links, four joints, one fixed link and one constraint.

McCarthy and Soh (2010) studied geometric design of linkages and discovered that four-bar-linkage is a series of four rigid links connected with joints (revolt joints) to form a closed chain. Each link has two joints, and the joints have various degrees of freedom to allow relative motion. They also added that Four-bar-linkage play a key role in industrial machines, robotics, conveyors, diesel engines, and therefore, demands accurate configuration angles if the machines must perform satisfactorily.

Gupta (2012) examined theory of machines and simple mechanisms and he concluded that linkages are the foundation of machine design and creation and capable of producing rotational, translational and oscillation motions through the movement of crank. A linkage is called a mechanism if two or more links are movable with respect to a fixed link.

Methodology

The study considered actual angles and designed angles data gotten through Simulink in the MATLAB command window with block models that were used to represent all the elements of four-bar-linkage which was further simulated. The following block elements were used: 3 binary links, 4 revolute joints, 2 pivot mount, 2 rigid transforms, 1 world frame, 1 solver configuration and 1 mechanism configuration. Block ports, base and follower frame. The results was tabulated and subjected to MATLAB analysis.

Results and Presentations

Table1.0: simulation results for actual position angles and designed position angles of links.

S/N	JOINTS	Position angle specified(degrees)	Position actual angle	Priorities
1	Revolute joint	+30	-92.4196	High
2	Revolute joint 1	+30	-223.375	High

3	Revolute joint 2	-23	0	Low
4	Revolute joint 3	0	+101.66	High

```
>> % MATLAB PROGRAMME FOR LINEAR REGRESSION OF ACTUAL AND DESIGNED ANGLES OF FOUR BAR LINKAGE.
>> % X = DESIGNED OR SPECIFIED ANGLES IN DEGREES
>> % Y = ACTAUL OR OPERATIONAL ANGLES IN DEGREES
>> X = [30 30 -23 0];
>> Y = [-92.4196 -223.375 0 101.66];
>> mdl = fitlm(X,Y)
mdl =
Linear regression model:
    y ~ 1 + x1
Estimated Coefficients:
                   Estimate      SE       tStat      pValue
                   ________    ______    ________    _______
    (Intercept)    -18.647     65.243    -0.28581    0.80191
    x1             -3.7715     2.7038    -1.3949     0.29777
Number of observations: 4, Error degrees of freedom: 2
Root Mean Squared Error: 121
R-squared: 0.493,  Adjusted R-Squared 0.24
F-statistic vs. constant model: 1.95, p-value = 0.298
>> tbl = anova(mdl)
tbl =
            SumSq    DF    MeanSq      F       pValue
            _____    __    ______    ______    _______
    x1       28260    1     28260     1.9457    0.29777
    Error    29049    2     14524
>> [R,P] = corrcoef(X,Y)
R =
    1.0000   -0.7022
   -0.7022    1.0000
P =
    1.0000    0.2978
    0.2978    1.0000
>> end
```

The computed linear regression model between designed position angle and actual position angle is shown below;

$$\boldsymbol{Y = -3.7715X - 18.647}$$

Where Y = Actual position angle in degrees and X = Designed or specified angle in degrees.

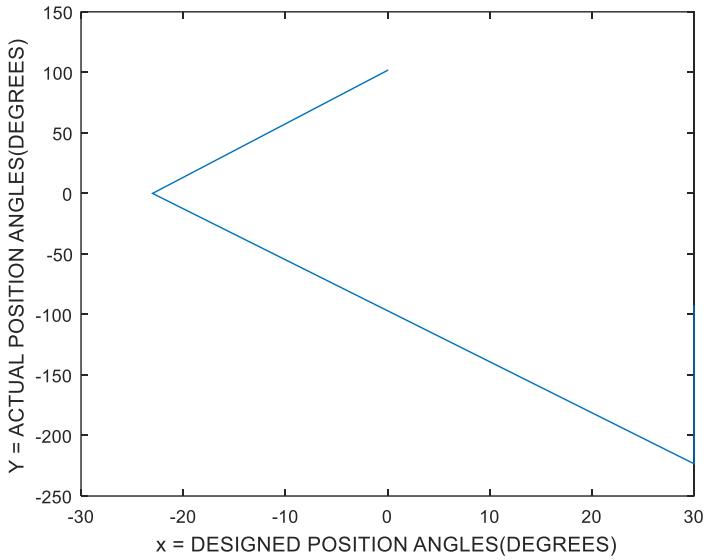

Fig 1.0: Graph of Actual angles Against Designed angles.

MATLAB CODES/SCRIPTS OF THE GRAPH ABOVE

```
function createfigure1(X1, Y1)
%CREATEFIGURE1(X1, Y1)
%  X1:  vector of x data
%  Y1:  vector of y data
% Create figure
figure1 = figure;
% Create axes
axes1 = axes('Parent',figure1);
box(axes1,'on');
hold(axes1,'on');
% Create plot
plot(X1,Y1);
% Create xlabel
xlabel({'x = DESIGNED POSITION ANGLES(DEGREES)'});
% Create ylabel
ylabel({'Y = ACTUAL POSITION ANGLES(DEGREES)'});
```

Discussion

The results of the study, linear regression modeling of actual and designed angles of a four bar linkage through MATLAB approach were discussed here. The linear regression modeling was achieved using designed angles of +30, +30, -23 and 0 degrees with the corresponding actual position angles of -92.4196, -223.375, 0, +101.66 degrees. The correlation coefficient of -0.7022 and p-value coefficient of 0.2978 from data analysis indicated that there is negative and significant relationship between actual position angle and designed position angle; however, the linear graph showed some region of positive relationship.

The MATLAB analysis also computed the linear regression model between actual position angle and designed position angle;

$$\boldsymbol{Y = -3.7715X - 18.647}$$

$$\boldsymbol{Actual\ angle(degrees) = -3.7715 \times Designed\ angle - 18.647}$$

The root mean squared error was observed to be 121 with standard error of 65. 234. The P-value 0.2978 and degrees of freedom 2 of the linear regression model are consistent with the P-value and degrees of freedom of ANOVA model, that proves correctness of the model.

Conclusion

The linear regression modeling of actual and designed angles of a four bar linkage was obviously achieved. Undoubtedly, results revealed that at any given value of designed position angle, actual position angle of links can be easily computed.

Recommendations

The following recommendations are suggested based on the study:

1) To avoid failure of machines and mechanisms and to minimize operational noise, actual position angles of links must be computed before linkage configuration is carried out.

2) This research can also be done using other advanced software for generalization.

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