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Design and Analysis of Automated Pneumatic Vice using Compressed Air

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Abstract

Pneumatic systems are safer than electromotive systems because they can work in inflammable environment without causing fire or explosion. Apart from that, overloading in pneumatic system will only lead to sliding or cessation of operation. Unlike electromotive components, pneumatic components do not burn or get overheated when overloaded. The operation of pneumatic systems does not produce pollutants. The air released is also processed in special ways. Therefore, pneumatic systems can work in environments that demand high level of cleanliness. One example is the production lines of integrated circuits.

Keyword

Compressor, Direction control valve, Double acting cylinder, Batch vice, Pneumatic pipe, Auto cad.

Introduction

An incredible range of manufacturing systems use the force and power of fluids such as water, oil and air. Powered clamps open and close with the force of pressurized air or oil, large presses shape and form metal with hydraulic pressure, and assembly torque tools fasten components with pressurized air. In each example, fluid power provides the energy necessary to exert significant mechanical forces. Systems that use air are called pneumatic systems while systems that use liquids like oil or water are called hydraulic system. The pneumatic systems will be the subject of the first three sessions in the course starting from this session. Pneumatics is all about using compressed air to make a process happens. Compressed air is simply the air we breathe squeezed into a small space under pressure. You might remember that air under pressure possesses potential energy which can be released to do useful work. Their principle of operation is similar to that of the hydraulic power systems. An air compressor converts the mechanical energy of the prime mover into, mainly, pressure energy of the compressed air. This transformation facilitates the transmission, storage, and control of energy. After compression, the compressed air should be prepared for use. A pneumatic system consists of a group of pneumatic components connected together so that a signal (compressed air) is passed through the system to make something happen at the output. These groups of components can be divided into five categories according to their function in the pneumatic circuit as follows:

1. Supply elements: these elements are the sources of power that drives the system which are the compressors.
2. Input elements: these elements are used to send signals to the final control elements and come in two forms; either as components that is actuated by the operator like push buttons or sensors that determine the status of the power elements such as limit switches and proximity sensors.
3. Processing elements: these elements may perform operations on the input signals before sending the signal to the final control elements such as non-return valves, directional control valves and presser control valves.

4. Final control elements: to control the motion of actuators such as directional control valves.
5. Power elements (actuators): these are the outputs of the pneumatic system which use the stored potential energy to perform a certain task such as pneumatic cylinders and motors.

Literature Review

Pneumatic systems have been widely used in industrial automation due to their simplicity, low cost, and reliability. Several researchers have contributed to the development of pneumatic clamping and work-holding devices, which form the foundation for the pneumatic vice.

A study on low-cost automation using pneumatic systems highlights that pneumatic grippers and clamps are extensively used in industries to improve productivity, reduce manual effort, and enhance safety. The research shows that pneumatic clamping systems provide firm gripping, faster operation, and better precision compared to conventional manual systems.

Research on the design and fabrication of pneumatic clamping devices explains the use of double-acting cylinders and directional control valves for performing clamping operations. These systems are capable of performing repetitive operations efficiently and are widely used in bending, drilling, and machining processes.

A detailed review of pneumatic cylinder positioning techniques indicates that pneumatic systems are preferred in automation because of their low cost, safety, and continuous operation capability. However, achieving precise positioning and control of the piston movement remains a challenge, especially in high-accuracy applications.

Another study on pneumatic clamping systems emphasizes the importance of controlled clamping force during machining. Proper force control improves workpiece accuracy, reduces deformation, and enhances overall machining quality. Modern pneumatic systems can achieve high repeatability, although limitations in precision still exist.

Research specifically focused on pneumatic vice design shows that replacing manual screw mechanisms with pneumatic actuators significantly reduces operator effort and increases efficiency. Pneumatic vices provide quick clamping and unclamping, making them suitable for mass production and automated machining environments.

Furthermore, recent reviews on pneumatic gripping devices highlight ongoing advancements such as modular designs, smart control systems, and lightweight materials, which are improving the flexibility and performance of pneumatic systems in modern industries.

Problem Statement

In conventional workshops and machining operations, manual vices are widely used for holding workpieces. These vices require significant human effort to clamp and unclamp the job, which leads to increased operator fatigue and time consumption. Moreover, manual clamping does not provide uniform and consistent force, resulting in improper holding, reduced machining accuracy, and possible damage to the workpiece.

In mass production industries, where repetitive clamping and unclamping operations are required, manual systems become inefficient and slow down the overall production rate. Additionally, improper tightening may lead to slippage of the workpiece, causing safety hazards and affecting product quality.

Therefore, there is a need to develop an automated and efficient clamping system that can:

- Reduce human effort
- Provide uniform clamping force
- Increase productivity and speed
- Improve safety and accuracy in machining operations

The proposed solution is to design and fabricate a Pneumatic Vice, which utilizes compressed air to achieve quick, reliable, and consistent clamping of workpieces.

Objective

- To design and fabricate a pneumatic vice using compressed air system.
- To reduce manual effort in clamping and unclamping operations.
- To achieve fast and efficient work holding during machining processes.

- To provide uniform and consistent clamping force on the workpiece.
- To increase productivity in workshop and industrial applications.
- To develop a system suitable for automation in mass production.
- To ensure safe and reliable operation of the clamping mechanism.
- To study the working of pneumatic components like cylinder and control valve.

System Components

- Compressor
- Direction Control Valve
- Flow Control Valve
- Double Acting Cylinder
- Batch Vise
- Pneumatic Pipe

Scope of the Project

The scope of this project includes the design, fabrication, and testing of a pneumatic vice system for workshop and industrial use.

- The project focuses on automatic clamping using a pneumatic cylinder.
- It can be used in drilling, milling, and CNC machines.
- Suitable for small-scale and medium-scale industries.
- The system is designed for repetitive operations to improve efficiency.
- Can be further upgraded with sensors and PLC for full automation.
- Limited to moderate clamping force applications (not for heavy-duty operations like hydraulic systems).
- The project mainly deals with mechanical and pneumatic aspects, not advanced electronics.

Design and Construction-

First of all, we have to take a plate as per our requirement (335*210 mm).

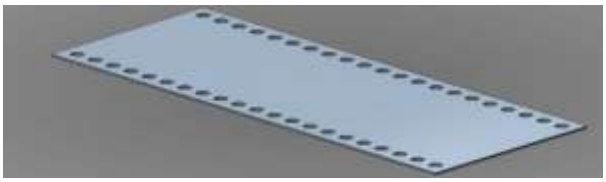

Figure 1. Metal Plate with multiple holes

Take batch vice of 3 mm stock length capacity. vice is in ruff casting form so some machining processes are like milling, drilling, grinding are to be carried out on it to make as per our requirement.

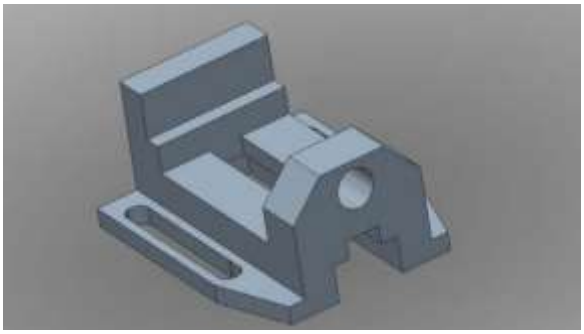

Figure 2. Batch vice

Now we have taken a vice and fix it on a plate and fit it with the help of bolts (hexagonal).

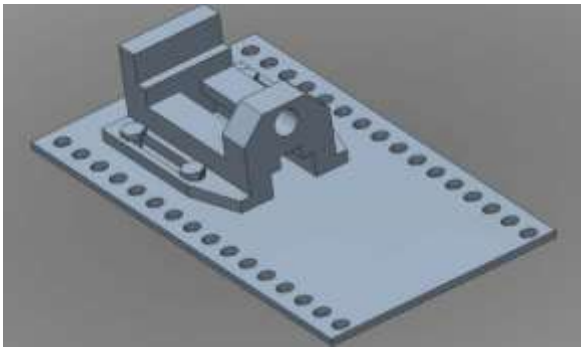

Figure 3. Fixed vice on metal plate

We have taken a cylinder of bore diameter of 50 mm, rod diameter 20 mm & length of cylinder is 100 mm.

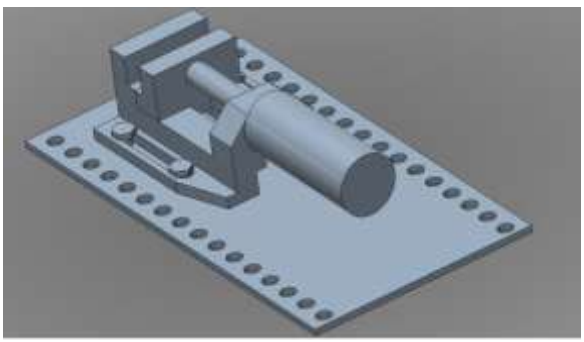

Figure 4. Cylinder fitment

The rod of cylinder is fitted with the help of fabrication work.

Cylinder is supported by its end with a rectangular block.

We provide two hard metal pieces to clamping object in a vice.

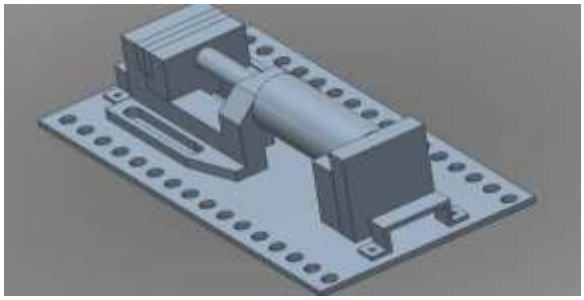

Figure 4. Pneumatic vice

Experiment Setup-

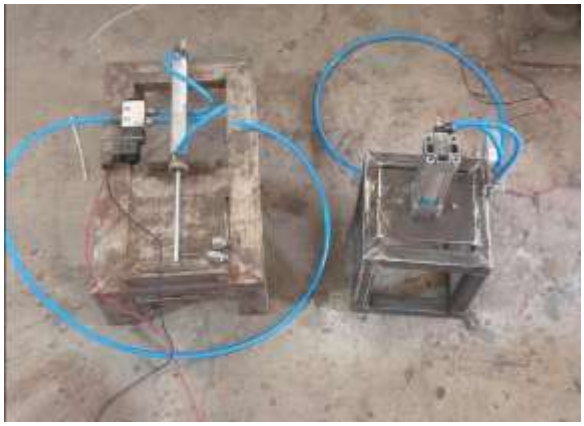

Figure 5. Working Model of Pneumatic Vice

Working Principle

A pneumatic vice works on the principle of compressed air energy converting into mechanical motion

- The system uses compressed air supplied by an air compressor.
- This air is directed into a pneumatic cylinder through a control valve.
- When compressed air enters the cylinder, it exerts pressure on the piston.
- The piston moves in a linear motion, pushing the movable jaw of the vice.
- The workpiece is clamped firmly against the fixed jaw.
- When the air flow is reversed or released, the piston moves back, and the vice opens

Calculation

Pressure Measurement 1 Bar = 100Kpa = 100KNm-2 = 14.5 PSI

P = F A

Equation: P= F/A P= 10 bar = 1.01 N/mm2

Diameter of piston = d = 50mm

A= (3.14 / 4) * (d *d)

= (3.14 / 4) * (50 * 50)

= 1963 mm2

P= F / A

1.01 = F / 1963

F = 2000 N

F= 200 Kg

So, we have selected pneumatic cylinder move 200 Kg. Of force at 10 bar pressure.

Testing and Results

The fabricated pneumatic vice was tested under different operating conditions to evaluate its performance:

1. The system was connected to an air compressor.
2. Air pressure was set between 4 to 8 bar.
3. Different workpieces were placed between the jaws.
4. The control valve/foot switch was operated to clamp and unclamp the job.
5. Observations were recorded for clamping force, time, and stability.

Advantages

- Reduces human effort
- Time-saving
- Low cost and simple design
- Portable and easy to operate
- Suitable for wet and dry cleaning

Applications

Pneumatic control systems are widely used in our society, especially in the industrial sectors for the driving of automatic machines. Pneumatic systems have a lot of advantages.

- High effectiveness
- High durability and reliability
- Simple design
- High adaptability to harsh environment
- Safety
- Easy selection of speed and pressure
- Environmental friendly
- Economical
- Quick operation.
- Stable and rigid design.
- Extremely high clamping force.
- High accuracy and repeatability.
- Reduces production costs.
- Design is compact and very simple to operate requiring almost no maintenance.
- Can be mounted horizontally or vertically

Results and Discussion

- **Clamping Time:** Approximately **1–2 seconds.**
- **Operating Pressure:** Efficient working observed at 5–6 bar.
- **Clamping Force:** Sufficient for light to medium machining operations.
- **Performance:** Stable and reliable under continuous use.

Future Scope

The pneumatic vice developed in this project can be further improved and enhanced in several ways to increase its efficiency, accuracy, and industrial applicability**.**

Conclusion

The project thus gives a system that can easily fixed the workpiece & work on it. The pneumatic vice provides extremely high clamping force & High accuracy and repeatability. Pneumatic system can get high production rate. When compressed air is released from the pneumatic components then noise can produce. The operation of pneumatic systems does not produce pollutants system fully autonomous.

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