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Tasneem Bano
Undergraduate Students, Department of Mechanical Engineering, Himalayan Institute of Technology and Management, Lucknow, Uttar Pradesh, India

Sourav Kumar
Undergraduate Students, Department of Mechanical Engineering, Himalayan Institute of Technology and Management, Lucknow, Uttar Pradesh, India

Ankit Verma
Undergraduate Students, Department of Mechanical Engineering, Himalayan Institute of Technology and Management, Lucknow, Uttar Pradesh, India

Dr. Preetesh Saxena
Undergraduate Students, Department of Mechanical Engineering, Himalayan Institute of Technology and Management, Lucknow, Uttar Pradesh, India

Dr.Ashish Kumar Dixit
Undergraduate Students, Department of Mechanical Engineering, Himalayan Institute of Technology and Management, Lucknow, Uttar Pradesh, India

Corresponding Author:
Tasneem Bano
Undergraduate Students, Department of Mechanical Engineering, Himalayan Institute of Technology and Management, Lucknow, Uttar Pradesh, India

Design and development of an automatic pneumatic hammer machine

Tasneem Bano, Sourav Kumar, Ankit Verma, Preetesh Saxena and Ashish Kumar Dixit

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Abstract
The significant motive of this research is to design a cost-effective and compact solution that reduces human dependency to achieve continuous, uniform, repeatable, and reliable hammering action for industrial functions, Which include the repetitive hammering operations that are essential in manufacturing industry such as metal fabrication, forging, and assembly, still traditional manual methods or techniques even suffer from inconsistent force application, reduced productivity, and increased safety risks. This work presents the design and analysis of an automated pneumatic hammering system that utilizes the compressed air and electronically controlled solenoid valves to deliver uniform and repeatable hammering effect. The proposed system unites a pneumatic cylinder that adjusts and synchronises the air supply, and automated control circuitry used to overcome manual needs during operation. Force generation is analytically evaluated to ensure suitability for light to medium-duty industrial work and applications.
These experimental observations reflect the improved operational consistency, decreased with operator fatigue, and enhanced the process reliability when compared with conventional hammering techniques. The simplicity of the design, combined with its adaptability and cost- effectiveness, makes the system suitable for small-scale industries as well as academic and research environments.

Keywords: Automatic pneumatic hammer, solenoid valve control, compressed air systems, repetitive impact mechanism and industrial automation

1. Introduction
In the modern times manufacturing environment pneumatic automation plays an important role in increasing productivity and further quality. Hammering is one of the most common mechanical operations used in processes such as metal forming, riveting, forging, sheet metal fabrication and assembly work.
In old times, the hammering was mostly done by human hand, which required skill and hard physical work through the human beings. This activity increases uneven hits, poor quality, tired workers, and safety risks but in modern automation, the automatic pneumatic system is becoming trendy with air-powered tools which is famous nowadays because they are safe, less time consuming, with high accuracy and precision. And also improves the efficiency and consistency of hammering operations. This type of system is easy to use in modern times which is dependable, and it can generate high power without investing high energy. The Pneumatic hammers are widely used in present time but some work is also done by hand.
This invention focuses on developing or creating an automatic pneumatic hammer machine which reduces the manual work of the hammering by using a control system and Solenoid Valve.

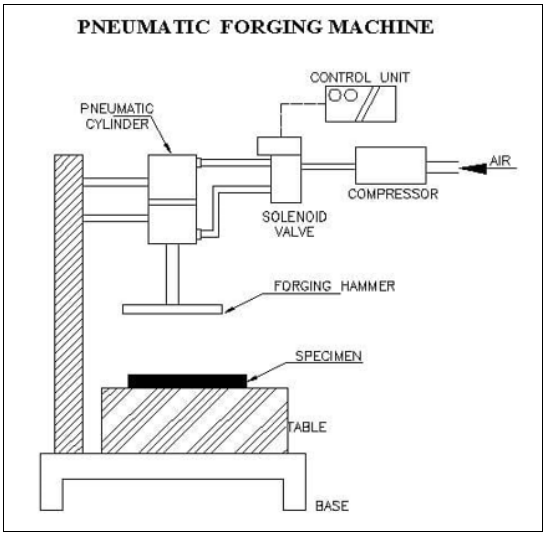


Fig 1: Schematic diagram of Automatic pneumatic system

1.1 Types of Pneumatic Hammers

- **Pneumatic Chipping Hammer:** Pneumatic Chipping Hammer are those types of hammer which are mainly used for surface cleaning and finishing operations. It produces rapid light blows that help remove unwanted material.
- **Pneumatic Riveting Hammer:** This pneumatic riveting hammer is made for and fastens rivets work by applying controlled repeated blows.
- **Pneumatic Forging Hammer:** A pneumatic forging hammer used to deliver high-energy work suitable for shaping hot metal.
- **Pneumatic Breaker Hammer:** Pneumatic breaker hammers are those types that are built for demolition and breaking operations.
- **Automatic Pneumatic Hammer:** An automatic pneumatic hammer is a machine-based system which involves the techniques of controlled and repetitive hammering without human interaction
- **Pneumatic Power Hammer:** This hammering energy is commonly used in manufacturing for metal forming where precision and productivity are required

2. Literature Review

The current literature review on pneumatic hammer technology has focused on improving operational efficiency and safety key elements and also performing continuous automated operation. In the manufacturing industry hammering is the most common operation for mechanical engineering. Most industries are frequently used for hammering for fabrication and machining for metal components.

The goal of this research is to design an automatic pneumatic hammering machine that can perform continuous hammering tasks easily without human efforts with the help of automated repetitive hammering which makes it cost effective.

Earlier work

There are many projects that rely on automation hammering machines for example I would like to consider the work of (Mr. M. Rajesh) he made an automatic portable hammering machine for rotor testing. It is little significant to our project in this author's design automatic hammering testing machine using pulley and DC rotor for shaping operation.

Research Gap

In his work there are some gaps that arise like delivering lower striking force and slower working speed due to the 12- volt battery for mechanical transmission mechanism and not sufficient for continuous heavy duty work.

Improvement

This project addresses these gaps by implementing a fully automated, compact pneumatic hammer system.

Adding a pneumatic cylinder and air compressor which can generate stronger and more uniform impact energy. It is also suitable for continuous and heavy-duty industrial operations.

3. Objectives of the Project

Primary Objectives

- To design and develop an automatic hammering system by using pneumatic power
- To reduce manual effort and physical strain
- To improve process reliability and uniforms hammering force

Secondary Objectives

- To enhance operator safety through automation
- To increase production speed and accuracy
- To create a cost-effective and space efficient design suitable for workshops and laboratories.

4. Methodology

A pneumatic automatic hammer machine methodology involves using a pneumatic cylinder and air compressor to provide motion so piston can move easily which converts compressed motion into repetitive linear motion via a connecting piston rod and paneumat cylinder

Work piece for fast, consistent impacts, controlled by a unit that manages speed/force, often for tasks like forging or testing, featuring safety features and portability. The core process is converting controlled compressed energy into automated hammering by replacing manual hammering.



Fig 2: Automatic Pneumatic Hammer System

4.2 Selection of Components

A. Pneumatic Cylinder

A pneumatic cylinder is a mechanical component which uses the compressed air energy and transforms it into linear motion and force. It consists of a piston, piston rod, and cylinder barrel .The up and down movement of the piston generates the hammering force.

B. Air Compressor

It transmitted the compressed air to the compressor when it required pressure. It acts like the energy source of the system.

C. Solenoid Valve

The solenoid valve maintains the direction of airflow into the pneumatic cylinder. It operates electrically and permits automatic control of the hammering effect.

D. Control Circuit

The control circuit is the plane frame that consists of the switches button for the ON and OFF functions of the solenoid valve and ensures automatic and repetitive hammering.

E. Frame and Base Foundation

The hard frame carries all components and sucks up vibration produced during hammering. It also maintains stability during operation.

F. Hammer Tool

The hammer tool looks like a circular disc which is connected to the piston rod and directly impacts the work piece

4.3 System Design

The hammer tool is mechanically linked to the piston rod and mounted on a rigid frame. And this frame is designed to stand up to repeated impact forces while maintaining consistency and proper alignment that ensures smooth motion and effective energy transfer.

4.4 Design Consideration

The following elements were considered during system design:

1. Required hammering force and operating air pressure
2. Stroke length of the cylinder
3. Structural strength of the frame
4. Condition monitoring and safety assurance
5. Portable with minimal maintenance
6. The selected pneumatic cylinder supplies sufficient force for light to medium industrial operations often packing maximum features into minimum space

4.5. Fabrication and Assembly

The frame was created using mild steel sections welded joints to form a rigid framework.

The pneumatic cylinder was installed vertically to ensure proper force transmission.

The solenoid valve and control circuit mounted on a wooden or metal platform for insulation and accessibility.

4.6 Principle of Operation

The working principle of the automatic pneumatic hammer machine is based on the fundamental laws of fluid mechanics, particularly Pascal's Law. According to this law When applied the pressure to an enclosed, incompressible fluid then it is transmitted in all directions throughout the fluid and to the container wall. Compressed air initiated by an air compressor is delivered to a pneumatic cylinder through a solenoid valve. When the solenoid valve is activated, compressed air enters into the pneumatic cylinder with high pressure and it's pushing the piston in the forward direction. This piston movement delivers kinetic energy to the hammer mechanism, resulting in an impact on the material or work piece. Once the solenoid valve is switched off, air is released through the exhaust port, allowing the piston to move back its original position. This sequence of forward and backward strokes of the piston continues automatically in response to the control input. The automation of the hammering operation is achieved by controlling the timing of solenoid valve using a relay circuit or a microcontroller. This control arrangement ensures consistent and accurate hammering.

Performance Evaluation

The experimental testing of the automatic pneumatic hammer machine describes continuous hammering force acting across multiple cycles.

This system substantially drew the operator requirement and improved the production speed through balancing manual hammering. The continued effect shows energy resulted in improved work quality and reduced rework.

The system performs reliably under uniform conditions. Sound creation was noticed but remained within sustainable industrial limits. Regular lubrication and air filtration were necessary to maintain smooth operation.

4.7 Working Cycle

This machine is working on compressed air power and it follows theses cycle

Air Supply

The compressed air is stored in the air tank.

This air passes through FRL Unit which filters the dust and Controls pressure during lubricated air flow and performs a smooth pneumatic operation.

Control System Activation

When the power supply is on, the electrical signal goes to the solenoid valve and timer circuit controls ON / OFF timing.

This makes the system automatic and can perform manual operation that allows continuous hammering cycles. The control unit can be programmed to adjust stroke frequency and timing.

Air Flow to Cylinder

The solenoid valve directly compresses air into the Pneumatic cylinder and air pressure pushes the piston downward direction.

Hammer Action

The piston rod is connected to hammer tool,

When the piston moves down then the hammer strikes the job surface.

Return Stroke
After a strike the solenoid valve changes position. And air is sent to the opposite side of the cylinder and pushes the piston in upward direction.

Continuous Automatic Cycle
Timer circuit keeps switching valve:
So piston moves:
- Downward (Strike)
- Upward (Return)

Result = Continuous hammering action.

4.8 Force Analysis and Calculations
The impact force generated by the pneumatic system depends on air pressure and the piston area.

F = P × A
Where:
- F = Force,
- P = Pressure
- A = Piston Area

Assuming
Operating pressure = 6 bar (600,000 Pa)
Cylinder bore diameter = 40 mm

Area = $\pi \div 4 \times (0.04)\hat{}2 = 0.00126\ m^2$
Force $= 600{,}000 \times 0.00126 = 756$ N

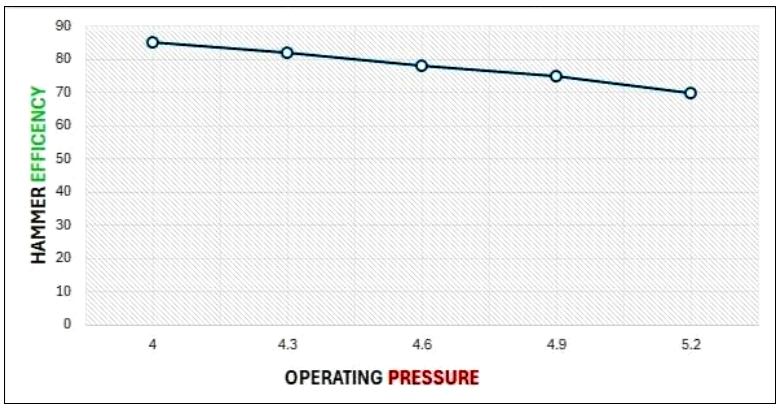
This force is sufficient for light to moderate industrial hammering tasks. The frequency of hammering is controlled by the solenoid valve switching speed and airflow rate.

4.9 Working Data of the Automatic Pneumatic Hammer under Different Materials
The automatic pneumatic hammer system shown in table which was tested and evaluated for its operational efficiency under different material conditions.

Table 1: Material Performance Characteristics under Varying Operating Conditions

Material	Material nature	Operating pressure	Blow per minute	Average deformation depth (mm)	Air consumption (l/min)	Hammer efficiency
Aluminium	Soft	4	200	0.5	15	85
Brass	Medium soft	4.3	190	0.38	20	82
Mild steel	Medium	4.6	180	0.28	25	78
Cast iron	Hard	4.9	170	0.2	30	75
Stainless steel	Very hard	5.2	160	0.16	35	70

4.10 Pressure and Efficiency Analysis
Efficiency = useful output energy/Input energy ×100
The gradual drop in efficiency from soft to very hard materials confirms that hammer performance is strongly dependent on material resistance. This relatively working data verify the efficiency of the hammer under different load conditions and shows its suitability for a range of materials.



This graph shows the relationship between operating pressure and hammer efficiency

4.11 Advantage & Limitations
Advantages
1. Remove manual hammering requirement
2. Ensures the consistent and repeatable force.
3. Enhances the operation with safety.
4. Increases productivity
5. Suitable for small-scale industries work
6. Simple in design
7. Easy to carry compare to other

Limitations
1. Need continuous compressed air supply
2. Generates operational noise
3. Higher initial installation cost
4. Periodic maintenance required

Applications
1. Forging and blacksmithing operations
2. Sheet metal fabrication
3. Riveting and punching processes
4. Automobile workshops
5. Industrial training laboratories

5. Results and Discussion

After completing this project we examine the results of an automatic pneumatic hammering machine which describes smooth and consistent operations performed during testing.

This system conveys the uniform impact of force with minimal vibration and the results of minimal vibration shows the reduction of automated operators without requirements of human involvement and improved repeatability, which makes the system reliable for continuous operation.

6. Conclusion

The automatic pneumatic hammering system demonstrates the study of this project which offers an effective and efficient solution by replacing manual hammering in repetitive industrial operations. By employing pneumatic power combined with controlled and automated impact mechanisms. The use of solenoid valve, pneumatic cylinder device and compressed air to do hammering work automatically which works continuously by reducing human effort. The test result shows that the system works smoothly and reduces vibration during repeated cycle and this system improves work quality and makes the workplace safe during increasing productivity.

The size of this system is small and low in cost so it is suitable for small industries/workshops and educational laboratories.

However, this system requires regular maintenance and continuous air supplied for performing continuous work with safety.

7. Acknowledgment

I respectfully acknowledge the support and guidance of my teachers for successfully completing this project on the Pneumatic Forging Machine. I also extend my thanks to my team-mates and the authors of M. Rajesh, “Development and assembly of automatic portable hammering machines, standard textbooks such as R.K. Rajput – Manufacturing Technology, S.R. Majumdar – Pneumatic Systems, and Anthony Esposito – Fluid Power with Applications, whose concepts of pneumatic systems and forging technology helped in developing and understanding this diagram. Their theoretical knowledge on pneumatic cylinders, solenoid valves, compressors, and automated forging systems served as an important reference in preparing this model layout. Finally, I would like to thank everyone who directly or indirectly supported me in completing this work successfully.

8. Future Scope

1. In future, this pneumatic forging machine can be made fully automatic by using sensors and PLC control systems. It can reduce human effort and increase production speed.
2. This system can also be used in small scale industries because it is cheaper than hydraulic machine
3. In future, this machine can be made more powerful by using higher pressure air systems, which will allow it to forge bigger and stronger metal parts.

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