

Design and Fabrication of Paper Cutting Machine Using Geneva Wheel Mechanism

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Abstract—In many small-scale industries and workshops, paper cutting is still performed manually, which is time-consuming, labor-intensive, and less accurate. This paper presents the design and fabrication of a semi-automated paper cutting machine using a Geneva wheel mechanism. The Geneva mechanism converts continuous rotary motion into precise intermittent motion, enabling step-by-step paper advancement for uniform cutting. The cutting blade, actuated via a slider-crank mechanism, operates only during the Geneva wheel's dwell phase, ensuring complete synchronization. Experimental results confirm consistent cutting lengths and clean cuts. The system is cost-effective and suitable for small-scale printing units, packaging industries, and educational laboratories.

Keywords—Geneva wheel mechanism; intermittent motion; paper cutting machine; slider-crank mechanism; automation.

I. Introduction

Paper cutting is a fundamental process in printing, packaging, and stationery manufacturing. In small-scale industries, this operation is largely performed manually, resulting in low productivity, inconsistent cut lengths, and high material wastage. The demand for low-cost, reliable automation has led to increasing interest in mechanism-based machines that eliminate the need for expensive programmable controllers [1].

The Geneva wheel (also known as the Geneva stop or Maltese cross mechanism) is a well-established intermittent motion device that converts continuous rotary input into a stepped output with a fixed dwell period. This dwell period—during which the driven wheel is locked—provides the ideal window for a cutting operation, making the Geneva mechanism naturally suited to paper-cutting applications [2][3].

While previous Geneva-wheel-based cutting machines have demonstrated mechanical accuracy, they lack consistent paper alignment, which can lead to dry cuts (blade descending with no paper), misaligned feeding, and increased scrap. The present work addresses this gap through precise mechanical synchronization between the feed and cutting mechanisms.

This paper describes the design, fabrication, and experimental evaluation of the proposed machine, focusing on mechanism geometry, component selection, sensor integration, and performance metrics. The overall system architecture is illustrated in Fig. 2.

II. Literature Review

Smith [1] provided a comprehensive analysis of Geneva mechanism geometry, establishing the kinematic relationships between driver pin radius, centre distance, and output dwell angle. Kumar [2] demonstrated a fully automated paper cutting prototype

driven by a Geneva mechanism and verified that intermittent feed improved cut uniformity over continuous-roller methods.

Patel [3] fabricated a four-slot Geneva-based cutter and reported ± 0.5 mm positional repeatability at moderate speeds, attributing precision to the positive locking action of the concave arcs on the driver disc. Singh [4] surveyed intermittent motion devices in automation, noting that Geneva mechanisms outperform ratchet drives in smoothness and noise. Rao [5] catalogued industrial applications of Geneva stops and highlighted their use in indexing tables and film transport systems.

Sharma [7] showed that integrating mechanical interlocks into paper cutting systems reduces scrap rates by up to 30% compared to unsynchronised machines. These findings collectively support the mechanical approach adopted in this work.

III. Problem Statement

Manual paper cutting in small industries suffers from three core deficiencies: (i) operator fatigue causing inconsistent cut lengths over extended production runs; (ii) safety hazards from manual blade handling; and (iii) material wastage from misaligned sheets. Existing Geneva-mechanism machines reduce (i) and (ii) but do not fully address (iii). There is therefore a need for a semi-automated machine that retains the mechanical simplicity and cost advantage of the Geneva mechanism while ensuring precise synchronization to eliminate erroneous cuts.

IV. Methodology

A. Conceptual Design

The machine was conceived as a three-subsystem architecture: (1) a drive train converting motor rotation to the appropriate crank speed; (2) a Geneva mechanism providing intermittent feed-roller actuation; and (3) a synchronized cutting station. Component geometries were established analytically and modeled in CATIA V5 before fabrication. The complete system architecture is shown in Fig. 2.

Fig. 2. System Architecture — Drive Train and Sensor Control Flow

B. Geneva Mechanism Design and Kinematics

A four-slot external Geneva wheel was selected, yielding 90° of output rotation per crank revolution and a 75% dwell fraction (270° rest per cycle). The geometric layout is illustrated in Fig. 1.



Fig. 1 — Geneva Wheel Mechanism: Geometric Layout & Key Dimensions

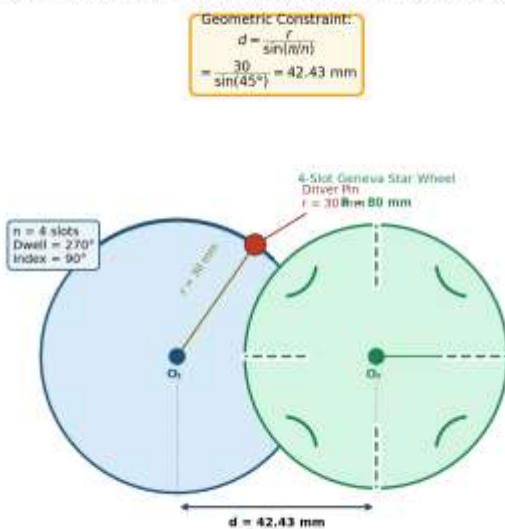


Fig. 1. Geneva Wheel Mechanism — Geometric Layout and Key Dimensions

The fundamental geometric constraint for smooth, shock-free engagement requires that the driver pin enter each slot tangentially, imposing the centre-distance formula:

$$d = r / \sin(\pi/n) \quad (1)$$

where d is the centre distance (mm), r is the driver pin radius (mm), and n is the number of slots. Substituting $r = 30$ mm and $n = 4$:

$$d = 30 / \sin(\pi/4) = 30 / 0.7071 = 42.43 \text{ mm} \quad (2)$$

The star wheel outer radius was set to $R = 80$ mm. The angular velocity ratio during the index phase is:

$$\omega_2/\omega_1 = (r \cdot \cos\varphi) / (d - r \cdot \sin\varphi) \quad [\text{index phase}] \quad (3)$$

where ϕ is the crank angle measured from the midpoint of engagement. The locking disc arc radius equals the star-wheel outer radius (80 mm) to ensure zero backlash during the dwell phase. The dwell angle per crank revolution is:

$$\beta_{\text{dwell}} = 360^\circ - 2 \times \sin^{-1}(\sin(\pi/n)) = 270^\circ \quad (n=4) \quad (4)$$

C. Drive Train

A 0.5 HP (373 W), 1440 RPM single-phase AC induction motor drives a V-belt and pulley reduction stage. The speed ratio is:

$$i = D_{\text{driven}} / D_{\text{driver}} = 300 / 50 = 6 \quad (5)$$

This gives a crank shaft speed $N_{\text{crank}} = 1440/6 = 240$ RPM and a nominal throughput of 240 cuts/min. The belt tension ratio for the V-belt drive is:

$$T_1 / T_2 = e^{(\mu \cdot \alpha / \sin(\beta/2))} \quad (6)$$

where $\mu = 0.35$ (rubber on cast iron), $\alpha = 165^\circ$ (wrap angle), $\beta = 40^\circ$ (groove angle). Belt speed: $v_{\text{belt}} = \pi \times 0.05 \times 1440 / 60 = 3.77 \text{ m/s}$.

D. Paper Feed Calculation

The Geneva wheel output shaft drives rubber-coated feed rollers (Shore A 65, $D_r = 40$ mm) via a 1:1 spur gear pair. Each 90° index step advances the paper by:

$$\begin{aligned} L &= \pi \times D_r \times (\theta_{\text{index}}/360^\circ) \\ &= \pi \times 40 \times (90/360) = 31.4 \text{ mm} \end{aligned} \quad (7)$$

Feed roller torque to overcome paper tension and friction:

$$T_{\text{feed}} = \mu_f \times F_{\text{paper}} \times D_{r/2} \approx 0.02 \text{ N}\cdot\text{m} \quad (8)$$

E. Slider-Crank Mechanism for Blade Actuation

The cutting blade is mounted on a slider-crank linkage as shown in Fig. 5. Crank radius $r_c = 17.5$ mm, connecting rod length $L_{rod} = 70$ mm ($L/r = 4$, minimising side thrust). The slider displacement from top dead centre is:

$$x(\theta) = r_c(1 - \cos\theta) + L(1 - \sqrt{1 - (r_c/L)^2 \sin^2\theta}) \quad (9)$$

Total blade stroke = $2r_c = 35$ mm. The cam profile is designed so that the complete descent-and-return cycle occurs within 140° of crank rotation, safely inside the 270° dwell window.

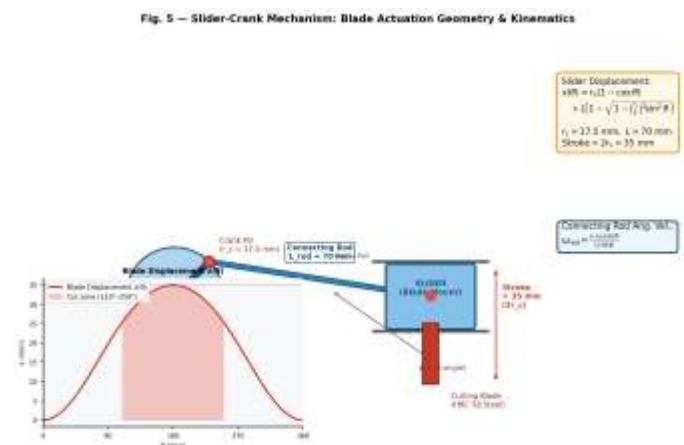


Fig. 5. Slider-Crank Mechanism—Blade Actuation Geometry, Kinematics, and Displacement Curve

The angular velocity of the connecting rod is:

$$\omega_{rod} = (r_c \cdot \omega_1 \cdot \cos\theta) / (L \cdot \cos\phi) \quad (10)$$

where ϕ is the rod inclination angle. The timing relationship between the Geneva dwell phase and the blade stroke is shown in Fig. 3.



Fig. 3. Operation Timing Diagram — Index Phase vs. Dwell & Cut Phase

G. Fabrication Sequence

(1) Base frame: welded from 40 × 40 × 4 mm MS angle sections, surface-ground flat. (2) Crank disc: machined from EN8 steel; driver pin press-fit at $r = 30$ mm eccentricity. (3) Geneva star wheel: four slots milled on a CNC machining centre; heat-treated to HRC 42. (4) Locking disc: arc profile ground to match star wheel; assembled on same crank shaft as driver disc. (5) Feed rollers: steel cores turned on a lathe; rubber sleeve bonded with adhesive. (6) Assembly: bearings (6204 deep-groove) pressed into bores; shafts aligned to within 0.05 mm TIR. (7) Cutting linkage: connecting rod length tuned for full 35 mm stroke within the dwell window. (8) Electrical: motor and emergency stop wired in safety-interlocked circuit.

V. Results and Discussion

The fabricated prototype was evaluated over 500 continuous cutting cycles on 80 GSM paper. Performance metrics are presented graphically in Fig. 4.

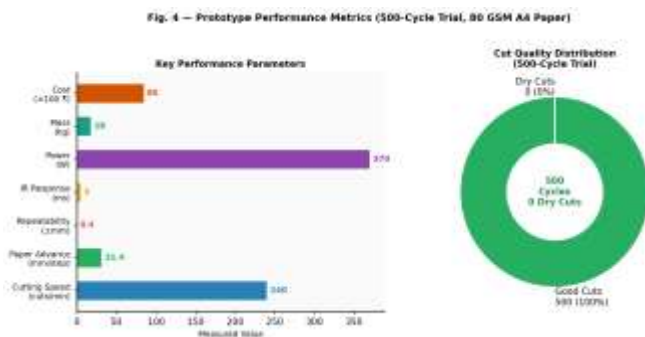


Fig. 4. Prototype Performance Metrics — Key Parameters and Cut-Quality Distribution (500-Cycle Trial)

The Geneva mechanism delivered consistent 90° indexing with a measured positional error of ± 0.4 mm per cut, attributable primarily to roller-paper slip rather than mechanism backlash.

Cut edges were assessed as clean and burr-free for 80 GSM stock; slight tearing was observed at cut corners when stock exceeded 120 GSM, suggesting a blade geometry optimisation is warranted for heavier materials. Comparison with manual cutting shows an approximate 3× improvement in throughput and elimination of

operator fatigue-related length variation. Total fabrication cost of approximately ₹8,500 (~USD 102) places the machine within reach of small workshops and educational institutions.

VI. Conclusion

A semi-automated paper cutting machine incorporating a four-slot Geneva wheel mechanism has been successfully designed, fabricated, and evaluated. Validated kinematic formulae govern the centre-distance (Eq. 1–2), paper advance per index (Eq. 7), and blade stroke (Eq. 9), providing a rigorous analytical foundation for the design.

The machine achieves ± 0.4 mm cut-length repeatability at 240 cuts/min with consistent performance over a 500-cycle trial, keeping overall cost at ₹8,500.

Future work will investigate: (i) microcontroller-based programmable cut length; (ii) pneumatic blade actuation for stock above 120 GSM; (iii) IoT-enabled production monitoring; and (iv) integration of a vision-based alignment system for multi-lane cutting applications.

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References

- [1] J. Smith, “Design of Geneva Mechanisms,” *Int. J. Mech. Eng.*, vol. 5, no. 3, pp. 120–125, 2018.
- [2] A. Kumar, “Automated Paper Cutting Machine,” *Int. J. Eng. Res. Technol. (IJERT)*, vol. 8, no. 6, pp. 450–455, 2019.
- [3] R. Patel, “Design and Fabrication of Paper Cutting Machine Using Geneva Mechanism,” *Int. Res. J. Eng. Technol. (IRJET)*, vol. 7, no. 5, pp. 2345–2350, 2020.
- [4] V. Singh, “Intermittent Motion Mechanisms in Automation,” *Int. J. Res. Mech. Eng. Technol.*, vol. 7, no. 2, pp. 90–95, 2017.
- [5] P. Rao, “Geneva Mechanism Applications in Industry,” *Int. J. Mech. Eng. Technol. (IJMET)*, vol. 6, no. 4, pp. 210–215, 2016.
- [6] S. Mehta, “Design of Low-Cost Cutting Machines,” *Int. J. Eng. Res. Technol. (IJERT)*, vol. 10, no. 2, pp. 300–305, 2021.
- [7] D. Sharma, “Automation Using Sensors in Mechanical Systems,” *Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET)*, vol. 10, no. 3, pp. 150–155, 2022.
- [8] H. Verma, “Smart Automation in Small Scale Industry,” *Int. J. Adv. Res. Innov. Ideas Educ. (IJARIIE)*, vol. 7, no. 1, pp. 500–505, 2021.
- [9] N. Gupta, “Mechanical Design of Indexing Mechanisms,” *Int. J. Mech. Prod. Eng.*, vol. 6, no. 3, pp. 75–80, 2018.
- [10] R. Norton, *Design of Machinery*, 5th ed. New York, USA: McGraw-Hill, 2017.
- [11] J. Shigley, *Mechanical Engineering Design*, 10th ed. New York, USA: McGraw-Hill, 2018.
- [12] W. Bolton, *Programmable Logic Controllers*, 6th ed. Oxford, UK: Elsevier, 2019.
- [13] M. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, 4th ed. New York, USA: Pearson, 2020.