DEVELOPMENT OF PEAUCLLIER AND WATT'S MECHANISM USING SMART TECHNOLOGY (CNC ROUTER)

A. VJAY KUMAR, ASSEMSETTI AKSHAY, JANGAMPALLY AKHIL, JOKARA SANGAMESH

ABSTRACT

The object of this project is to design peaucellier mechanism using smart manufacturing. Machining is a metal/wood removing process. It removes a material & decreases the material mass hence this is a subtractive process. Conventional Machining process is a machining process in which the machining carry out with the traditional method. In this process the sharp point cutting tools are used for the machining purpose, such as the taper tool in the lathe machine for tapering.

smart manufacturing (SM) is a technology-driven approach that utilizes Internet-connected machinery to monitor the production process. The goal of SM is to identify opportunities for automating operations and use data analytics to improve manufacturing performance. Using smart manufacturing here we are going to produce peaucellier mechanism , it is a straight line motion mechanism and a four bar mechanism used to enlarge or reduce drawings etc. peaucellier mechanism is designed in cad version 2020 and it is imported to the art cam 2018 software by applying boundary conditions & tool paths saved .tap file and which is imported to CNC Router. After feeding Program in the CNC Router Machine the object/ the Prototype model would be produced. Here working material would be MDF [Medium-density fiberboard] having thickness 8mm to 10mm. The peaucellier mechanism assembly consists of the following major components:

1) 8 links

2) 1 turning pair

CHAPTER 1 INTRODUCTION

1.1 Definition of Smart Technology

The term smart technologies (Smart-Tech) is understood as a generalization of the concept of. smart structures. Smart technologies encompass mechanical systems equipped with sensors, actuators and pre-programmed controllers, which allow a structure to adapt to unpredictable. Smart manufacturing (SM) is a technology-driven approach that utilizes Internet-connected machinery to monitor the production process. The goal of SM is to identify opportunities for automating operations and use data analytics to improve manufacturing performance.

SM is a specific application of the Industrial Internet of Things (IIoT). Deployments involve embedding sensors in manufacturing machines to collect data on their operational status and performance. In the past, thatinformation typically was kept in local databases on individual devices and used only to assess the cause of equipment failures after they occurred.

Now, by analyzing the data streaming off an entire factory's worth of machines, or even across multiple facilities, manufacturing engineers and data analysts can look for signs that particular parts may fail, enablingpreventive maintenance to avoid unplanned downtime on devices.

1.2 Types of Smart Technology

1.2.1 Additive manufacturing

Additive manufacturing is the process of creating an object by building it one layer at a time. eIt is the oppositeof subtractive manufacturing, in which an object is created by cutting away at a solid block of material until the final product is complete.

Technically, additive manufacturing can refer to any process where a product is created by building somethingup, such as molding, but it typically refers to 3-D printing.

Additive manufacturing was first used to develop prototypes in the 1980s — these objects were not usually functional. This process was known as rapid prototyping because it allowed people to create a scale model ofthe final object quickly, without the typical setup process and costs involved in creating a prototype. As additive manufacturing improved, its uses expanded to rapid tooling, which was used to create molds for finalproducts. By the early 2000s, additive manufacturing was being used to create functional products.

More recently, companies like Boeing and General Electric have begun using additive manufacturing as integral parts of their business processes.

Figure.1.1 3D Printing

1.2.2 Robotics

Robotics is an interdisciplinary branch of computer science and engineering.[1] Robotics involves design, construction, operation, and use of robots. The goal of robotics is to design machines that can help and assisthumans. Robotics integrates fields of mechanical engineering, electrical engineering, information engineering, mechatronics, electronics, bioengineering, computer engineering, control engineering, softwareengineering, mathematics, etc.

Figure 1.2 Robotic Arm

1.2.3 CNC Router

A computer numerical control (CNC) router is a computer-controlled cutting machine related to the hand-held router used for cutting various hard materials, such as wood, composites, aluminium, steel, plastics, glass, and foams. CNC routers can perform the tasks of many carpentry shop machines such as the panel saw, the spindle moulder, and the boring machine. A CNC router is very similar in concept to a CNC machine milling machine. Instead of routing by hand, tool paths are controlled via computer numerical control (CNC). The CNC router is one of many kinds of tools that have CNC variants."

Other names: CNC milling machine, CNC routing machine, 3D carving machine.

New style open-source CNC Routers are cost-effective alternatives to laser cutters. Both types of machines have different affordances, but some tasks can be done on either one, e.g. cutting wood to create furniture and sculptures, or engravings. The precision and resolution of laser cutter is much higher, but a typical laser cutter cannot cut through heavy planks and do deep and large engravings.

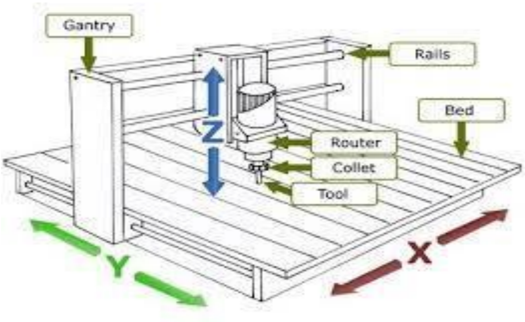

Figure 1.3 CNC Router

1.3 History of CNC Machine

The First CNC Machine

The first CNC machine was credited to James Parsons in 1949. Parsons was a computer pioneer who worked on an Air Force Research Project. The research was on how to produce helicopter blades and betteraircraft skin.

Parsons was able to calculate helicopter airfoil coordinates with an IBM 602A multiplier. He then fed the data into a punched card, which he used on a swiss jig borer. This information led to the manufacture of many helicopter blades and aircraft skins. According to the accepted CNC history, this was considered the first CNC machine. Parson would later receive the Joseph Maria Jacquard Memorial Awards for his work.

Development of CNC Technology

Before the development of the first CNC machine, some machines could be instructed to make other tools. This was called Numerical Control (NC).

1.4 Types of CNC Machines

1.4.1 Lathe CNC machines

Lathe CNC machines are defined by their capability to turn materials during operation. They have less number of axes than CNC milling machines, making them shorter and more compact.

CNC lathe machines consist of a lathe at the center that manages and transfers material programmatically tothe computer. At the present time, it is widely used as a lathe due to its fast and accurate function.

Once the initial setup is done, a semi-skilled worker can operate it easily. This type of lathe is also used for mass production such as capstan and turret. But there is no programmed fed system.

Figure 1.6 CNC Lathe Machine

1.4.2 CNC Milling Machine

It is one of the most common types of CNC machine, that have built-in tools for drilling and cutting. The materials are located inside a milling CNC machine, after which the computer will lead the tools to drill or cut them.

Most of the CNC milling machines are available in 3 to 6-axis configurations. This machine is used to produce gears like spur gear and is also used to drill the workpiece bore and make slots by inserting part program into the system.

A semi-skilled worker can operate it easily. It is also used for mass production such as a capstan and turret. But there is no programmed fed system. The parts made by this machine are very precise in dimensional tolerance.

Figure 1.7 CNC Milling Machine

Scope and limitations of CNC Router

Computer numerical control machining's advantages make it the preferred manufacturing method for severalindustries, such as medical equipment, automobile and aerospace. This manufacturing method can deliver highly precise made-to-order parts.

Due to the accuracy of this process, delicate parts that must adhere to strict designs are among the best types of projects for CNC machines. However, with all these advantages, CNC machining has some limitations. When choosing part creation methods, learn as much as you can about CNC machining. When you understand how the process works, you can make an informed decision that balances your budgetary needs with the requirements of your project's precision.

1.4.3 Advantages of CNC Router

- Constant Use With Minimal Maintenance
- High Precision and Accuracy Can Be Obtained
- Quick Machining Speed
- Simulated Models or Prototypes
- More Capability
- High Production and Scalability
- Design Retention

1.4.4 Disadvantages of CNC Router

- High Initial Cost
- Need Skilled Labour

- Steep Learning

Applications of CNC Router

- CNC machining can be repeated
- It is used in dental equipments
- Transportation
- Research and Development
- Construction

1.4.5 straight line Motion Mechanism

A straight-line mechanism is a mechanism that converts any type of rotary or angular motion to perfect or near-perfect straight-line motion, or vice-versa. Straight-line motion is linear motion of definite length or "stroke", every forward stroke being followed by a return stroke, giving reciprocating motion. The first such mechanism, patented in 1784 by James Watt, produced approximate straight-line motion, referred to by Wattas parallel motion.

Straight-line mechanisms are used in a variety of applications, such as engines, vehicle suspensions, walkingrobots, and rover wheels. These are the few types of straight line motion mechanism.

1.4.6 Types of Straight-line Motion Mechanism.

- The Watt Mechanism.
- The Grass-hopper Mechanism
- The Hart's Mechanism
- The Peaucellier Mechanism

1.7.5.1 The Watt Mechanism:

In kinematics, Watt's linkage (also known as the parallel linkage) is a type of mechanicallinkage invented by James Watt in which the central moving point of the linkage is constrained to travel on a nearly straight line. It was described in Watt's patent specification of 1784 for the Watt steam engine.

Watt's linkage consists of three bars bolted together in a chain. The chain of bars consists of two end bars and a middle bar. The middle bar is bolted at each of its ends to one of theends of each outer bar.

The two outer bars are of equal length, and are longer than the middle bar. The three barscan pivot around the two bolts. The outer endpoints of the long bars are fixed in place relative to each other, but otherwise the three bars are free to pivot around the two joints where they meet.

Watt's linkage is used in the rear axle of some car suspensions as an improvement overthe Panhard rod, which was designed in the early twentieth century.

Both methods are intended to prevent relative sideways motion between the axle and body of the car. Watt's linkage approximates a vertical straight-line motion much more closely, and it does so while consistently locating the centre of the axle at the vehicle's longitudinal centreline, rather than toward one side of the vehicle as would be the case if asimple Panhard rod were used.

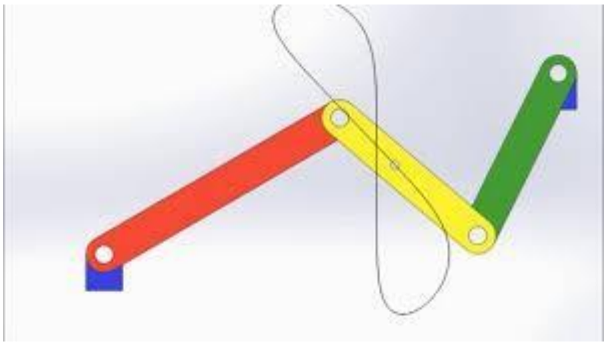

Figure 1.21 The Watt Mechanism.

The Peaucellier Mechanism

The Peaucellier–Lipkin linkage (or Peaucellier–Lipkin cell, or Peaucellier–Lipkin inversor),invented in 1864, was the **first** true planar straight line mechanism – the first planar linkage capable of transforming rotary motion into perfect straight-line motion, and vice versa. It is named after Charles-Nicolas Peaucellier (1832–1913), a French army officer, and Yom TovLipman Lipkin (1846–1876), a Lithuanian Jew and son of the famed Rabbi Israel Salanter.

Until this invention, no planar method existed of converting exact straight-line motion to circular motion, without reference guideways. In 1864, all power came from steam engines, which had a piston moving in a straight-line up and down a cylinder. This piston needed to keep a good seal with the cylinder in order to retain the driving medium, and not lose energy efficiency due to leaks. The piston does this by remaining perpendicular to the axis of the cylinder, retaining its straight-line motion. Converting the straight-line motion of the piston into circular motion was of critical importance. Most, if not all, applications of these steam engines, were rotary. The mathematics of the Peaucellier–Lipkin linkage is directly related tothe inversion of a circle.

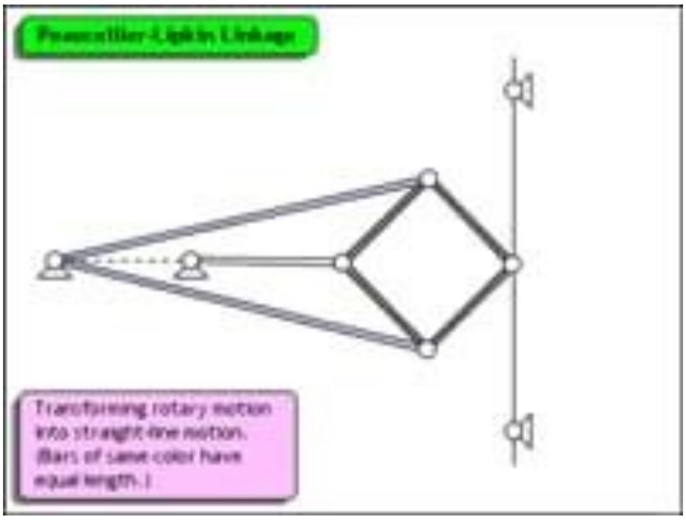

Figure1.24 The Peaucellier Mechanism

LITERATURE SURVEY

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Earlier Sarrus linkage:There is an earlier straight-line mechanism, whose history is not well known, called the Sarrus linkage. This linkage predates the Peaucellier–Lipkin linkage by 11 yearsand consists of a series of hinged rectangular plates, two of which remain parallel but can be moved normally to each other. Sarrus' linkage is of a three-dimensional class sometimes known asa space crank, unlike the Peaucellier–Lipkin linkage which is a planar mechanism.

Slider-rocker four-bar acts as the driver of the Peaucellier–Lipkin linkage. Peaucellier–Lipkin linkages

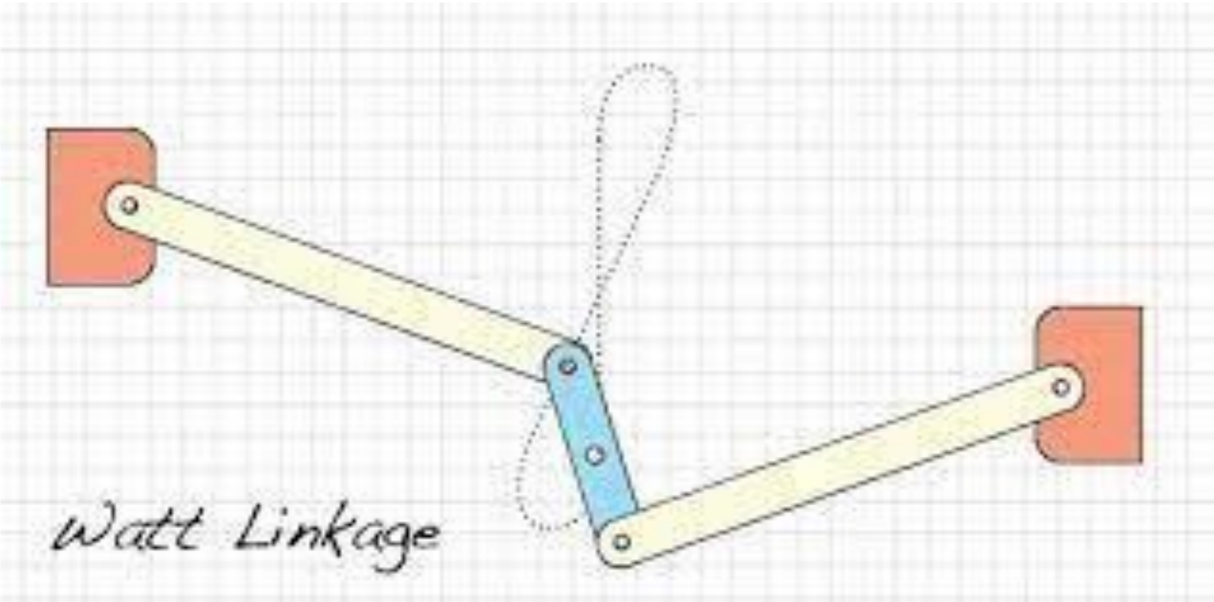
(PLLs) may have several inversions. A typical example is shown in the opposite figure,in which a rocker-slider four-bar serves as the input driver. To be precise, the slider acts as the input, which in turn drives the right grounded link of the PLL, thus driving the entire PLL in June 1784.

I have got a glimpse of a method of causing a piston rod to move up and down perpendicularly by only fixing it toa piece of iron upon the beam, without chains or perpendicular guides [...] and one of the most ingenious simple pieces of mechanics I have invented.[2]

This type of linkage is one of several types described in Watt's 28 April 1784 patent specification. However, in hisletter to Boulton he was actually describing a development of the linkage which was not included in the patent.

The slightly later design, called a parallel motion linkage, led to a more convenient space-saving design whichwas actually used in his reciprocating, and his rotary, beam engines.[3]

The context of Watt's innovation has been described by C. G. Gibson:



. **DESIGN AND KINEMATICS ANALYSIS**

DesignConcepts

The design concepts are provided by a software designer or engineering design with a foundation of design methodsthat can be applied in a set of fundamental concepts. In designing a concept, a prototype is more essential to improvise the design and find out the complexation of the modal. For the prototype, a manufacturing software (3DPrinting Methods) is used. The computer software of designing for the machine that can be used to create or improvise the concept by a set of tools and command with help of its definitions and magnitude valves. An application of the software can determine by use and user friendly to the person familiar to it.

Software

The computer software of designing for the machine that can be used to create or improvise the concept by a set of tools and command with help of its definitions and magnitude valves. An application of the software can determine by use and user friendly to the person familiar to it.

CAD Software

CAD software is helping to develop a design or concept by using some commands and tools with its specific definitions and magnate valves. Moreover, Cad software there is much software like ,AutoCAD: Autodesk Computer-Aided Design and Drafting software with works on the set of commands and programming methods like line command, circle command, and its specific location of the pointer by using a coordinate system CAD/CAE/CAM systems are now widely accepted and used throughout the industry. These systems moved fromcostly workstations based mainly on UNIX to off-the-shelf PCs. 3D modeling has become a norm, and it can be found even in applications for the wider public, like 3D buildings modeling in Google Maps, house furnishing (IMSI Floorplan), or garden planning. Advanced analysis methods like FEM (Finite Element Method as for structural analysis), flow simulations are a ubiquitous part of the design process. CAM systems are used for simulation and optimization of manufacturing, and NC code is created and loaded to NC machines

ARTCAM Software

Most CAD/computer-aided manufacturing (CAM) tools are designed to enable engineers to design and manufacture products. From the very beginning Art CAM software has been developed to enable artists and designer to create whatever they can imagine. Art CAM is used in a variety of sectors from jewelry and coin minting, to the design and manufacture of architectural cornicing and facades. The common theme across these sectors is the desire to produce intricate artistic forms with incredible detail that can then be quickly and easily machined or 3D printed. This class will introduce you to the process that will enable you to take a simple 2Ddrawing and convert it into a complex decorative relief and machine it.

ARTCAM is one of the simulating software in which we can generate tool paths for different designs which areimported from AUTOCAD software in stl file formate.

Design of peucellier mechanism using AUTOCAD and ARTCAM

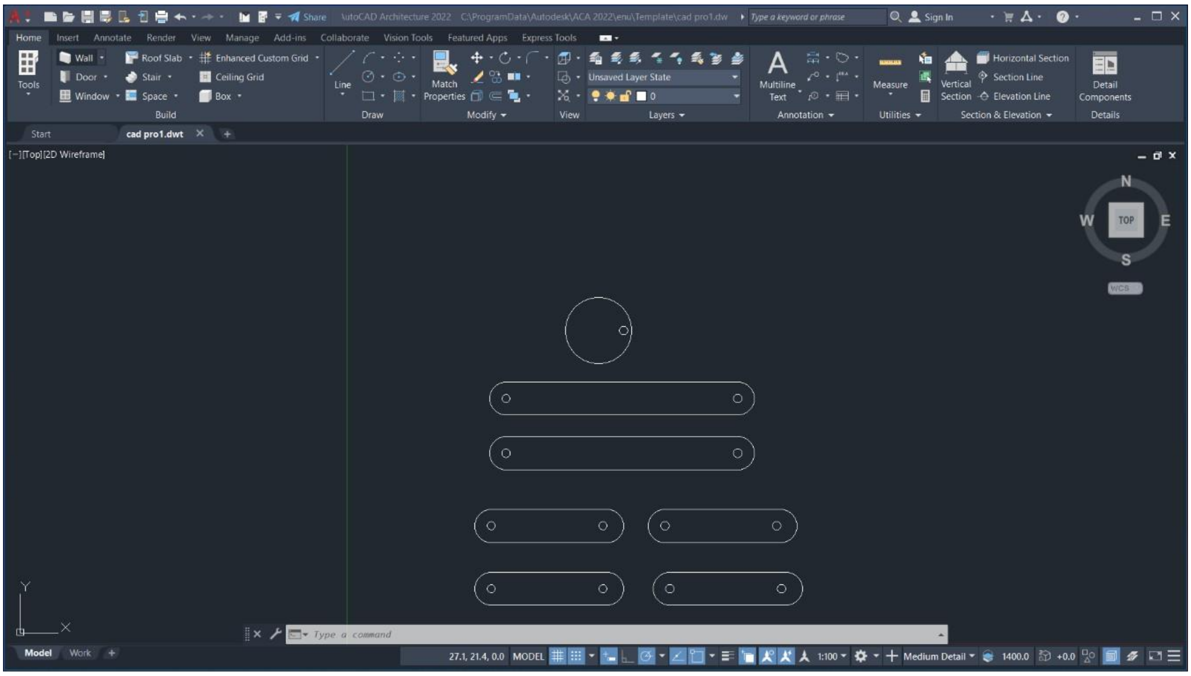


Figure 4.1 design of peaculiar linkage

Using autocad software we have designed this peucellier mechanism In which eight links and one turning pair so,that we can have the reference of the image can be identified while we are simulating and drawing toolpath that would be easy

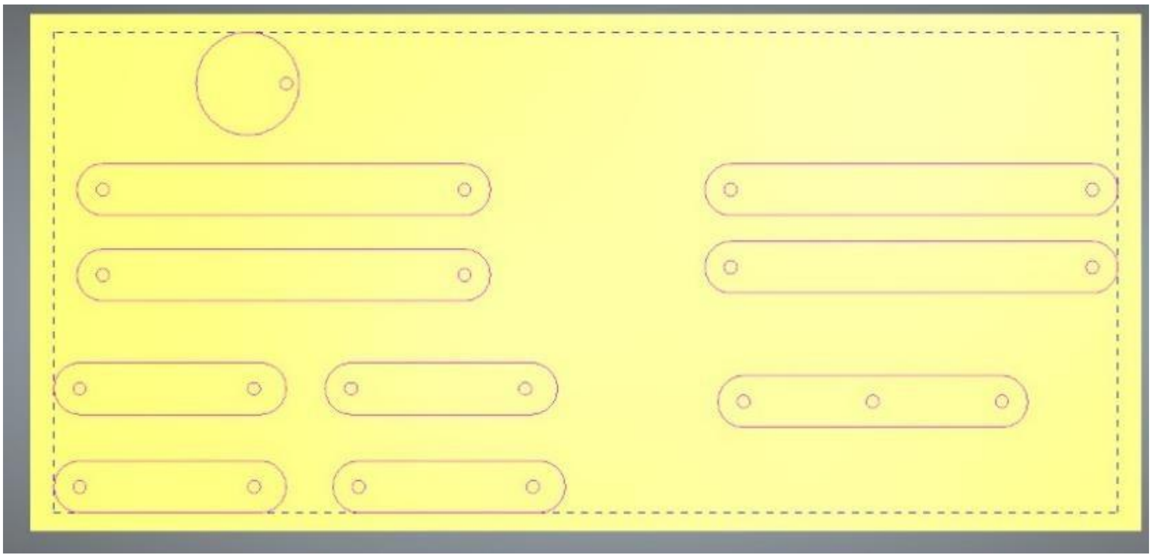


Figure 4.2 Artcam design

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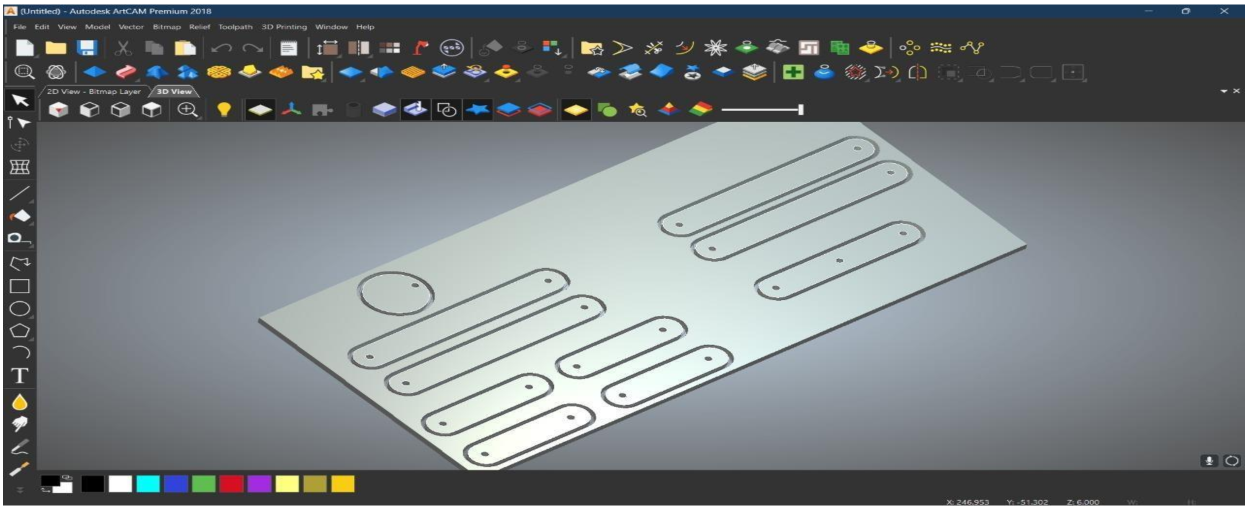
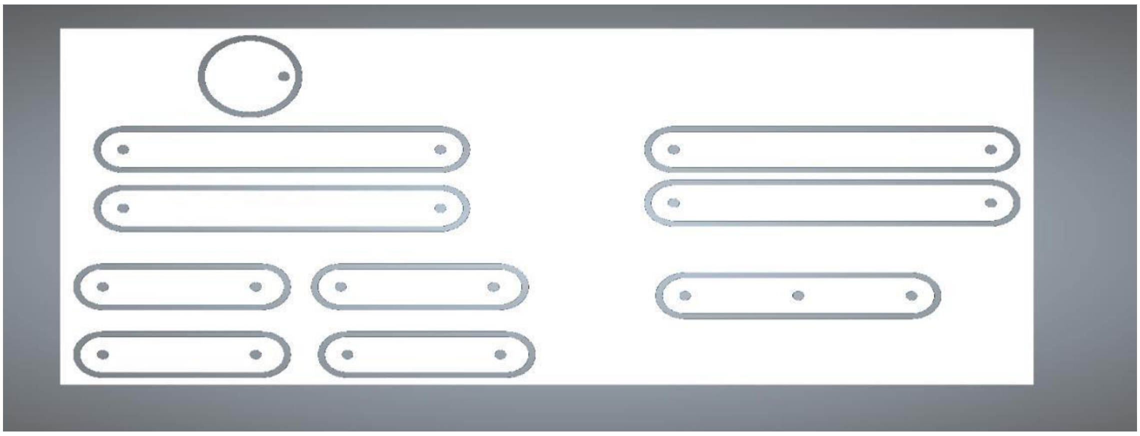


Figure 4.2 Artcam design



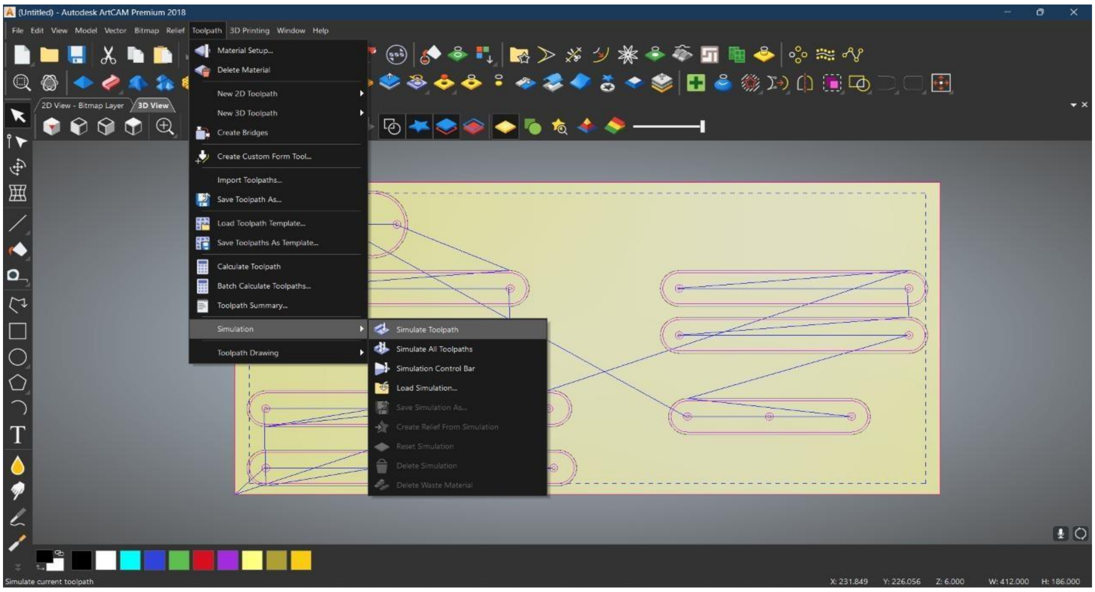


Figure 4.2 Artcam design

Mechanism of Designed Model

Peaucellier Exact Straight-Line Mechanism

Peaucellier linkage can convert an input circular motion to the exact straight-line motion. The construction of thismechanism is such that the point which is connected to the crank moves in a circular path and the point traversing the straight line is selected as the output point. The linkage has a rhombic loop formed of the equal length members, 5, 6, 7 and 8. Two equal length length links are connected to the opposite corners of the rhombus at one end and to a common fixed point at the other ends. The point A of the rhombus is connected to fixed point O2 through the link 2. The length of the link 2 is equal to the distance between points O2 and O4. By the constraints of the geometry point A moves in a circular path and as the point A moves in a circle point P traverses an exact straight-line path normal to the line joining O2 and O4.

From the construction of the Peaucellier linkage it is clear that this is a much more complex mechanism than themechanisms generating approximate straight lines, which were simple four bar linkages. This mechanism has eight members and six joints.

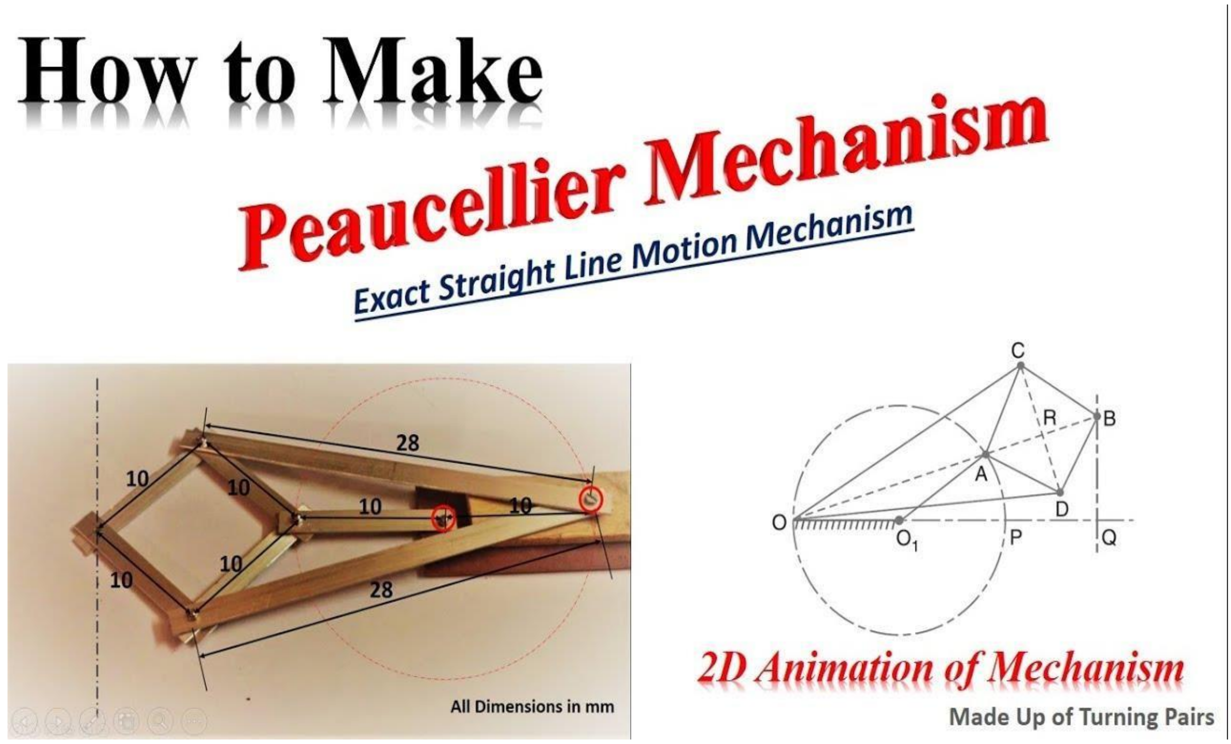


Figure 4.3 Peaucellier Mechanism

4.2 Degree of Freedom

The basic Peaucellier–Lipkin linkage with 1 degree of freedom was transformed into a more skillful mechanism, through the addition of 4 more degrees of freedom. The resulting 5-degree-of-freedom leg enables the walking machine to move along paths that are straight lines and/or concave or convex curves**.** The Peaucellier mechanism generates exact straight lines, meeting some restrictions among theirlinks dimensions and the input angle. The mechanism has eight links, but due to those initial restrictions, only requires to find relations among three of its eight links and rotation angle

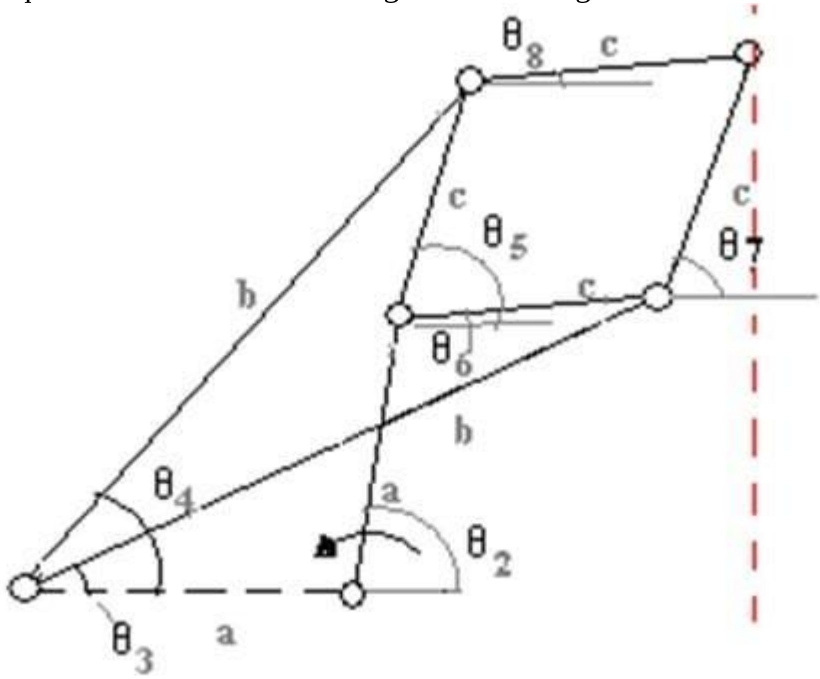


Figure 4.4 Line Diagram(1)

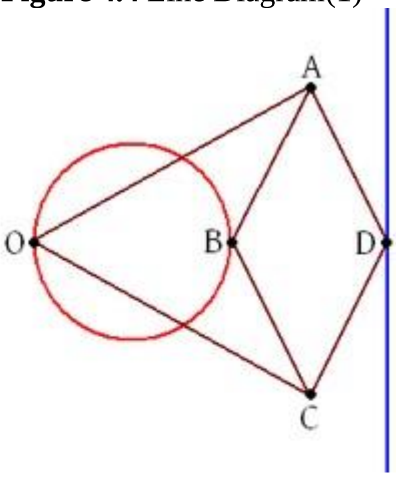


Figure 4.5 Line Diagram(2)

Geometric diagram of a Peaucellier linkage

In the geometric diagram of the apparatus, six bars of fixed length can be seen: *OA*, *OC*, *AB*, *BC*, *CD*, *DA*. The length of *OA* is equal to the length of *OC*, and the lengths of *AB*, *BC*, *CD*, and *DA* are all equal forming a rhombus. Also, point *O* is fixed. Then, if point *B* is constrained to move along a circle (for example, by attaching it to a bar with a length half way between *O* and *B*; path shown in red) which passes through *O*, then point *D* will necessarily have to move along a straight line (shown in blue). On the other hand, if point *B* were constrained to move along a line (not passing through *O*), then point *D* would necessarily have to move along a circle (passing through *O*).

4.3 Mathematical proof of concept

4.3.1 Collinearity

First, it must be proven that points *O*, *B*, *D* are collinear. This may be easily seen by observing that the linkage is mirror-symmetric about line *OD*, so point *B* must fall on that line.

More formally, triangles △*BAD* and △*BCD* are congruent because side *BD* is congruent to itself, side *BA* iscongruent to side *BC* , and side *AD* is congruent to side *CD* . Therefore, angles ∠*ABD* and ∠*CBD* are equal.

Next, triangles △*OBA* and △*OBC* are congruent, since sides *OA* and *OC* are congruent, side *OB* is congruent to itself, and sides *BA* and *BC* are congruent. Therefore, angles ∠*OBA* and ∠*OBC* are equal.

Finally, because they form a complete circle, we have but, due to the congruences, ∠*OBA* = ∠*OBC* and ∠*DBA* = ∠*DBC*, thus therefore points *O*, *B*, and *D* are collinear .Inverse points

Let point *P* be the intersection of lines *AC* and *BD*. Then, since *ABCD* is a rhombus, *P* is the midpoint of both line segments *BD* and *AC*. Therefore, length *BP* = length *PD*.

Triangle △*BPA* is congruent to triangle △*DPA*, because side *BP* is congruent to side *DP*, side *AP* is congruent to itself, and side *AB* is congruent to side *AD* . Therefore, angle ∠*BPA* = angle ∠*DPA*. Butsince ∠*BPA* + ∠*DPA* = 180°, then 2 × ∠*BPA* = 180°, ∠*BPA* = 90°, and ∠*DPA* = 90°.

Let:

Then:
(due to the Pythagorean theorem)(same expression expanded) (Pythagorean theorem)
Since *OA* and *AD* are both fixed lengths, then the product of *OB* and *OD* is a constant: and since points *O*, *B*, *D* are collinear, then *D* is the inverse of *B* with respect to the circle (O,*k*) with center *O* and radius *k*. Inversive geometry

Thus, by the properties of inversive geometry, since the figure traced by point *D* is the inverse of the figure traced by point *B*, if *B* traces a circle passing through the centre of inversion *O*, then *D* is constrained to tracea straight line. But if *B* traces a straight line not passing through *O*, then *D* must trace an arc of a circle passing through *O*. Q.E

CONCLUSION

This project is all about formulating the relations between the lengths and angles subtended by the linkages of the Peaucellier Mechanism during its motion. The main goal of this project is to provide a properdesign procedure for this mechanism so as to minimize the errors occurring during the manufacturing and working of the mechanism and to avoid the usage of hit and trial method for determining the various lengths and working angle of the mechanism. In this project few relations are deduced to calculate the working angle and by knowing the value of the working angle we can easily programthe motor so as to operate the mechanism as per the requirement of the working stroke. Further research on this mechanismcan be done on its optimum utilization by calculating theminimumworking area needed for its antilocking condition at its center and at the end points so as to maximize the stroke length

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