Resolving the four – Bar Link Mechanism by Kinamatics and Revolving Angle Solution

Pankaj Aswal, Rajkumar Singh, Rohit kumar, Avinash Bhatt, Tej Raj

Abstract: Four bar link mechanism now days are beneficial for various vehicles for power transmission and Mechanical stability with respect to the motion on various Terrains. The stability regarding the motion transitional is easier rather than motion related to rotational. Author trying to resolve the complexity with respect to Matlab codes helpful in the automation of various four bar link mechanism vehicles. The author indicated the source code for four bar link mechanism, as well as simulating the module based on the real time system, lines of code determines the new configurations of the mechanism for an incrementally varying position of the crank. This is based on the standard cosine formulas and other triangle properties used for analyzing four-bar linkages. . Obviously, torque and power are not the amount that has been in the kinematics and whatever kinematic amount we use to characterize the presentation of the instrument, this amount will just inexact the static power qualities of the component.

Keywords: Four-bar Link Mechanism, Matlab, Mechanics.

Abbreviations
s = length of shortest bar
l = length of longest bar
p, q = lengths of intermediate bar
F = total degrees of freedom in the mechanism
n = number of links (including the frame)
l = number of lower pairs (one degree of freedom)
h = number of higher pairs (two degrees of freedom

I. INTRODUCTION-FOUR BAR MECHANISM

A four bar link mechanism or linkage is the most fundamental of the plane kinematics linkages. It is a much preferred mechanical device for the mechanization and control of motion due to its simplicity and versatility. Basically it consists of four rigid links which are connected in the form of a quadrilateral by four pin joints.
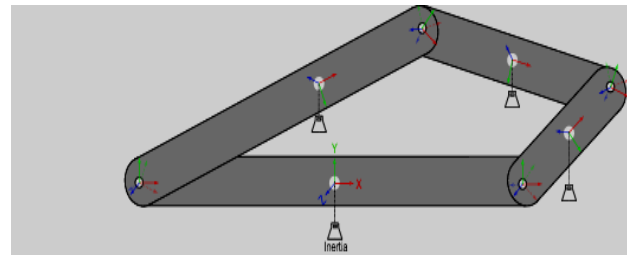
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Fig1. Four bar linkage

1.1 Important concepts in link mechanisms

1. **Crank**: A side link which revolves relative to the frame is called a *crank*.
2. **Rocker**: Any link which does not revolve is called a *rocker*.
3. **Crank-rocker mechanism**: In a four bar linkage, if the shorter side link revolves and the other one rocks (*i.e.*, oscillates), it is called a *crank-rocker mechanism*.
4. **Double-crank mechanism**: In a four bar linkage, if both of the side links revolve, it is called a *double-crank mechanism*.
5. **Double-rocker mechanism**: In a four bar linkage, if both of the side links rock, it is called a *double-rocker mechanism*.

1.2 Classification of Linkage

In a four-bar linkage, the line segment between hinges on a given link is referred as a bar where:

Grashof's theorem states that a four-bar mechanism has *at least* one revolving link if

$$s + l <= p + q \qquad (1\text{-}1)$$

and all three mobile links will rock if

$$s + l > p + q \qquad (1\text{-}2)$$

The inequality (1-1) is **Grashof's criterion.** All four-bar mechanisms fall into one of the four categories. [1], [7]

Case	l + s	Vers.	p + q	Shortest bar	Type
1		<		frame	Double-crank
2		<		side	Rocker-crank
3		<		coupler	Double rocker
4		=		any	Change point
5		>		any	Double rocker

1.3 Degrees of freedom

Degree of freedom of a mechanism is the number of independent relative motions among the rigid bodies.[5]

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Gruebler's equation

F = 3(n-1) -2l –h   (1-3)

Degree of freedom four bar

F = 3(n-1) -2l –h

F=3(4-1)-2(4)-0

F=9-8

F=1

Therefore the four bar mechanism has 1 degree of freedom.

II.   RESEARCH GAP

With the fast, over-burdening, the quick development of exactness mechanical and aeronautic design, precise prediction of Mechanical component motion demand is ever more elevated. In the greater part of the mechanical framework, the component of antiquities for the most part by kinematic pair association. Because of error during the time span of production, assembly and component motion delivered by friction resistance, wear, and the impact of such factors as development exists between vice clearance. What's more, the presence of the hole pulverized a perfect association model, cause the impact of kinematic pair, cause the violent vibration of organization substituted model, prompted the diminishing of the mechanical framework dependability and exactness, and in this way the productivity and administration life. Lately, for system with freedom, and there were many research of adaptable parts [9], yet for considering study of its kinematic pair is not upto measurable mark and adaptable associating pole four-bar linkage study additionally is also less. In this paper, in light of two state model utilizing coulomb erosion model and crash model [9-12], and consider the associating bar for the adaptable body, including four Crank-rocker mechanisms with degree of freedom joints and delicate model for the investigation of elements.

III.   RESEARCH METHODOLOGY

A significant assignment in a structure procedure is the manner by which to makes mechanism which will fulfil wanted attributes of movement of a part, for example a mechanism in which one section will most likely perform wanted (given) movement.[2,5]

There are three regular prerequisites in kinematic union of systems: way generation, work generation and movement generation. In dimensional blend there are two methodologies: union of accuracy focuses and rough or ideal synthesis.[10]

Exactness point synthesis suggests that the point toward the end part of a component (it is most as often as possible a coupler in a four-bar linkage) goes through a specific number of wanted (precise) focuses, however without the plausibility of controlling a basic synthesis on a way out of those focuses. Exactness point combination is limited by the quantity of focuses which must be equivalent to the quantity of autonomous parameters denied by the measurement. The most extreme number of focuses for a four-bar linkage is nine. In the event that the quantity of conditions produced by the quantity of careful focuses is littler than the quantity of anticipated factors, at that point there is a choice of free factors, so the issue of combination doesn't have a solitary esteemed arrangement. At the point when the quantity of

precision focuses builds, the issue of exactness point combination turns out to be exceptionally nonlinear and very difficult for comprehending, and the instrument got by this sort of blend is much of the time pointless: on the grounds that elements of the system individuals are in lopsidedness, or the got arrangements are as perplexing numbers so there is no system.[2,3] The most extreme number of exactness focuses on the way of the coupler in a four-bar linkage is positive in composed movement, and nine in clumsy movement. It is seen that the combination of measurement by methods of accuracy focuses" is confined by the quantity of given focuses, and the expansion of accuracy focuses to in excess of nine is for all intents and purposes unthinkable.

In the improvement calculation, the target work is given a numerical incentive for each arrangement and it would be perfect for the target capacity to have the outcome in a base [11]

(worldwide least), which compares to the most ideal system which ought to play out a mechanical methodology, however it is difficult to be accomplished as a result of complex issues.The target capacity may contain different limitations, for example, limitation of proportion of lengths of the individuals, anticipation of negative lengths of the individuals, limitations with respect to transmission points, and so on.[12] So as to accomplish this, the alleged punishment capacities are presented also, they extensively increment the estimation of the target work when the referenced qualities go toward undesired heading. Punishment capacities remembered for the target work during combination of components are additionally called equalizing capacities since they turn the limited issue of advancement into the unlimited one.

In this paper, Hooke-Jeeves' advancement strategy is utilized for amalgamation of a four-bar linkage, which, as a technique for direct looking, does not utilize conclusions of the goal work, yet it looks at its qualities in every cycle and alters component parameters in the course of diminishing the estimation of the goal work.[4] The system is finished at the point when uprooting of the space doesn't bring about an extensive change of the estimation of the target work or when the quantity of emphases arrives at the given worth. The calculation empowers control of progress of the target work for each anticipated variable, free of changes in the other anticipated factors. This technique brings about the neighbourhood least of the goal work, yet finding increasingly nearby essentials builds the probability of giving worldwide union inside the arrangement.

IV.   CODE OF FOUR BAR

The following is the script for finding the parameter of four bar such as mass, inertia, centre of gravity etc., they depend on the coordinate of bar (x,y). The script has to be saved as .m file then the program is run.

```
function fourbar
disp(' ')
disp
disp
disp
disp
disp
```

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```
disp
disp(' ')
V = input;
a=V(1); b=V(2); c=V(3); d=V(4); r=V(5); f=V(6)*pi/180;
Check if the mechanism is Grashofian
shortest=min(V(1:4));
longest=max(V(1:4));
P=shortest + longest;
Q=sum(V(1:4))- P;
```

The following check rejects the mechanism specified by the user and prompts the user to enter another mechanism specification if the current specification is not purely Grashofian[3]

```
if P>Q
    disp(' ')
    disp
    fourbar
elseif P==Q
    disp(' ')
    disp
    disp
    disp(' ')
    disp('Enter another set of linkage parameters to continue.')
    fourbar
end
```

If the mechanism IS purely Grashofian then the program proceeds to check if the specified mechanism is in the crank-rocker or double crank configuration. If the specified Grashofian mechanism is in a double rocker mode, the following routine rejects it and prompts the user to enter a new mechanism specification

```
 if a==min(V(1:4)) | d==min(V(1:4))
    disp(' ')
    disp
    disp(' ')
    disp
else
    disp(' ')
    disp
    disp(' ')
    disp
    fourbar
end
 s = input;
s=s/abs(s);
x1=0; y1=0; Coordinates of the crank ground point : Point 1
x4=d; y4=0; Coordinates of the follower ground point: Point 4
```

The following lines of code determines the starting configuration of the mechanism.This is based on the standard cosine formulas and other triangle properties used for analyzing four-bar linkages[2][3][7]

```
 n=0;
    theta1=n*360/20*pi/180;
    x2=a*cos(theta1);
    y2=a*sin(theta1);
    e = sqrt((x2-d)^2+y2^2);
    phi2=acos((e^2+c^2-b^2)/(2*e*c));
    phi1=atan(y2/(x2-d))+(1-sign(x2-d))*pi/2;
    theta3=phi1-s*phi2;
    x3=c*cos(theta3)+d;
    y3=c*sin(theta3);
    theta2=atan((y3-y2)/(x3-x2))+(1-sign(x3-x2))*pi/2;
    phi3=theta2+f;
```

```
    x5=x2+r*cos(phi3);
    y5=y2+r*sin(phi3);
    x=[x1 x2 x3 x4];
    y=[y1 y2 y3 y4];
    u=[x2 x3 x5];
    v=[y2 y3 y5];
    figure  t=plot(x5,y5,'r.','EraseMode','none');
    hold on
    p=plot(x,y,'bo-','EraseMode','xor');
q=fill(u,v,'g','EraseMode','xor');
    scale=max(V(1:5));
    axis([-scale scale -scale scale])
    axis equal
```

The following lines of code determines the new configurations of the mechanism for an incrementally varying position of the crank.[8][9] This is based on the standard cosine formulas and other triangle properties used for analyzing four-bar linkages

```
 for n=1:1000,
    theta1=n*360/1000*pi/180;
    x2=a*cos(theta1);
    y2=a*sin(theta1);
    e = sqrt((x2-d)^2+y2^2);
    phi2=acos((e^2+c^2-b^2)/(2*e*c));
    phi1=atan(y2/(x2-d))+(1-sign(x2-d))*pi/2;
    theta3=phi1-s*phi2;
    x3=c*cos(theta3)+d;
    y3=c*sin(theta3);
    theta2=atan((y3-y2)/(x3-x2))+(1-sign(x3-x2))*pi/2;
    phi3=theta2+f;
    x5=x2+r*cos(phi3);
    y5=y2+r*sin(phi3);
    x=[x1 x2 x3 x4];
    y=[y1 y2 y3 y4];
    u=[x2 x3 x5];
    v=[y2 y3 y5];
    set(t,'XData',x5,'YData',y5)
    set(p,'XData',x,'YData',y)
    set(q,'XData',u,'YData',v)
    drawnow
    pause(0.02)
end
return
```

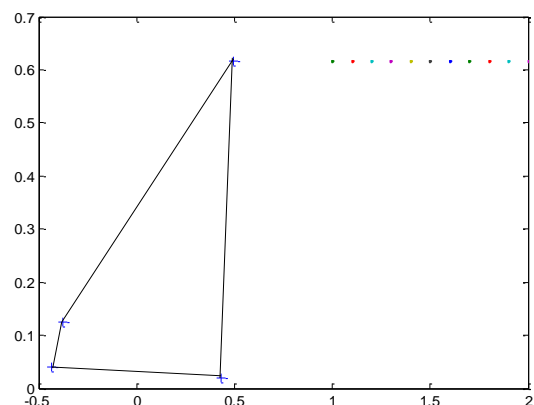After the program is run, the figure and parameters of four bar is displayed

Fig2. Four bar

x = [6.5000   7.4000   3.3000   1.3000]

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y = [0   2.4000   2.4000   -1.1000]
theta1_ang = 69.4440
theta3_ang =60.2551
bar1_length =2.5632
mass_bar1 = 22.8102
r = 0.0189 (density of rod is assumed)
Inertia of bar1

$$\begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}$$

$$\begin{bmatrix} \dfrac{mr^2}{2} & 0 & 0 \\ 0 & \dfrac{mL^2}{12} & 0 \\ 0 & 0 & \dfrac{mL^2}{12} \end{bmatrix}$$

$$\begin{pmatrix} 22.8102x(0.0189)^2 \div 2 & 0 & 0 \\ 0 & 22.8102x(2.5632)^2 \div 12 & 0 \\ 0 & 0 & 22.8102x(2.5632)^2 \div 12 \end{pmatrix}$$

Ixx_bar1 = 0.0041
Iyy_bar1 =12.4886
Izz_bar1 = 12.4886
bar2_length = 4.1000
mass_bar2 = 36.4864
Inertia of bar2

$$\begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}$$

$$\begin{bmatrix} \dfrac{mr^2}{2} & 0 & 0 \\ 0 & \dfrac{mL^2}{12} & 0 \\ 0 & 0 & \dfrac{mL^2}{12} \end{bmatrix}$$

$$\begin{pmatrix} 36.4864x(0.0189)^2 \div 2 & 0 & 0 \\ 0 & 36.4864x(4.1)^2 \div 12 & 0 \\ 0 & 0 & 36.4864x(4.1)^2 \div 12 \end{pmatrix}$$

Ixx_bar2 =0.0065
Iyy_bar2 =51.1113
Izz_bar2 = 51.1113
bar3_length =4.0311
mass_bar3 =35.8735
Inertia of bar3

$$\begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}$$

$$\begin{bmatrix} \dfrac{mr^2}{2} & 0 & 0 \\ 0 & \dfrac{mL^2}{12} & 0 \\ 0 & 0 & \dfrac{mL^2}{12} \end{bmatrix}$$

$$\begin{pmatrix} 22.8102x(0.0189)^2 \div 2 & 0 & 0 \\ 0 & 22.8102x(4.0311)^2 \div 12 & 0 \\ 0 & 0 & 22.8102x(4.0311)^2 \div 12 \end{pmatrix}$$

Ixx_bar3 = 0.0064
Iyy_bar3 = 48.5787
Izz_bar3 = 48.5787
ground_length (bar 4) =5.3151
cg_1= [0.45 1.2   0]
cg_2 = [-2.05 0   0]
cg_3 = [-1.0 -1.75 0]
cs1_1= [0 0 0]
cs1_2 = [0 0 0]
cs1_3 = [0 0 0]
cs2_1 = [0.9 2.4 0]
cs2_2=[-4.1 0 0]
cs2_3 = [0 0 0]
The following parameters are then inserted to their corresponding blocks in four bar model.
Classification of four bar
s=2.5632
l=5.3151
p=4.0311
q=4.1
s + l= 2.5632 + 5.3151 = 7.8783
p + q= 4.0311 + 4.1 = 8.1311
Since, s + l < p + q where the side link is shortest, the four bar mechanism is crank –rocker mechanism.

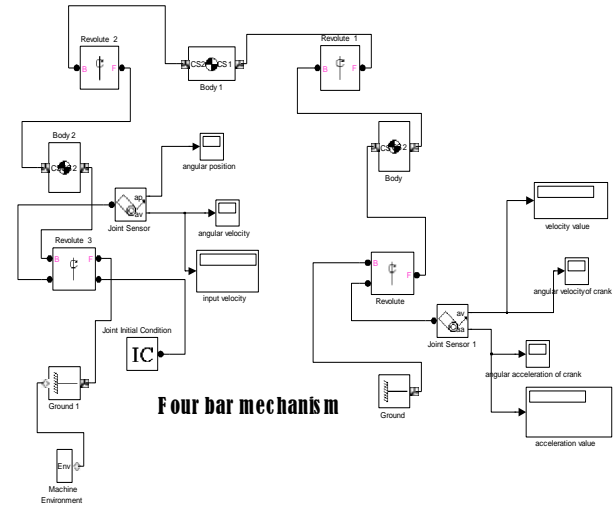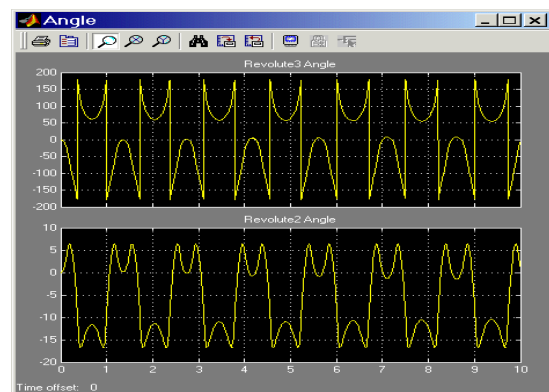**Figure1:-Simulink of Four Bar Link Mechanism**

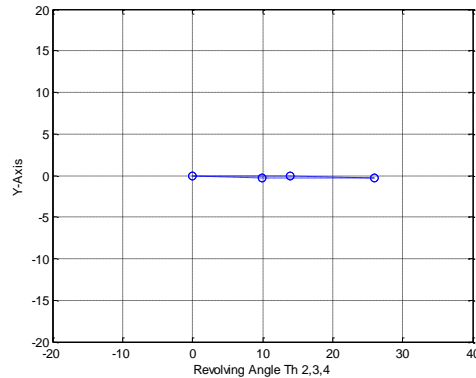**Figure2:- Output of Matlab showing Revolving Angle**

Variable	Value
Th2	**28 degree**
Th3	**36 degree**
Th4	**65 degree**
Y	**29 degree**

V. RESOLVING ANGULAR ROTATION

The rotational angle describes the link mechanism for the stabilize output, the angular rotation has been well explained by the space or mechanical stability of the system, the analysis has been made for the simulating the 6-bar link mechanism for crack-rocker mechanism.[10][4][3]

```
for th=0:0.1:8*pi;
    a=10; c=12; d=14; b=16;
    AC=sqrt(a^2+d^2-2*a*d*cos(th));
    th1=acos((d^2+(AC^2)-a^2)/(2*d*AC));
    th2=acos(((AC^2)+b^2-c^2)/(2*AC*b));
    th3=(th2-th1);
    x= plot([0 a*cos(th)], [0 a*sin(th)],'bo--');
    hold on;
    y= plot([a*cos(th) a*cos(th)+b*cos(th3)], [a*sin(th) a*sin(th)+b*sin(th3)], 'bo--');
    hold on;
    plot([0 d], [0 0], 'bo--');
    hold on;
    plot([d a*cos(th)+b*cos(th3)], [0 a*sin(th)+b*sin(th3)], 'bo--');
    hold on;
    grid on
    hold off;
    axis([-20 40 -20 20]);
    pause(0.1);
end
```
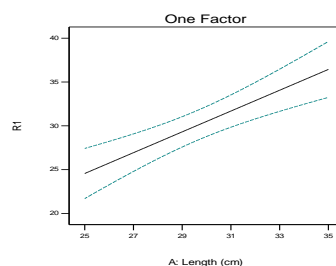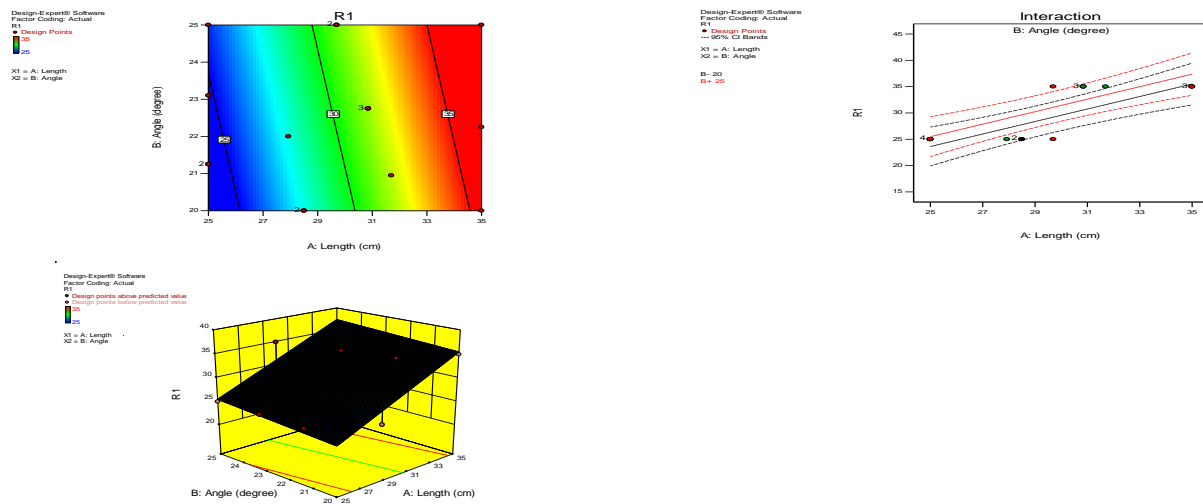

VI. RESULT

	Factor 1	Factor 2	Response 1
Run	A:Length	B:Angle	Length
	cm	degree	cm
1	29.7	25	25
2	30.85	22.75	35
3	27.9288	22	25
4	25	25	25
5	29.7	25	35
6	28.5	20	25
7	25	21.25	25
8	30.85	22.75	35
9	35	25	35
10	35	22.25	35
11	25	23.1	25
12	31.7	20.95	35
13	35	20	35
14	28.5	20	25
15	30.85	22.75	35
16	25	21.25	25

The Model F-value of 13.57 implies the model is significant. There is only a 0.07% chance that an F-value this large could occur due to noise. values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A is a significant model term. values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy),model reduction may improve your model. The "Lack of Fit F-value" of 0.99 implies the Lack of Fit is not significant relative to the pure error. There is a 52.77% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good -- we want the model to fit.

Power calculations are performed using response type "Continuous".

Term	StdErr[1]	VIF	Ri-Squared	Power at 5 % alpha level to detect signal/noise ratio of
				2 Std. Dev.
A	0.37	1.02	0.0190	68.4 %
B	0.36	1.02	0.0196	71.5 %
AB	0.52	1.02	0.0209	41.5 %
A^2	0.54	1.02	0.0167	91.5 %
B^2	0.57	1.04	0.0405	88.9 %

VII.   CONCLUSION

Standard errors should be similar within type of coefficient. Smaller is better. The ideal VIF value is 1.0. VIFs above 10 are cause for concern. VIFs above 100 are cause for alarm, indicating coefficients are poorly estimated due to multicollinearity.Ideal Ri-squared is 0.0. High Ri-squared means terms are correlated with each other, possibly leading to poor models. If the design has multilinear constraints multicollinearity will exist to a greater degree,thus increasing the VIFs and the Ri-squareds, rendering these statistics useless.Using FDS instead,Power is an inappropriate tool to evaluate response surface designs. Using precision-based metrics provided in this program via fraction of design space (FDS) statistics. It is somewhat essential to see how the component will work under stacked conditions by and by while the kinematic attributes of the instrument is being considered. By the presentation of the component we mean the powerful transmission of movement (and power) from the information connect to the yield interface. This likewise implies for a consistent torque contribution, in a well performing component we should acquire the greatest torque yield that is conceivable and the bearing powers must be a base. Obviously, torque and power are not the amount that has been in the kinematics and whatever kinematic amount we use to characterize the presentation of the instrument, this amount will just inexact the static power qualities of the component. The dynamic attributes, which is an element of mass and snapshot of latency of the unbending bodies, might be a few times more than the static powers and the conduct of the system under the dynamic powers can't be anticipated by kinematics.

All things considered, some standard guideline of the conduct of the instrument under burden is better than none. Alt characterized the transmission edge.

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