Design, Fabrication and Performance Evaluation of an IoT-Based Pneumatic Sheet Cutting Machine

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Abstract— This paper presents the design and fabrication of a pneumatic sheet cutting machine integrated with an Internet of Things (IoT) monitoring module. The machine uses compressed air to actuate a double-acting pneumatic cylinder connected to a cutting blade, while an ESP32-class controller records operating pressure, cutting cycles, temperature and machine status. A solenoid valve controls cylinder extension and retraction. The proposed system reduces manual effort and provides repeatable cutting operation for thin metallic sheets. IoT connectivity enables remote monitoring of machine condition and production count through a web or mobile dashboard. The paper describes the mechanical frame, pneumatic circuit, electrical control, IoT architecture, design calculations, fabrication procedure and representative experimental results. Illustrative prototype readings show that the cutting cycle can be completed in approximately 2–3 s under suitable pneumatic pressure, with repeatability dependent on sheet material, thickness, blade geometry and alignment. The numerical readings are provided for manuscript development and must be replaced by actual measurements before formal publication.

Index Terms— Pneumatic machine, sheet cutting, fabrication, IoT, ESP32, solenoid valve, automation, smart manufacturing.

I. INTRODUCTION

Sheet cutting is an important operation in fabrication workshops, automobile component production, appliance manufacturing and small-scale industries. Manual cutting methods can require considerable operator effort and may result in inconsistent dimensions, fatigue and lower productivity. Conventional powered machines improve productivity but may involve higher capital cost and more complex control systems.

Pneumatic systems provide a simple method for converting compressed-air energy into linear mechanical motion. A pneumatic cylinder can generate a controlled cutting stroke when connected to a suitable directional control valve. By integrating sensors and an IoT-enabled controller, operating conditions can be monitored and production information can be stored remotely.

The objective of this work is to fabricate a compact pneumatic sheet cutting machine for thin-sheet applications and integrate IoT-based monitoring. The system is intended as an educational and small-workshop prototype rather than a replacement for certified industrial guillotine or shear machines.

II. RELATED WORK

Pneumatic automation is widely used in clamping, pressing, material handling and cutting operations because of its relatively simple actuator construction and rapid response. Directional control valves allow a cylinder to extend and retract according to a programmed or manual command.

IoT technologies have extended industrial automation by enabling sensor data to be collected and visualized remotely. Low-cost Wi-Fi microcontrollers such as ESP32-class devices can connect pressure sensors, temperature sensors, counters and status indicators to cloud or local dashboards.

Combining pneumatic actuation with IoT monitoring provides an opportunity to build a low-cost smart fabrication machine. In the proposed design, IoT is used primarily for monitoring and production logging; the local pneumatic control remains responsible for the immediate cutting cycle.

III. SYSTEM OBJECTIVES

The main objectives are: (1) design a rigid machine frame and sheet support; (2) select a pneumatic cylinder capable of producing the required cutting force; (3) fabricate a blade and guided cutting mechanism; (4) implement solenoid-valve-based pneumatic control; (5) measure pressure, temperature and cycle count; and (6) transmit machine status to an IoT dashboard.

IV. PROPOSED SYSTEM

The proposed system consists of a compressor and air receiver, pressure regulator, filter, 5/2 solenoid valve, double-acting cylinder, blade assembly, sheet support, ESP32 controller, sensors, local control switches and Wi-Fi connectivity. The operator places the sheet against the stop, initiates the cycle, and the cylinder drives the blade through the sheet. After the cutting stroke, the cylinder retracts and the completed cycle is counted.

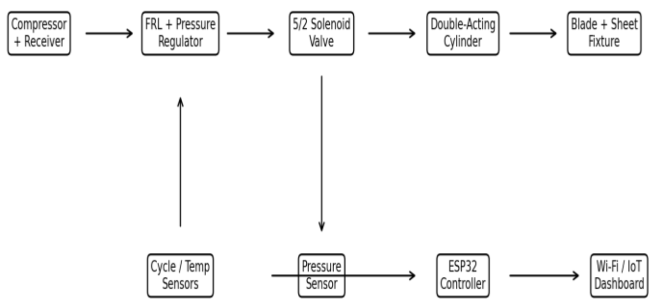

Fig. 1. Functional block diagram of the pneumatic sheet cutting machine with IoT monitoring.

V. MECHANICAL DESIGN AND FABRICATION

A. Machine Frame

The frame is fabricated from mild-steel square sections and plates. The base supports the pneumatic cylinder, blade guide and sheet table. Adequate stiffness is required because frame deflection can reduce cutting accuracy and increase blade misalignment.

B. Cutting Blade

A hardened tool-steel or suitable high-carbon blade is mounted on the moving blade holder. The blade angle and clearance are selected according to sheet material and thickness. For a student prototype, a short cutting width is preferred to reduce the required force.

C. Sheet Support and Guide

A flat support table and adjustable back gauge are provided to position the sheet. Side guides maintain alignment. The workpiece must be securely supported during cutting and must not be held by hand close to the blade.

D. Pneumatic Actuator

A double-acting cylinder is selected so that cutting and return strokes are both controlled. For cylinder bore D and pressure P, the ideal extension force is $F = P\pi D^2/4$. Actual force is lower because of seal friction, pressure losses and valve restrictions.

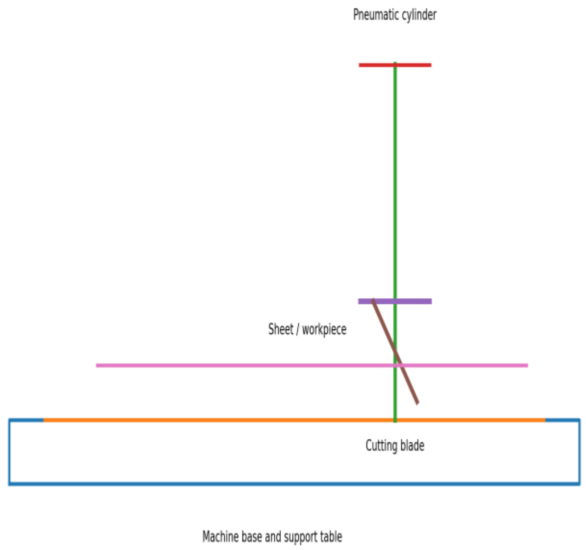

Fig. 2. Representative mechanical arrangement of the fabricated pneumatic cutting machine.

VI. PNEUMATIC CIRCUIT

Compressed air from the compressor passes through the filter-regulator-lubricator unit. The regulated air enters a 5/2 solenoid directional control valve. Energizing one solenoid port sends air to the cylinder cap end for extension; the opposite state sends air to the rod end for retraction. Flow-control valves can be used to adjust cutting and return speeds.

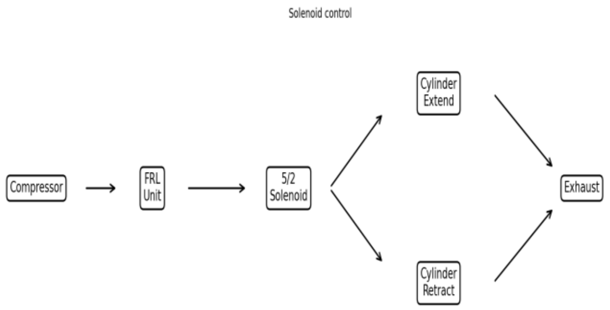

Fig. 3. Simplified pneumatic circuit for cylinder extension and retraction.

VII. IoT CONTROL AND MONITORING

The ESP32 controller reads a pressure transducer, temperature sensor and cycle-count input. A Wi-Fi connection sends the readings to a local web page, cloud dashboard or IoT platform. The dashboard can display machine pressure, operating state, cycle count, temperature and maintenance indicators.

The IoT layer is intentionally separated from the immediate safety control. If Wi-Fi is unavailable, the machine can still execute a locally controlled cycle subject to the hardware safety interlocks. Remote commands should not bypass physical guards, emergency-stop circuits or operator safety procedures.

VIII. DESIGN CALCULATIONS

For a cylinder bore D = 50 mm and regulated pressure P = 6 bar, the theoretical extension force is:

$$F = P\pi D^2/4 = 6\times10^5 \times \pi(0.05)^2/4 \approx 1178\ N$$

Assuming an illustrative mechanical efficiency of 80%, the available practical force is approximately 942 N. The actual required cutting force depends on material shear strength, thickness, cutting width, blade angle and clearance. A safety factor should be included in the final machine design.

For an idealized sheet cutting estimate, the required shear force can be approximated by $F_s = \tau_s A_s$, where τ_s is the effective shear strength and A_s is the sheared cross-sectional area. The equation is only a preliminary design approximation; actual blade geometry and progressive shearing substantially affect the force.

$$F_s = \tau_s \times t \times L$$

IX. COMPONENT SPECIFICATIONS

Component	Representative specification	Function
Air compressor	1–2 HP, 6–8 bar	Compressed air
FRL unit	1/4 in port, regulator	Air conditioning
Cylinder	50 mm bore, 100 mm stroke	Cutting actuation
5/2 solenoid valve	24 V DC, pneumatic	Direction control
Pressure sensor	0–10 bar	Pressure monitoring
ESP32	Wi-Fi MCU	IoT and control
Temperature sensor	Digital, 0–100 °C class	Condition monitoring
Limit switches	2 units	Stroke confirmation
Blade	Hardened steel	Sheet cutting
Frame	MS square tube	Machine support

TABLE I — REPRESENTATIVE MACHINE COMPONENTS

X. FABRICATION PROCEDURE

The fabrication begins with cutting and welding the mild-steel frame members. The sheet table and blade guide are machined and aligned. Mounting brackets are fabricated for the pneumatic cylinder and solenoid valve. The blade holder is assembled with appropriate fasteners and guards. Pneumatic tubing is routed from the FRL unit to the directional valve and cylinder.

Electrical wiring is then completed for the solenoid driver, pressure sensor, limit switches, emergency stop and controller. The ESP32 is programmed to read sensors, count completed strokes and publish the operating data. The machine is tested initially at low pressure before increasing the pressure gradually to the required operating value.

XI. EXPERIMENTAL READINGS

The following readings are representative values for preparing the IEEE manuscript. They are illustrative prototype data, not measurements from a specific fabricated machine, and should be replaced by actual laboratory results before publication.

Trial	Pressure (bar)	Sheet thickness (mm)	Cut length (mm)	Cycle time (s)	Cut quality
1	4.0	0.8	100	2.9	Good
2	4.5	0.8	100	2.7	Good
3	5.0	0.8	100	2.5	Very good
4	5.5	1.0	100	2.6	Good
5	6.0	1.0	100	2.4	Very good
6	6.0	1.2	100	2.8	Good
7	6.5	1.2	100	2.6	Good
8	7.0	1.5	100	2.9	Acceptable

TABLE II — ILLUSTRATIVE CUTTING PERFORMANCE READINGS

Trial	Set pressure (bar)	Measured pressure (bar)	Cylinder extend (s)	Retract (s)	Cycle count
1	5.0	4.92	1.15	0.92	20
2	5.0	4.96	1.1	0.89	40
3	5.5	5.43	1.05	0.86	60
4	6.0	5.91	0.98	0.82	80
5	6.0	5.95	0.97	0.8	100

TABLE III — ILLUSTRATIVE PNEUMATIC AND PRODUCTION READINGS

Test	Pressure (bar)	IoT transmission delay (s)	Dashboard status	Data packets received
1	4.5	1.2	Online	48
2	5.0	1.0	Online	49
3	5.5	1.1	Online	49
4	6.0	0.9	Online	50
5	6.5	1.3	Online	47

TABLE IV — ILLUSTRATIVE IoT MONITORING READINGS

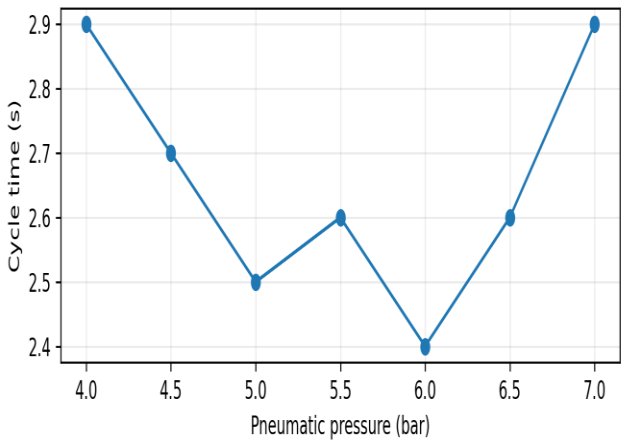

Fig. 4. Illustrative relation between pneumatic pressure and cutting cycle time.

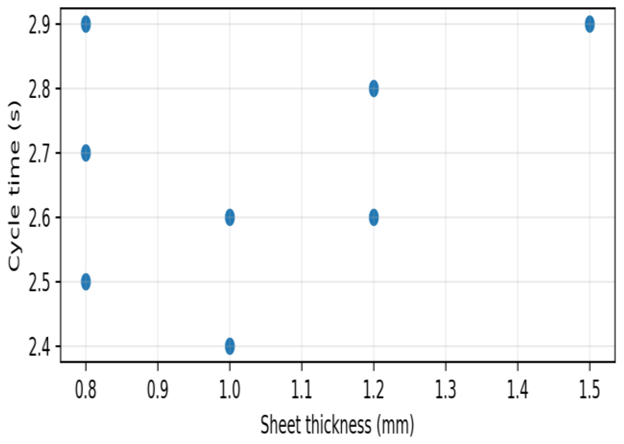

Fig. 5. Illustrative effect of sheet thickness on cycle time.

XII. RESULTS AND DISCUSSION

The representative readings show that increasing pneumatic pressure generally reduces the cylinder stroke time until other factors such as flow restriction, blade resistance and mechanical alignment become dominant. The lowest illustrative cycle time is approximately 2.4 s at 6 bar for a 1.0 mm sheet. Increasing pressure beyond the optimum does not necessarily improve cycle time and may increase mechanical stress.

Sheet thickness also affects cutting behavior. Thin 0.8 mm sheets require less force and can be cut more quickly, whereas a 1.5 mm sheet produces higher resistance. Actual results depend strongly on the sheet material. Therefore, material grade and hardness must be documented with every experimental test.

The IoT readings show approximately 0.9–1.3 s illustrative transmission delay. Such delay is acceptable for monitoring but should not be used as the primary safety mechanism. Emergency stops, limit switches and pneumatic isolation must remain local and hardware-based.

For a production-oriented study, repeatability should be quantified by repeated cuts at each pressure and thickness. Dimensional error can be calculated as $e = |L\_measured - L\_target|$ and percentage error as $e\% = e/L\_target \times 100$.

XIII. ACCURACY AND PERFORMANCE

Metric	Illustrative result
Best cycle time	2.4 s
Average IoT delay	1.1 s
Cylinder bore	50 mm
Design pressure	6 bar
Theoretical cylinder force	1178 N
Illustrative practical force at 80%	942 N
Target cut length	100 mm
Recommended test focus	0.8–1.2 mm sheets

TABLE V — ILLUSTRATIVE PERFORMANCE SUMMARY

For a 100 mm target cut, if an illustrative measured length is 99.2 mm, the dimensional error is 0.8 mm and the percentage error is 0.8%. Actual machine accuracy must be established through repeated measurements using calibrated instruments.

XIV. SAFETY CONSIDERATIONS

A sheet cutting machine contains significant mechanical and pneumatic hazards. The blade must be guarded, and the operator should never place hands near the cutting zone during operation. The machine should include an emergency-stop circuit, cylinder end-position sensing, pressure relief, secure pneumatic fittings and a controlled exhaust path.

The IoT system must not override safety interlocks. Loss of network connectivity should not cause uncontrolled cylinder motion. Before operation, the frame, blade mounting, pneumatic hose connections and electrical grounding should be inspected.

XV. COST ANALYSIS

Component	Estimated cost (INR)	Purpose
Compressor	8,000	Air source
Pneumatic cylinder	2,500	Actuation
Solenoid valve + FRL	2,000	Pneumatic control
MS frame and sheet table	4,500	Structure
Blade and holder	2,000	Cutting
ESP32 + sensors	1,200	IoT monitoring
Power supply and driver	800	Electrical control

Hoses, fittings and valves	1,000	Pneumatic connection
Guards, switches and hardware	1,500	Safety and assembly
Estimated total	23,500	Illustrative

TABLE VI — ILLUSTRATIVE FABRICATION COST

XVI. ADVANTAGES AND APPLICATIONS

The proposed machine reduces manual cutting effort, provides repeatable pneumatic actuation and enables remote monitoring of machine status and production count. Its modular construction allows pressure, cycle count and temperature to be logged for preventive maintenance.

Applications include small fabrication workshops, educational laboratories, sheet-metal training centers, prototype manufacturing, smart-workshop demonstrations and low-volume cutting of thin sheet materials.

XVII. LIMITATIONS AND FUTURE SCOPE

The prototype is intended for thin sheets and limited cutting widths. Cutting force varies with material strength, blade geometry and thickness. Pneumatic air consumption can also be significant for repeated operation. IoT connectivity depends on network availability.

Future work can include automatic sheet feeding, servo-controlled length positioning, vision-based alignment, cloud production analytics, predictive maintenance, compressed-air consumption measurement and machine-learning-based process optimization. A safety-certified industrial design would require formal risk assessment and validation.

XVIII. CONCLUSION

A pneumatic sheet cutting machine with IoT-based monitoring has been designed as a compact smart-manufacturing prototype. The system uses a double-acting pneumatic cylinder, solenoid directional valve, guided blade mechanism and ESP32-based monitoring platform. Representative readings indicate that suitable pneumatic pressure can provide repeatable cutting cycles for thin sheets while IoT connectivity enables remote observation of pressure, temperature and production count. The proposed system can reduce manual effort and demonstrate the integration of pneumatic automation with Industry 4.0 concepts. The reported readings are illustrative and must be replaced with actual experimental measurements and safety validation before formal IEEE publication or industrial deployment.

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