DESIGN AND ANALYSIS OF WEIGHT SHIFT STEERING MECHANISM BASED ON FOUR BAR MECHANISM

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ABSTRACT

As the technology in Automobile sector is becoming advance day by day thus we are proposing a steering mechanism that will enable the rider to steer the vehicle with the help of weight transfer of the body. The weight shift steering system works on a four bar linkage that steers the vehicle in the same direction in which the rider tilts. This concept is proposed to simplify the process of steering fabrication by reducing the number of components and increasing the control and stability of vehicle. This steering system can be implemented in a vehicle with two wheels (one driver, other driven).

Key words: Bar Mechanism, Steering Mechanism, Weight Shift.


1. INTRODUCTION

1.1. Machine and Mechanism

Machine: An assemblage of parts that transmit forces, motion and energy in a predetermined manner.

Mechanism: It is a Mechanical device which has the purpose of transferring motion or force from source to output.

Simple Machine: Any of various elementary mechanisms having the elements of which all machines are composed. Included in this category are the lever, wheel and axle, pulley, inclined plane, wedge and the screw.

The word mechanism has many meanings. A mechanism is a means of transmitting, controlling, or constraining relative movement. Movements which are electrically, magnetically, pneumatically operated are excluded from the concept of mechanism. The central theme for mechanisms is rigid bodies connected together by joints. A machine is a combination of rigid or resistant bodies, formed and connected so that they move with definite relative motions and transmit force from the source of power to the resistance to
be overcome. A machine has two functions: transmitting definite relative motion and transmitting force. These functions require strength and rigidity to transmit the forces. The term mechanism is applied to the combination of geometrical bodies which constitute a machine or part of a machine. A mechanism may therefore be defined as a combination of rigid or resistant bodies, formed and connected so that they move with definite relative motions with respect to one another.

2. KINEMATIC LINKS

Machines consist of several material bodies, each one of them being called link or kinematic link or an element. It is a resistant body or an assembly of resistant bodies. The deformation, if any, due to application of forces is negligible. If a link is made of several resistant bodies, they should form one unit with no relative motion of parts with respect to each other. For example, piston, piston rod and cross head in steam engine consist of different parts but after joining together they do not have relative motion with respect to each other and they form one link.

Similarly, ropes, belts, fluid in hydraulic press, etc. undergo small amount of deformation which, if neglected, will work as resistant bodies and, thereby, can be called links.

2.1. Classification of Links

A resistant body or group of resistant bodies with rigid connections preventing their relative movement is known as a link. The links are classified depending on number of joints.

1. Singular link
   A link which is connected to only one other link is called a singular link.

2. Binary link
   A link which is connected to two other links is called a binary link.

3. Ternary link
   A link which is connected to three other links is called a ternary link.

2.2. Kinematic Pair

In a mechanism, bodies or links are connected such that each of them moves with respect to another. The behaviour of the mechanism depends on the nature of the connections of the links and the type of relative motion they permit. These connections are known as kinematic pairs. Hence kinematic pair is defined as a joint of two links having relative motion between them. Broadly, kinematic pairs can be classified as:

1- Lower pair
2- Higher pair
3- Wrapping pair

2.3. Kinematic chain and Mechanism

In a kinematic chain, four links are required which are connected with each other with the help of lower pairs. These pairs can be revolute pairs or prismatic pairs. A prismatic pair can be thought of as the limiting case of a revolute pair. Before going into the general theory of mechanisms it may be observed that to form a simple closed chain we need at least three links with three kinematic pairs. If any one of these three links is fixed, there cannot be relative movement and, therefore, it does not form a mechanism but it becomes
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a structure which is completely rigid. Thus, a simplest mechanism consists of four links, each connected by a kinematic lower pair (revolute etc.), and it is known as four bar mechanism.

3. LINK SYNTHESIS

We have seen that complex number utilization is a simple and powerful technique for expressing the loop closure equations. The analytical or numerical solution of planar mechanisms can be easily performed by simple algebraic manipulations in complex numbers.

In complex numbers:

\[ a_2e^{i\theta_{12}} + a_3e^{i\theta_{13}} = a_1 + a_4e^{i\theta_{14}} \]

If we equate the real and imaginary parts of this equation separately, we obtain two scalar equations in three position variables \( (q_{12}, q_{13} \text{ and } q_{14}) \). If one of the position variables is the input variable whose value is given, then we shall be able to solve variables.

In complex plane, when we have an equation in complex numbers, the complex conjugate of the equation is also true. The complex conjugate yields vectors which are the mirror image of the original vectors with respect to the real axis (x-axis); e.g. in case of a mechanism, if we place a mirror about the real axis, as we move the original mechanism its image will also move and corresponding to the original closed loop, the loop formed on the mirror image will also be closed at every position. Hence we obtain another loop closure.

\[ a_2e^{-i\theta_{12}} + a_3e^{-i\theta_{13}} = a_1 + a_4e^{-i\theta_{14}} \]

The original equation (1) and its complex conjugate (2) are the two independent equations in the complex plane (if we equate the real and imaginary parts of these equations they will yield the same two scalar equations in the real plane).

In general, the loop closure equations yield a non-linear relation between the position variables. The closed form solution of these equations is not straightforward. For simple mechanisms, utilizing complex algebra one can solve for the unknown position variables. In this section, closed form solution of the loop closure equations for simple mechanisms.

Using the equations (1) and (2), if we are to find \( q_{14} \) as a function of \( q_{12} \), we have to eliminate \( q_{13} \) from the above equations. We can write the loop closure equations in the
form:
\[ a_3 e^{j\theta_1} = a_4 e^{j\theta_4} - a_5 e^{j\theta_5} \]  
(3)
\[ a_3 e^{-j\theta_2} = a_4 e^{-j\theta_6} - a_5 e^{-j\theta_6} \]  
(4)

Multiplying equations (3) and (4):
\[ a_3^2 e^{j(\theta_1-\theta_2)} = (a_1 + a_4 e^{j\theta_4} - a_5 e^{j\theta_5}) (a_1 + a_4 e^{-j\theta_6} - a_5 e^{-j\theta_6}) \]  
(5)
\[ e^{j\theta_1} + e^{-j\theta_2} + 2a_4 \cos(\theta_4 - \theta_7) + 2a_5 \cos(\theta_5 - \theta_7) = 0 \]  
(6)

Noting \[ e^{j(\theta_1+\theta_2)} = e^{j\theta} - \frac{e^{j\theta}}{2} \], equation (6) reduces to the form:
\[ 2a_4 a_5 \cos(\theta_4 - \theta_5) - 2a_4 a_5 \cos(\theta_4 - \theta_5) + a_1^2 + a_2^2 + a_3^2 + a_4^2 = 0 \]

Or, dividing every term:
\[ \frac{a_1 \cos \theta_4}{a_2} - \frac{a_4 \cos \theta_1}{a_4} + \frac{a_2^2 + a_3^2 - a_5^2 + a_4^2}{2a_2 a_4} = \cos(\theta_4 - \theta_5) \]

or,
\[ K_1 \cos \theta_4 - K_2 \cos \theta_1 + K_3 = \cos(\theta_4 - \theta_5) \]  
(7)

Where,
\[ K_1 = \frac{a_1}{a_2}, \quad K_2 = \frac{a_4}{a_4}, \quad K_3 = \frac{(a_1^2 + a_2^2 - a_3^2 + a_4^2)}{2a_4 a_2} \]

Equation (7) is called “Freudenstein Equation” which can be used for the synthesis of four-bar mechanisms.

We have used this equation to find out the length of the links by the help of input and output angles.

We have assumed the length of fixed length and then calculated the length of other 3 links. The specifications can be seen in the calculation.

4. DESIGN METHODOLOGY

Designing is a comprehensive and elaborate process and it involves certain steps to be followed for generating an effective design which will meet all our requirements without compromising with the quality of the same. Design Methodology state various processes used while designing. Following are the steps followed by us in our project’s designing:

1- Determining Decision Variables: Various materials were also looked into like A 36 alloy steel, AISI 1018 alloy steel, ST 52 alloy steel and strength of each material was compared keeping in mind the cost and the section dimensions to be used.
2- **Hand Sketching and CAD modelling**: A basic sketch of the frame was drawn on paper keeping in mind all the components to be used in the vehicle. It was just like a blueprint of the CAD design. We also made a model of steering on 3D Max software. We made the CAD model on Solidworks 2013 version.

3- **Calculations**: After CAD modelling we did our design and calculations with the help of various static and dynamic analysis equations.

4- **Analysis of CAD Model of Steering on Geogebra**: Analysis was done next to formation of model on SolidWorks by using Geogebra software as the analysis tool and results were thoroughly studied for proper working of steering mechanism.

5- **Modifications Based On Geogebra Results**: After the study of analysis results the link lengths were changed in order to achieve the double rocker mechanism.

6- **Analysis of Modified Design of Steering**: Again the analysis of this new design was performed and results were studied.

7- **Final Design**: After the study of analysis results it was found that the new results were satisfactory and this new steering mechanism was the one that can be worked with. So this was finalized and different components were added to the design to generate actual picture of how the vehicle would look after its completion. The pictures attached above shows the final design.

5. **STEERING DESIGN**

![Model of steering on 3DS Max](image)

Model of steering on 3DS Max
Model of steering on 3DS Ma

Rendered Picture of Chassis

6. ANALYTICAL CALCULATIONS

By Freudenstein’s Equation,
\[ K_1 \cos \theta_{14} - K_2 \cos \theta_{12} + K_3 = \cos(\theta_{14} - \theta_{12}) \]

Where,
\[ K_1 = \frac{a_1}{a_2}, \quad K_2 = \frac{a_1}{a_4}, \quad K_3 = \frac{(a_1^2 + a_2^2 - a_3^2 + a_4^2)}{2a_4a_2} \]

For three positions of input and output link,

We have
Now assuming, value of link 

\[ a_1 = 34 \text{ cm} \]

so by solving the equation and putting the value of length of \( a_1 \) in equation we get \( a_2 = 11 \text{ cm} \), \( a_3 = 27 \text{ cm} \), \( a_4 = 11 \text{ cm} \). We fix the length of \( a_1 \), this means that \( a_2 \) and \( a_4 \) act as rocker arms and \( a_3 \) as coupler. Since, the link opposite to the shortest link is fixed therefore we get double rocker mechanism.

### REFERENCES

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