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Kinematic analysis of Automated Elliptical Trammel for cutting applications

Manthan Kumar, Anmol Verma, Manish Sharma, Utkarsh Srivastava and R. K. Tyagi

Amity School of Engineering and Technology, Amity University, Noida, India

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ABSTRACT

This article presents the automation of elliptical trammel mechanism by applying rack and pinion and DC Motor arrangement on the rod of the trammel which moves on the channel. The power supply is done by batteries and the entire system is carried out to have its operation by making ellipses of varying sizes. Moreover, a compass system attached at the end of the pinion makes it easy to fix and remove the cutting tools of every kind. Equations relating the position of two sliders with the position of drawing or cutting element provided at the end of connecting rod are derived. The results are experimentally verified by fabricating an elliptical trammel and drawing ellipses from it. The sliders of the mechanism move perpendicular to each other and the drawing or cutting element produces the ellipse on the required surface and of the required major and minor axes which in turn provides a very convenient mechanism for cutting out elliptical pieces of whatever sizes out of any kind of material.

Keywords: Elliptical trammel, rack and pinion, ellipse, major axis, minor axis

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INTRODUCTION

An Elliptical trammel also knowm as the trammel of Archimedes is a mechanism that is used to trace out an ellipse. It is basically an inversion of double crank chain mechanism. A double slider crank chain has four links having two sliding and two turning pairs. It consists of two sliders or shuttles which are confined ('trammelled') to perpendicular channels or rails, and a coupler which is attached to the sliders by pivots at fixed positions along the rod. By the back and forth movements of sliders along their channels, the coupler or connector rod follows an elliptical pattern drwaing out an ellipse. The semi-axes a and b are basically the distances between connectiong rod's end and the two pivoted points.

The size of ellipses can be varied by varying the sizes of a and b respectively. The general mechanism cans be explained as, different mechanisms can be obtained by fixing different links in a kinematic chain. And this particular method of obtaining different mechanism is known as inversion of the Mechanism. A completely different mechanism named, the Stiller-Smith Mechanism had also been obtained by changing rotational characteristics of the slider of the trammel [1]. This Stiller-Smith mechanism was later compared with a normal slider crank mechanism through a comapartive study for eight cylinder I.C. Engine and was found significant [2]. Different types of four bar double slider crank mechanism can be enlisted as elliptical erammel, scotch yoke mechanism, oldham's coupling.

Various experiments and researches has been done on the mechanism to broaden it's area of applications. The force analysis on the side wall model of a one liter I.C. Engine has successfully shown the utlilization of motion of elliptical trammel with a floating crank [3]. Also, for automatic tool changing (ATC) purposes on machines the elliptical trammel mechanism had been implemented to reduce the tool changing time which was also found to be cost effective [4]. Various software based methods like MSC ADAMS and solutions have also been adopted to perform the dynamic analysis and ensure the working of mechanisms for particular applications [5].

The kinematic analysis must be studied to find out the posititon and motion aspects of the mechanism [6]. In this research, kinematic analysis i.e. position analysis has been found out to justify the significant tool motion path clamped at the end of the tool holder attached to the coupler of the device. The readings have been taken and plotted for three cases i.e., at the extreme outside position of the cutter, middle position of the cutter along the range of the cutter, and at the extreme inside position of the cutter. The position of cutter was changed by using the switch. The main objective of performing the test was to justify the use of mechanism as a device to cut out the significant elliptical shapes from a surface with utmost flexibilty in changing the sizes automatically by using the motor and rack and pinion arrangements on the coupler or connecting rod. The device made was capable enough of showing relevance for the objective to accomplish and was also cost effective.

MATERIALS AND METHODS

The mechanism of elliptic trammel has been fabricated and automated by using rack and pinion and a DC Motor. The fabricated device showed cost effectiveness and applications over large fields of manufacturing. The components of the device are enlisted as, a wooden base of (30x30 cm), four square wooden platforms (13x13 cm), two wooden sliders, steel connecting rod used for a connection between the two sliders, DC motor (10 rpm, 4.116 Nm or 42Kgcm), rack and pinion arrangement, battery (9V), and a switch with wires.

Motor's spindle has been attached to the rack and pinion inside which a cutting tool holder is attached for the back and forth motion of the cutter which provided it a certain range for the variation in ellipse cutting process. Further to automate the mechanism, this arrangement has been connected with two batteries and a switch from other end of the rod for power supply to the motor and the connections were soldered. The switch works as a toggle device as it could be used to vary the major and minor axes to achieve the targeted ellipse, this happens because of the rotation of motor's spindle which further powers the rack and pinion arrangement connected to it and finally the position of the cutting tool can be set up by using the switch. The complete assembly of the device has been shown in Fig.1. Further, kinematic analysis or position analysis of the device has been performed by drawing sets of ellipses considering three different cases and graphs have been plotted for each case between distance moved by both the sliders vs angle traced on ellipse.

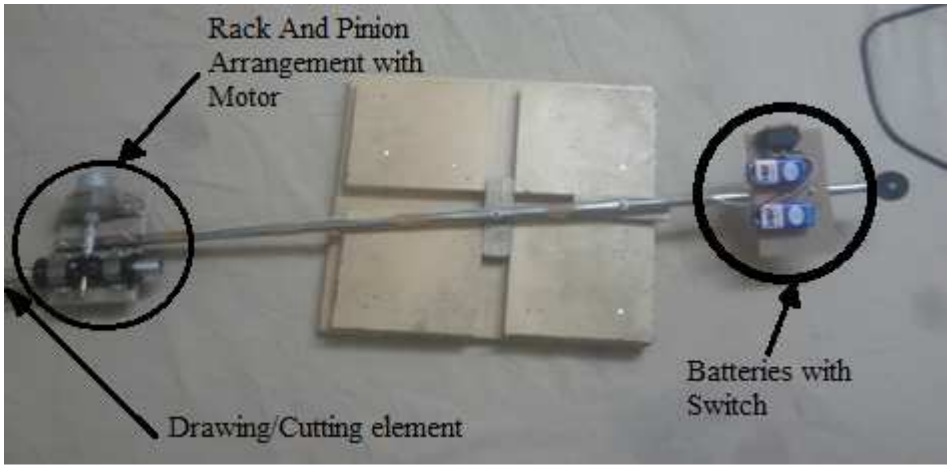

Fig1. Assembly of Automated Elliptical Trammel

RESULTS AND DISCUSSION

The Elliptical trammel has been automated by using Rack and pinion arrangement with power supply from motor. Henceforth, sets of readings have been taken for the movement of sliders of elliptical trammel along the channel at certain angles of the drawn ellipses. The Elliptical Trammel fabricated inaugurate the capability to draw the ellipses and the motion of the cutter or the drawing element has been automated to move through any varying distance from the inner most point of the rack and pinion to the outer most point of the rack and pinion, the rack and pinion is being automatized using a 4.116 Nm torque or 10 rpm motor connected to batteries of 9V each through the connection of wire.

Three ellipses of different sizes have drawn and each quadrant was divided into 3 parts, thus the 4 quadrants were divided into 12 parts, a reference point was set and the distance travelled by each slider for the each subpart has been noted and 3 sets of readings have been made. Thus from the above test being performed using the fabricated Elliptical Trammel following work has been done, the readings have been taken for three cases:-

a. Extreme outside position of the cutter,
b. Middle position of the cutter along it's moving range,
c. Extreme inside position of the cutter.

And hence graphs have been plotted for each case between distance moved by both the sliders vs angle traced on ellipse. Readings taken for different cases have been shown in Table 1, table 2 and table 3 respectively. Fig.3. to Fig.5., shows the graph plots of the readings for different cases. It is found that the use of mechanism as a device to cut out the significant elliptical shapes from a surface has utmost flexibilty in changing the sizes automatically by using the motor and rack and pinion arrangements on the coupler or connecting rod.

Table1: Extreme Outside position of the cutter (a =59, b=48)

S.No.	Angle (Degree)	Position of Slider 1 (cm)	Position of Slider 2 (cm)
1	0	11.4	0
2	30	8.7	7.4
3	60	4	10.7
4	90	0	11.4
5	120	-5.6	10.3
6	150	-9.8	6.2
7	180	-11.4	0
8	210	-8.9	-7.1
9	240	-4.5	-10.4
10	270	0	-11.4
11	300	5.7	-9.9
12	330	9.9	-5.9
13	360	11.4	0

Table 2: Middle position of the cutter along its range, (a=56.5, b=44.5)

S.No.	Angle (Degree)	position of slider1(cm)	position of slider2 (cm)
1	0	11.4	0
2	30	8.6	7.2
3	60	3.9	10.5
4	90	0	11.4
5	120	-5.7	10.1
6	150	-9.9	6
7	180	-11.4	0
1	210	-9	-7.3
2	240	-4.6	-10.6
3	270	0	-11.4
11	300	5.6	-10.1
12	330	9.8	-6.1
13	360	11.4	0

Table 3: Extreme inside position of the cutter, (a=54, b=42.5)

S.No.	Angle (Degree)	position of slider 1 (cm)	position of slider 2 (cm)
1	0	11.4	0
2	30	8.5	7.1
3	60	3.8	10.4
4	90	0	11.4
5	120	-5.8	10
6	150	-10	5.9
7	180	-11.4	0
8	210	-9.1	-7.4
9	240	-4.7	-10.7
10	270	0	-11.4
11	300	5.5	-10.2
12	330	9.7	-6.2
13	360	11.4	0

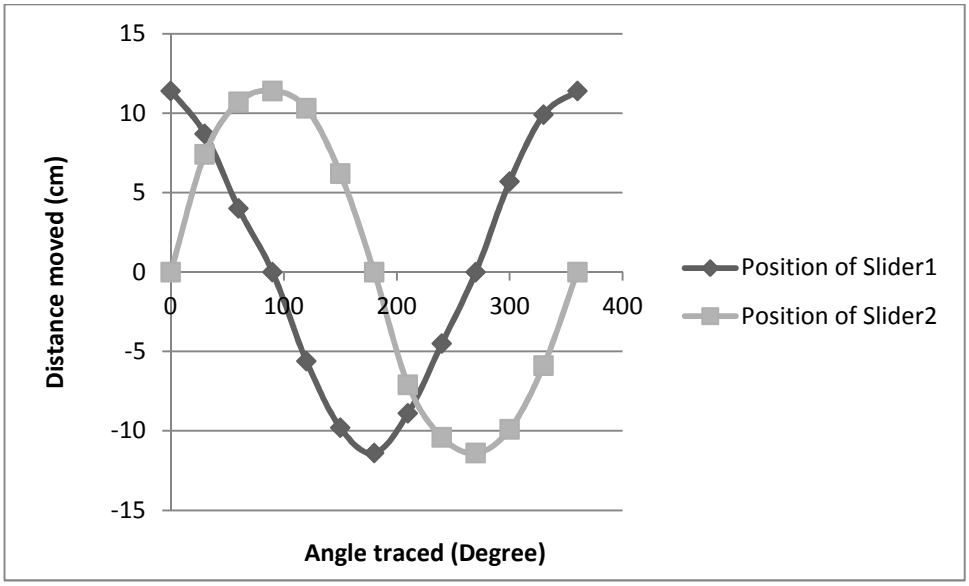

Fig.3. Distance moved by the sliders vs angle traced on ellipse for extreme outside position

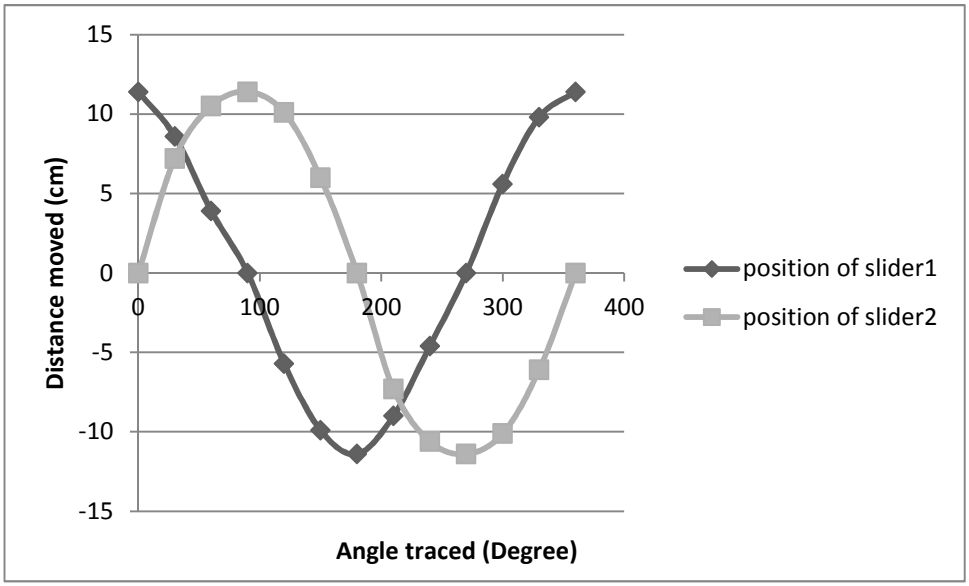

Fig.4. Distance moved by the sliders vs angle traced on ellipse for middle position of the cutter along its range

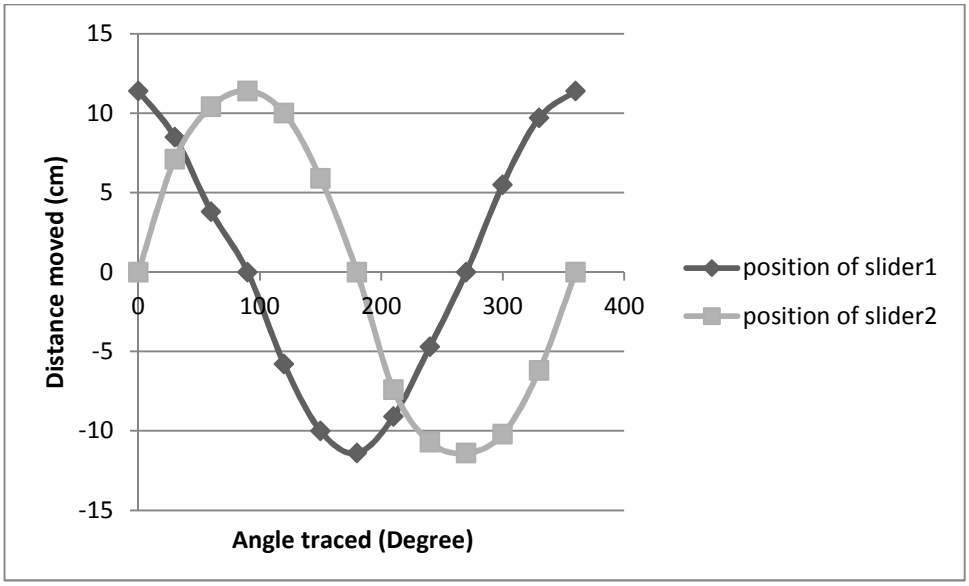

Fig.5. Distance moved by the sliders vs angle traced on ellipse for extreme inside position

CONCLUSION

Elliptical Trammel is a kinematic inversion of four bar mechanism which is used to draw ellipse of given major and minor axis. Elliptical trammel consists of two rotating pairs and two sliding pairs in which the sliders and the connecting rod makes the rotating pairs and the sliders and the fixed link make the sliding pairs.

The elliptical trammel mechanism made has been automated by using rack and pinion arrangement and supply through a 10 rpm motor using 3 point switch connected to 9V batteries. The mechanism is automated by using rack and pinion on the bar by using a DC Motor supply, however this idea helped in fabrication of the model of elliptical trammel.

The motion of the drawing or cutting element can be automated using rack and pinion arrangement controlled through battery supply and the drawing element is moved manually by the person drawing or cutting the ellipses on the given surfaces of the material like wood, steel and other given surfaces, thus the ellipse of given surface can be generated.

Initially, only ellipses could be drawn by the use of this mechanism but now it could be used on the surface of wood, steel and other material using automated mechanism for cutting, marking, drawing and various other processes. The ellipse of required major and minor axis can be drawn on the required surface, the ellipse drawn on the surface can be cut out and the ellipse obtained is used in the production of required machines and other products which require the elliptical surfaces.

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