



Application Of Geneva Mechanism In Automated Paper Cutting Machine

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Abstract

Industry 4.0, the fourth industrial revolution, is the cyber-physical transformation of manufacturing. Digitization and intellectualization of the manufacturing process are the needs of today's industry. Today's manufacturing industry is changing from mass production to specialized production. Rapid advances in manufacturing technology that help to increase productivity become possible with the knowledge of different mechanisms and their industrial applications in a complex form with computer and sensor control.

During the study of different mechanisms Geneva mechanism is found to have a wide application in automation and towards industry 4.0 in industries like packaging & shifting, production and assembly lines, liquid filling equipment, coal handling, steel plants, bottling plants, etc. The paper presents theoretical and practical aspects based on the Geneva mechanism model. This type of mechanism is an example of an intermediate device that converts continuous rotation into intermittent rotary motion. It consists of alternating periods of movement and rest. The most commonly used are the gear mechanism, cam-wheel mechanism, and intermediate gear mechanism. Compared with the four mechanisms, the noise of the inflated mechanism is large and the accuracy is low. The cam-wheel is very accurate and can be controlled with various motion curves, but the processing requirements are quite high. The impact of the intermediate gear mechanism is large and requires a light load. The purpose of this project is to build a model of an automatic paper-cutting machine. A Geneva drive is an indexing mechanism that changes continuous motion into intermittent motion, moving between equal intervals when cutting paper. This tool is used to reduce manual paper cutting and save time. This machine is useful for the paper cutting industry and we can avoid human labor and error.

Keywords- Geneva Mechanism, Industry 4.0, intermittent motion, Production, Manufacturing

1. Introduction

Mechanisms are fundamental components of the physical world that underlie the functioning of countless objects and systems. They serve as the intricate frameworks responsible for transmitting, transforming, and controlling motion, energy, and forces. From the simple gears in a clock to the complex biomechanics of a human body, mechanisms play an integral role in shaping the way we interact with and understand the universe.

Throughout history, humans have harnessed the power of mechanisms to enhance productivity, drive innovation, and enable progress across various fields, including engineering, physics, biology, and even philosophy. The study of mechanisms not only unveils the underlying principles governing the behavior of objects but also provides a bridge between theoretical concepts and real-world applications.

In this exploration of mechanisms, we will delve into the diverse world of mechanical systems, from the elegantly simple to the astonishingly complex. We will examine the principles that govern their operation, the ingenuity behind their designs, and the profound impact they have on modern technology and society. By understanding mechanisms, we gain insights into the inner workings of our world and empower ourselves to create, innovate, and shape the future.

2. Literature Review and Findings

We have studied different mechanisms with their advantages and limitations and are summarized as follows

2.1 Ratchet Wheel Mechanism

(a) Basic Function: The ratchet wheel mechanism is designed to convert rotary motion into unidirectional intermittent motion. It consists of a toothed wheel and a pawl that allows rotation in one direction while preventing backward motion.

(b) Advantages: Simple design, low cost, and effective for applications requiring intermittent motion in a single direction.

(c) Limitations: Limited to unidirectional motion only, less precise compared to other mechanisms, and may produce more noise and wear over time.

2.2 Geneva Wheel Mechanism

(a) Basic Function: The Geneva wheel mechanism converts continuous rotary motion into intermittent motion with a fixed angular displacement. It consists of a driving wheel and a Geneva cross (a rotating pin or plate with slots).

(b) Advantages: Highly precise, allows for accurate positioning, smooth motion, and can be used for applications requiring precise indexing and intermittent motion.

(c) Limitations: Limited to a fixed angular displacement, which may not suit all applications. It requires careful design and alignment for optimal performance.

2.3 Cam Wheel Mechanism

(a) Basic Function: A cam wheel mechanism is used to convert rotary motion into reciprocating or oscillatory motion. It utilizes a cam (a specially shaped rotating disc) and a follower (a component in contact with the cam) to achieve the desired motion.

(b) Advantages: Versatile, capable of producing various complex motion profiles, and can be used for applications requiring a wide range of motion patterns.

(c) Limitations: This may introduce higher mechanical complexity and manufacturing costs. Depending on the design, it may experience wear and tear due to the sliding contact between the cam and the follower.

2.4 Intermittent Gear Mechanism

(a) Basic Function: The intermittent gear mechanism converts continuous rotary motion into intermittent motion using gears with one or more notches or teeth gaps. It can provide precise indexing and controlled intermittent motion.

(b) Advantages: Highly accurate, can achieve a wide range of intermittent motion patterns, and suitable for various applications requiring precise positioning.

(c) Limitations: More complex design compared to other mechanisms, which may increase manufacturing and assembly complexity.

2.5 Summary of Study

- Ratchet wheel mechanism is simple and cost-effective but limited to unidirectional intermittent motion.
- Geneva wheel mechanism is highly precise and suitable for applications requiring fixed angular displacement and precise indexing.
- Cam wheel mechanism offers versatility in producing various motion profiles but may introduce higher complexity.

- Intermittent gear mechanism provides accurate indexing and intermittent motion but may be more complex to design and manufacture.

Table 1 Comparison of the four mechanisms

Name of mechanism	Structure and motion characteristics	Representative mechanism
Ratchet wheel mechanism	The structure is simple that is convenient to adjust the rotation angle; there exists a large impact and noise; the precision is poor	Shaper table horizontal feeding mechanism, one-way clutch, or overrunning clutch
Geneva wheel mechanism	The structure is simple, the size is small, the mechanical efficiency is high and it can be stable and intermittent for transposition. However, the changes in the acceleration rate in the process of motion are large and there exists a flexible impact, which is not applicable to the high speed	Film feeding device of film projector Automatic transmission chain device
Cam wheel mechanism	The structure is simple, the operation is reliable and the transmission is stable. The rigid impact and the flexible impact can be avoided. The additional positioning device is not required. The processing and the assembly have high requirements	Cog zipper machine Match packing machine
Intermittent gear mechanism	The variation range of the time angle is large and the design is flexible The process is complex, the impact is large and it is suitable for light load with low speed	Intermittent transposition and counting mechanism of the multi-station, multi-process automatic machine, and semi-automatic machine working table

2.5.1 Geneva Mechanism

The Geneva mechanism is a commonly used indexing mechanism where an intermittent motion is required.

The Inverse Geneva mechanism, which is a variation of the Geneva mechanism, is used where the wheel has to rotate in the same direction as the crank. It requires less radial space and the locking device can be a circular segment attached to the crank that locks by wiping against a built-up rim on the periphery of the wheel.

The design and fabricating of a conventional Geneva mechanism are generally simple and inexpensive because there is no specially curved profile on any of the components except straight lines and circular arcs. However, due to the discontinuity of the acceleration at the beginning and ending positions, the shortcoming of using the conventional Geneva mechanism is the large impact when the driving crank engages and disengages with the wheel slot.

Geneva Mechanism is classified according to its application. The different Geneva Mechanisms are (a) External Geneva Mechanism (b) Internal Geneva Mechanism (c) Spherical Geneva Mechanism.

2.5.1.1 Applications & uses

- i. Modern film projectors may also use an electronically controlled indexing mechanism or stepper motor, which allows for fast-forwarding the film.
- ii. Geneva wheels having the form of the driven wheel were also used in mechanical watches, but not in a drive, rather limiting the tension of the spring, such that it would operate only in the range where its elastic force is nearly linear.
- iii. Geneva drive includes the pen change mechanism in plotters, automated sampling devices
- iv. Indexing tables in assembly lines, tool changers for CNC machines, and so on.
- v. The Iron Ring Clock uses a Geneva mechanism to provide intermittent motion to one of its rings

2.5.1.2 Advantages of Geneva mechanism

- i. Geneva mechanism may be the simplest and least expensive of all intermittent motion mechanisms.
- ii. They come in a wide variety of sizes, ranging from those used in instruments to those used in machine tools to index spindle carriers weighing several tons.

- iii. They have good motion curves characteristics compared to ratchets but exhibit more “jerk” or instantaneous change in acceleration, than better cam systems
- iv. Geneva maintains good control of its load at all times since it is provided with locking ring surfaces.

2.5.1.3 Disadvantages of the Geneva mechanism

- i. The Geneva is not a versatile mechanism.
- ii. The ratio of dwell period to motion is also established Once the no of dwells per revolution has been selected.
- iii. All Geneva acceleration curves start and end With finite acceleration & deceleration.
- iv. This means they produce jerks.

3. Geneva mechanism in the paper-cutting machine

3.1 The main components used to fabricate the model are:

(a) Geneva wheel:

For the four-slot driven wheel, we are using this advance by one step of 90° for each rotation of the drive wheel. Hence the intermittent motion is achieved for $1/4(90^\circ)$ of the 360° . A mechanism that translates a continuous rotation into an intermittent rotary motion, using an intermittent gear where the drive wheel has a pin that reaches into a slot of the driven wheel and thereby advances it by one step, and having a raised circular blocking disc that locks the driven wheel in position between steps.

(b) Sprocket

A sprocket is profiled wheel with close-by teeth, and gear teeth that work with a chain. Sprockets are used for power transmission among 2 shafts through a roller chain. A sprocket is a profiled wheel with teeth that are structured with chains or other punctures. It is seen from a contraption in sprockets that never really fit together, and contrasts from a pulley in which sprockets have their teeth and pulley smooth. Sprockets are used in bicycles, motorcycles, cars, tracked vehicles, and other machinery either to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track.

(c) Roller chain

Chain drives are used to transfer the power from the motor to the mechanism, we have used a simplex chain in our model. Chain drives are positive drives. Positive drive is a type of mechanical drive system that does not allow slippage during the transmission of power. Length of the chain = 20 inches

(d) Paper cutter or cutting blade:

Paper cutting is a machine, proposed to cut paper with straight-edge paper cutters shift in size. Paper shaper is utilized as an oscillator in 4 bar wrench and switch structure. Pounds per Square Inch (PSI) and Kilopound per Square Inch (KSI) have been used in the given table as abbreviations

(e) Motor: An electric motor is used to generate motion from an electric power supply.

3.2 Working

In this project, we propose a model paper-cutting machine that overcomes the drawbacks of the existing system. This project works on the principle of the Geneva mechanism. When the rotating sprocket activates the mechanism then the paper gets fed into the machine as well as the cutting tool which gets attached to the separate cam is activated and the paper gets cut. The model is shown in figure-1. This project consists of one chain drive which is connected to a Geneva mechanism. Driven plate is connected to the cam which conveys the paper from the paper roll. The working principle is, when we rotate the hand lever it will turn the pin which is attached to the driven plate. Driven plate is connected to the conveyor which rolls the paper and spring acted knife cuts the paper. Driven plate consists of four slots it maintains the time gap to cut the paper.

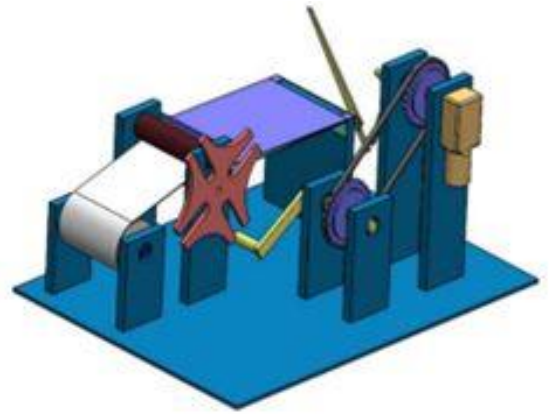


Figure 1. Assembled view of the model

3.2.1 Need Four-Slot of Geneva Wheel

In this model, we will be using a four-slot Geneva wheel. The number of slots in a Geneva wheel determines its motion characteristics and functionalities. Different slot numbers are chosen based on the application's requirements.

1. Number of Stops (Index Positions)

The Geneva mechanism provides intermittent motion, with each slot corresponding to a stop position. A four-slot Geneva wheel moves 90° per engagement, providing four equally spaced stops.

A six-slot Geneva wheel moves 60° per engagement, providing six stops.

More slots mean finer indexing steps, while fewer slots mean larger angular displacement per step.

2. Speed vs. Stability Trade-off

Fewer slots (e.g., 3 or 4 slots) → Larger angular movement per cycle → Faster transitions.

More slots (e.g., 6, 8, or more slots) → Smaller angular movement per cycle → More stable positioning.

3. Dwell Time Consideration

The Geneva wheel remains stationary for a fraction of its cycle, known as dwell time.

The fraction of dwell time increases as the number of slots increases:

$$\text{Dwell Fraction} = 1 - (360^\circ/N)/360^\circ = 1 - 1/N$$

4. Load Handling and Smoothness

A higher number of slots leads to smoother motion but may require more precise manufacturing to reduce backlash.

A lower number of slots results in higher torque transfer but may cause more abrupt movement.

5. Application-Specific Requirements

4-slot Geneva wheels are commonly used in film projectors, indexing tables, and packaging machines.

6- or 8-slot Geneva wheels are used where finer positioning is needed, such as CNC machines and automated assembly systems.

In this project to keep its simplicity we will be using a four-slot Geneva wheel.

3.2.2 Design of Four-Slot of Geneva Wheel

Designing a four-slot Geneva wheel involves several mathematical calculations to determine the dimensions, motion characteristics, and proper engagement between the driving and driven components. Below are the key calculations involved:

1. Basic Parameters

Number of slots (N): 4

Driving wheel angular displacement per cycle (Θ_d):

$$\Theta_d = 360^\circ/N$$

$$\Theta_d = 360^\circ/4 = 90^\circ$$

2. Radius of Geneva Wheel (R_g)

The radius of the Geneva wheel depends on the slot positions. A common choice is:

$$R_g = D/2 = 2r/\sin(\pi/N)$$

D is the pitch diameter of the Geneva Wheel.

r is the radius of the driving pin.

3. Driving Pin Radius (r)

The pin should be small enough to fit within the slots but large enough to provide smooth force transmission.

4. Driving Wheel Radius (R_d)

The driving wheel rotates continuously, engaging with the Geneva wheel once per cycle.

$$R_d = R_g \times \sin(\pi/N) / 1 - \cos(\pi/N)$$

5. Distance Between Geneva and Drive Wheel Centres (C)

The centre-to-centre distance (C) is given by:

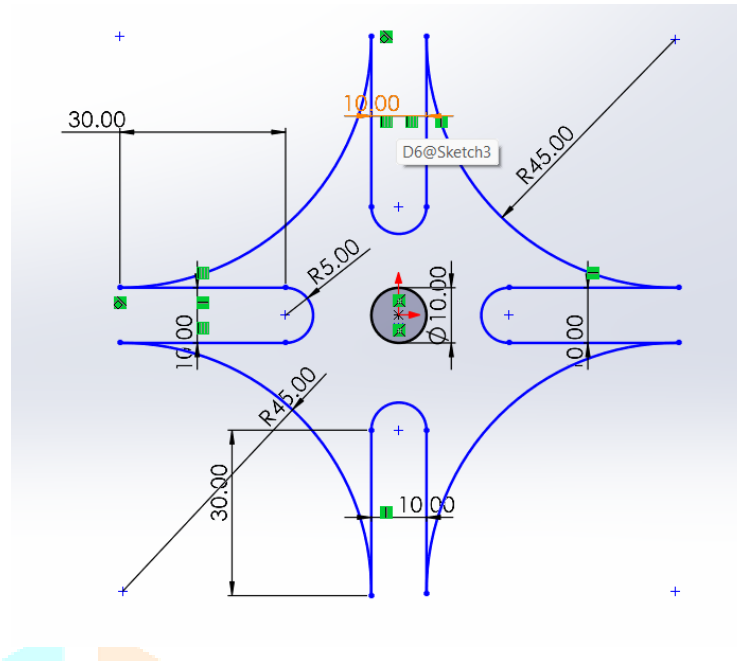
$$C = R_g + R_d - r$$

6. Dwell Time

The Geneva mechanism has a period where the Geneva wheel remains stationary (dwell). The dwell time fraction per cycle is:

$$\text{Dwell Fraction} = 1 - \Theta_d/360^\circ = 1 - 90^\circ/360^\circ = 3/4$$

7. 2-D Design in SolidWorks



The distance travelled with each engagement of the driving pin:-

Circumference of the Geneva Wheel: - The circumference of the Geneva wheel can be calculated using the formula:

$$C = \pi \times D$$

Where,

D is the diameter of the Geneva wheel.

Distance per Slot Engagement: - Since the Geneva wheel moves 90 degrees ($\frac{1}{4}$ turn) with each slot engagement, the distance travelled by the pin is one-quarter of the wheel's circumference:

$$\text{Distance per Engagement} = C/4 = (\pi \times D)/4$$

Here,

$$\text{Circumference (C)} = \pi \times 100 \text{ mm} = 314.16.$$

$$\text{Distance per Engagement: } 314.16 \text{ mm} / 4 = 78.54 \text{ mm}.$$

4. Conclusion

The design and analysis of paper-cutting machines using the Geneva mechanism will be very useful for small-scale industries. There are machines based on paper cutting but it has demerits like being large in size, costly, needing skilled labor to operate and it needs electrical input. But we have our machine which will overcome this demerit by compact size, less cost no need for skilled people The main aim of this machine is to reduce the time for paper cutting and reduce the time for marking the paper.

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