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FOUR-BAR MECHANISM FOR A PORTAL CRANE: A BRIEF OVERVIEW

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Abstract: The present article aims to increase knowledge of a four-bar mechanism. A four-bar system is a planar mechanism. There are many types of simple mechanisms, such as: Chebyshev, Chebyshev lamda, Hoecken, Roberts, Watt's, Grasshopper, horse-head, pantograph and Peaucelier. More complex mechanisms are: Stewart platform or Jansen's linkage. The determination of the degrees of freedom (DOF) for a system is done using the Chebychev-Gruebler-Kutzbach relationship. Due to this fact, the DOF for the four-bar system has the value one. Moreover, we analyze the following angles: θ, α, β and $\varphi_3$in the mechanism. Finally, using Matlab software the drawing and the dynamic simulation of a four-bar mechanism is carried out. Besides, the dynamic simulation is represented after 3s, 6s and 12s.

Key words: mechanism, linkage, DOF, angle, triangle.

1. INTRODUCTION

There are various mechanical mechanisms. These mechanisms can be: planar, spherical and spatial. In this paper, we studied just one system which is a planar mechanism.

The simplest mechanism known are: Chebyshev, Chebyshev lambda, Hoecken, Roberts, Watt's, Grasshopper, horse-head, pantograph and Peaucelier, Fig.1.

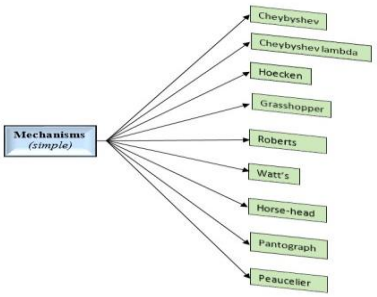

Figure 1 Simple mechanisms

Only Peaucelier and Grasshopper systems are exact straight-line mechanisms, [1].

There are also more complex mechanisms, such as: Stewart platform or Jansen's linkage.

In the field of mechanisms, a four-bar link is the simplest closed-chain movable link. It consists of four bodies, called bars of links. These bars are connected in a loop by four joints or pivots.

The four-bar mechanisms are widely used in various fields: medicine, research, education, transport, agriculture, industry, [2].

The movements of these systems is usually controlled and predictable, such as: rotation, oscillation and translation, Fig.2.

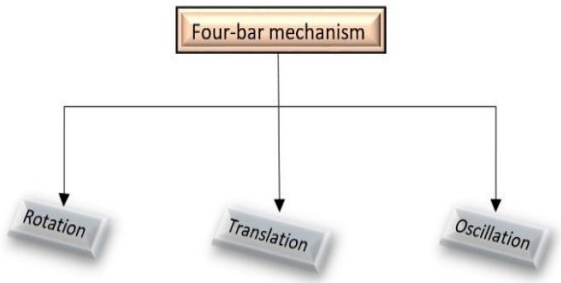

Figure 2 The movements of four-bar mechanism

2. STUDY ABOUT FOUR-BAR MECHANISM

In mechanical engineering, DOF is a number of independent motions that are allowed to the body. In the case of a mechanism made of several bodies, DOF represents the number of possible independent relative motions between the pieces of the system.

DOF is mostly studied in industrial robotics, [3]

The Chebychev-Gruebler-Kutzbach formula determines the number for degrees of freedom:

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$$DOF = 3(l-1) - 2j \quad (1)$$

Where:

- DOF – degrees of freedom.
- l – number of links.
- j – number of joints

Then, DOF of the four-bar linkage can be calculated as follows:

$$DOF = 3(4-1) - 2 \cdot 4 = 3 \cdot 3 - 2 \cdot 4 = 9 - 8 = 1 \quad (2)$$

Where:

- l = four links.
- j = four joints.

The conditions of mechanisms and structures are:

- DOF > 0, it is a mechanism.
- DOF = 0, it is a structure.
- DOF < 0, it is a preloaded structure.

From relation 2, DOF of the four-bar linkage is mechanism is 1, according to the conditions above,

A four-bar linkage is a mechanism having four rigid bars, Fig. 3:

- Frame is a fixed bar → l_1.
- Crank (driver) is one rotate bar → l_2.
- Connecting rod (coupler) is a floating link → l_3.
- Rocker (follower) is other rotating bar → l_4.

The connecting rod, however, does not rotate around a fixed center, [4].

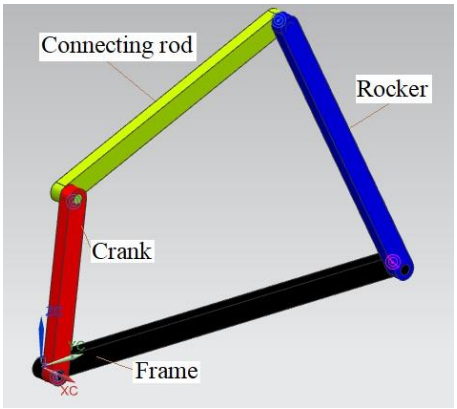

Figure 3 The linkages of mechanism

Furthermore, we studied the angles from a four-bar mechanism, Fig. 4.

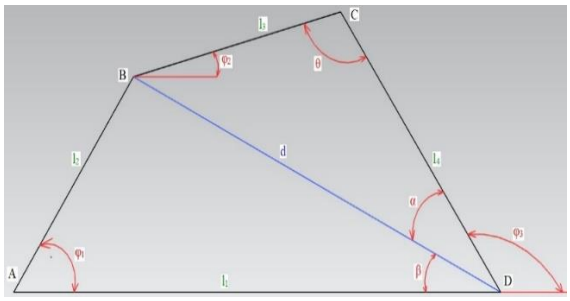

Figure 4 Angles from four-bar mechanism

By applying the law of cosine to triangle ΔABD, [5]:

$$d^2 = l_1^2 + l_2^2 - 2l_1 l_2 cos\varphi_1 \quad (1)$$

Also, applying the law of cosine to triangle ΔBCD:

$$d^2 = l_3^2 + l_4^2 - 2l_3 l_4 cos\theta \quad (2)$$

Therefore,

$$l_1^2 + l_2^2 - 2l_1 l_2 cos\varphi_1 = l_3^2 + l_4^2 - 2l_3^2 l_4^2 cos\theta \quad (3)$$

And

$$\theta = cos^{-1}\left(\frac{l_3^2+l_4^2-l_1^2-l_2^2+2l_1 l_2 cos\varphi_1}{2l_3 l_4}\right) \quad (4)$$

Where:

- φ_1 – input angle.
- θ - transmission angle (this angle is only a function of the input angle φ_1).

In the triangle ΔBDC, the angle α is determined with the relationship:

$$\alpha = cos^{-1}\left(\frac{d^2+l_4^2-l_3^2}{2dl_4}\right) \quad (5)$$

In the triangle ΔABD, the angle β is determined with the relationship:

$$\beta = cos^{-1}\left(\frac{d^2+l_1^2-l_2^2}{2dl_1}\right) \quad (6)$$

The last relationship is, [6]:

$$\varphi_3 = 180^0 - (\alpha + \beta) \quad (7)$$

We used Matlab program to model a four-bar mechanism and then to simulate the dynamic behaviour of that system, Fig. 5.

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```
% Calculations of angles and coordinates
for i = 1:length(theta)
    G(i) = atan((a*sin(T(i)))/(d-a*cos(T(i))));
    Phi(i) = acos((f(i).*f(1,i)+b*b-c*c)/(2*b*f(i)))-G(i);
    X(i) = a*cos(T(i))+e*cos(ar+Phi(i));
    Y(i) = a*sin(T(i))+e*sin(ar+Phi(i));
    hold on;
    title('Four bar mechanism');
    xlim([-50,110]);
    ylim([-50,110]);
    plot(X,Y,'b', 'LineWidth', 1);

    Cx = [0 a*cos(T(i)) b*cos(Phi(i))+a*cos(T(i)) d a*cos(T(i))+e*cos(Phi(i)+ar)];
    Cy = [0 a*sin(T(i)) b*sin(Phi(i))+a*sin(T(i)) 0 a*sin(T(i))+e*sin(Phi(i)+ar)];

    link_l1 = line([0 ,Cx(2)], [0 ,Cy(2)], 'LineWidth',4, 'Color', 'r');
    link_l2 = line([Cx(2) ,Cx(3)], [Cy(2) ,Cy(3)], 'LineWidth',4, 'Color', 'g');
    link_l3 = line([Cx(3) , d], [Cy(3) , 0], 'LineWidth',4, 'Color', 'b');
    link_l4 = line([0 , d], [ 0 , 0], 'LineWidth',4, 'Color', 'k');
      % Animation of mechanism
    pause(0.08);
    delete(link_l1);
    delete(link_l2);
    delete(link_l3);
    delete(link_l4);
end
```

Figure 5 Calculations of angles and coordinates

In this paper, the complete Matlab code built on top of the 41-line code, [7].
In the manuscript, a dynamic analysis was performed at three different time periods: 3s, 6s and 12s.
The simulation of a four-bar mechanism after three seconds is presented below, Fig. 6.

Figure 6 Four-bar mechanism after 3s

After that, the simulation of a four-bar mechanism after six seconds is presented below, Fig. 7.

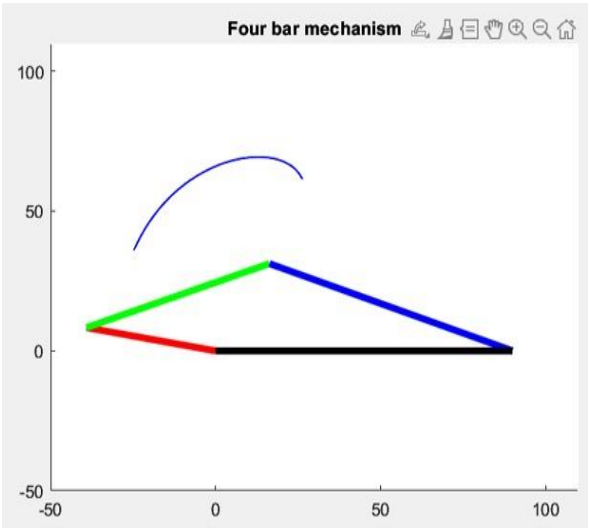

Figure 7 Four-bar mechanism after 6s

In finally, the simulation of a four-bar mechanism after twelve seconds is presented below, Fig. 8.

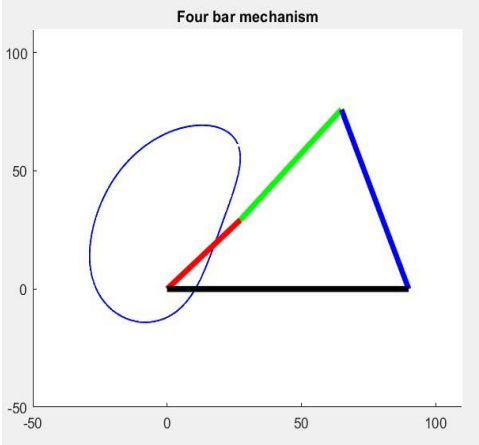

Figure 8 Four-bar mechanism after 12s

3. ACKNOWLEDGMENTS

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4. CONCLUSIONS

The four-bar mechanism occurs in many applications, such as in: robotics, automotive, pump jack, etc. Besides that, there are several advantages in using four-bar mechanisms:

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- They are relatively simple, easy to design and manufacture, which can make them cost-effective and reliable.
- These systems have a large range of motion and can be used to create complex positions and movements.
- The systems can be used to create a variety of different configurations, such as crossed, hinged or parallel, which can be useful for different applications.
- The devices are relatively robust and can withstand high loads, making them suitable for use in a variety of applications.

However, in specialized universities, students must use various software (i.e. Nx Siemens, Solidworks, Autodesk Inventor, PTC Creo, etc.) to study four-bar.

In the future, we intend to develop a study of the four-bar mechanisms, especially constructed with linkages made of aluminum. This analysis will also include velocity and acceleration analysis.

5. REFERENCES

[1] Panaitescu M., Dumitrescu M.V., Panaitescu F.V.., 2020, *Indoor air quality monitoring universal device*, IOP Conference Series: Materials Science and Engineering, Vol.916, no.1, IOP Publishing.

[2] Refalo P., Ghilardo, R. and Abela, S., 2014, *The Effect of Climatic Parameters on the Heat Transfer Mechanisms in a Solar Distillation Still*, Heat Transfer Engineering, DOI: 10.1080/01457632.2014.889479.

[3] Sant, Z., Vella, A., Blanchard, R., Hellmich, C., 2014, *Micromechanics applied to macro-model of a spinal segment*, Engineering Mechanics, 20th International Conference.

[4] Francalanza, E., Borg, J., Vella, P., Farrugia, P. Constantinescu C., 2018, *An 'Industry 4.0' digital model fostering integrated product development*, IEEE 9th International Conference on Mechanical and Intelligent Manufacturing Technologies (ICMIMT), DOI: 10.1109/ICMIMT.2018.8340428.

[5] Abela, E., Vella, P., Farrugia, P., Cassar G., Gauci, M., Balzan, E. 2023, *An Axiomatic Design Methodology for Manufacturing Process Selection Based on Multi-User Requirements Mapping*, Computer-Aided Design&Applications, DOI: 10.14733/cadaps.2023.20.S6, pp. 62-74.

[6] Zammit, D., Staines, CS., Apap, M., Licari, J., 2017, *Design of PR current control with selective harmonic compensators using Matlab*, Journal of Electrical Systems and Information Technology, ELSEVIER, DOI: 10.1016/j.jest.2017.01.003, 4(3): 347-358.