Mechatronic Control Unit For Pneumatic Operations

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ABSTRACT— **The following report explains the production as well as function of a simple mechatronic unit which can be used for the demonstration of pneumatic operations and also for the actuation of some pneumatic machines. The following set up comprises a cylinder tank (compressed air), a filter regulator lubricator system (FRL), a distributer, a DC power supply, six directional control valves (DC valves), four flow control valves and a double acting cylinder (output). All the components are attached to a portable wooden stand.**

INTRODUCTION

The aim of this project is to merge the concepts of pneumatics and mechatronics by creating a setup consisting of different mechatronic components which can be connected to a pneumatic device in order to operate it. The particular unit is designed in a way which is easy to comprehend and hence can also be used as a training kit for basic demonstrations.
In industrial applications there are various types of mechatronic and pneumatic components. Which are all powered differently and perform different operations. A basic pneumatic circuit would include a compressor tank, an FRL unit and a few directional control (DC) and flow control (FC) valves powering a cylinder or an actuator. However in the industry there are a variety of DC and FC valves, some of which are even mechatronic valves. Each valve functions in a different manner and has a different effect on the pneumatic cylinder/actuator. For industrial applications a particular set of valves is chosen based on the required output.

The following setup has been constructed using a variety of different valves and components which can be connected in many different circuits and can produce several different outcomes. The purpose this particular model unit serves is that it cannot only be used for basic demonstrations but it can also be used to power any basic pneumatic device. Although it cannot be used on the industrial level it provides a general idea of how a single comprehensive mechatronic unit could be used to power multiple different pneumatic systems for multiple different operations.
As mentioned above the following setup comprises of a variety of valves and components due to which it can form a variety of circuit connections and as a result this has very high functionality. A single unit with the flexibility of forming several different circuits and the capability of performing various tasks would be a very convenient and cost effective product. Hence it would have a huge demand and would make industrial applications a lot easier. The following system could be implemented in rock drills, pavement breakers, riveters, forging presses, paint sprayers, blast cleaners, and atomizers. This technology could also be used in vehicle tires, air brakes of buses, trucks or trains, compressed-air engines, vacuum pumps, and more. Not to forget it would be revolutionary in manufacturing industries, automation industries and even in the field of medicine.
The basic concept of pneumatics is that it uses compressed air to move or actuate a cylinder due to its pressure. So the compressed air needs to be stored in a tank or reservoir. An FRL (filter, regulator, and lubricator) is needed to clean the air, keep the moisture away, and regulate the pressure of the air and adding a mist of oil to reduce internal friction. A distributor or manifold may be used when multiple inputs are present, it basically acts as a circuit extension. Direction control valves are used to direct the flow of air whereas flow control valves are used to control the speed/rate of flow of the air. Actuators or pneumatic cylinders act as the output devices which manifest some kind of effect/change due to the flow of compressed air.

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1. BASIC PRINCIPLES

A. Mechatronics

Mechatronics is a branch of engineering which is extremely comprehensive and detailed as it is a combination of different engineering fields. It is the integration of mechanical, electrical and electronic engineering systems which combine with robotics, electronics, computer science, telecommunications, systems, control and product engineering. This integration of multiple engineering fields and concepts has led to the advancement of the automated manufacturing industry. Applications include automation, robotics, automobiles, bio mechatronics etc.

B. Pneumatics

Pneumatics is a sector of mechanical engineering which exploits compressed air to perform specific functions. Several industries have pneumatic systems. A compressor containing pressurized air is used to power pneumatic systems which include cylinders, air motors, pneumatic actuators and other types of pneumatic devices. Pneumatic systems are a better alternative to hydraulic systems and electrical motors as they are safer, more flexible and more affordable. Pneumatic systems have applications in construction, mining, dentistry, etc.

2. MATERIALS USED

1. Compressor and Air Reservoir

An air reservoir, sometimes referred to as a compressed air tank, is an integral part of any compressed air system. This is the first device of our project. Air will be sent from this air compressed tank to the FRL and other pneumatic valves.

2. 24 V DC Power Supply

DC power supply also known as bench power supply, is a type of power supply that gives direct current (DC) to a device. This device converts 240 V alternating current (AC) to 24 V direct current (DC).

3. Filter Regulator Lubricator (FRL)

In pneumatic applications, Filter Regulator Lubricators, commonly known as FRLs, are designed to deliver a clean air flow. Together, these components support optimum performance and avoid contamination-related downtime.

4. Pneumatic Tubes (8mm diameter)

We are using 5 meters long pneumatic tube of 8mm diameter. This tube is made up of polyurethane and polyvinyl chloride to have flexibility and avoid leakage.

5. Distributor Manifold

Distributor Manifold also known as air and steam headers, are used to divert a single air flow to multiple directions for other valves. The air flow is evenly distributed to other valves in multiple directions.

6. WOODEN BOARD STAND (DIMENSIONS: 120 CM × 80 CM)

Here we are using 1-inch-thick wooden board of 120 cm × 80 cm. The board has been made as a detachable piece and can be removed and inserted back to the table. Wheels have been attached at the bottom of the table to make it a potable unit.

7. *Directional Control (DC) Valves*

a. 3/2 24 V Solenoid Valve

3-port 2-position is designed to shut off and release the air with the power supplied by 24 V. For this we will connect the DC power supply to this valve to actuate the flow. This valve works only on 24 V Direct Current.

b. 3/2 Pilot Air Operated Normally Open Valve

3-port 2-position valve is useful because they make it possible for a modest, easily controlled flow to regulate a significantly higher pressure or flow rate.

c. 5/3 Pilot Air Operated Normally Closed Valve

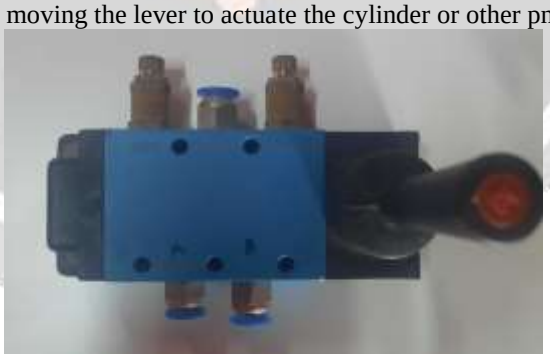
This is a 5-port 2-position valve. Due to the closed valve, no fluid can go from the inlet to outlet. As long as the pressure is higher at the inlet, the interval valve components move when the pilot pressure is applied so that it flows from inlet to outlet.

d. 5/2 Mechanical Push Button Valve

The valve has five ports and two positions that can be driven manually. In this valve we can block or pass the flow manually by pushing the button to actuate the cylinder or other pneumatic device.

e. 5/3 Mechanical Hand Lever Valve

The valve has five ports and three positions that can be driven manually. In this valve we can block or pass the flow manually by moving the lever to actuate the cylinder or other pneumatic devices.



f. Pedal Valve

This valve has three ports and two potential positions as it can be either pushed down or returned back to its original position. This way we can manually block the airflow or allow it to pass through in order to actuate the cylinder/pneumatic output device.

8. *Flow Control (FC) Valves*

a. Speed Control Valve

This valve helps us to control the air flow when the air is flowing through this valve.

b. Flow Cum Check Valve

The following valve is used to maintain constant flow rate. It is a combination of flow control valve and check valve.

c. Shuttle Valve

Its main function is to block one or both of the inlet ports. Each intake port has a shuttle seat. Fluid can freely flow from the typical system inlet port via a shuttle valve in its normal operating position and out of the valve's outlet port.

d. Quick Exhaust Valve

For fast extension and retraction of the machinery, quick exhaust valves are provided at the rod or blind end of a pneumatic cylinder. In order to directly expel the exhaust air from the cylinder's port, quick exhaust valves work by speeding up the pneumatic cylinder's rod.

9. Valve Fittings(8mm)

Every valve has fittings. The function of these fittings is to connect the valves to the pneumatic tube and hold them together. The thickness of all the fittings is 8mm however the threading is different.

10. Stoppers(8mm)

These are small nail like components which help block the fittings of valves not in use.

11. Push Button Switch

A pushbutton switch is a mechanical device used by an operator to manually press a button to control a circuit that operates an internal switching mechanism.

12. Actuated Cylinders/Pneumatic Devices

1. Double Acting Cylinder

This component is used as an output device. All connections and circuits could lead to this cylinder. It has two ports into which air flows which can cause the cylinder to move in one of two directions. Hence it is called double acting cylinder.

2. Pneumatic Jack Operated by Cylinder

The following component is another output device. The function of this device to manifest how a machine could be operated using this pneumatic control unit. This device is basically a jack which can move up and down with the help of the double acting cylinder it's connected to.

3. WORKING PRINCIPLE

a. *Compressed Air Reservoir*

The concept of pneumatics is one which makes use of compressed air for actuating and operating machines. This air passes through tubes and valves and eventually reaches the output device. However the first and most important step is to compress the air and store it. Hence this component is a combination of a compressor and a reservoir tank. The function of the compressor is to take in air from the atmosphere and create a vacuum in order to alleviate the pressure. The compressed air is then pushed out of the chamber by the vacuum and into the storage tank/reservoir. Once the tank is completely filled the compressor turns off.

b. 24 V DC Power Supply

The power supply is required for the solenoid valve as it functions with the help of current. Since the solenoid valve used in this setup has a coil of 24 volts, the power supply must be of that magnitude as well. The function of the power supply is to extract the AC current from the wall outlet and convert it into DC current with the voltage required by the load. Initially the AC current is changed to unregulated DC current. The voltage is then reduced by an input power transformer which steps down the voltage based on the requirement which in this case is 24 volts.

c. Filter Regulator Lubricator (FRL)

The FRL unit consists of three separate components working together; filter, regulator and lubricator. While the general objective of this unit is to remove the large air particles (filter), control the pressure of the air (regulator) and supply a controlled quantity of oil into the system (lubricator). The basic working principles of these components are much more complex.

Filter: The body of the filter is able to create a cyclonic action where all the moisture and heavy particles of air are sent to the bottom of the bowl. The filter element has a baffle which prevents these particles from entering output air flow. The output air is then passed through a filter element where the mesh size of the filter determines the maximum size of the particles passing through.

Regulator: The regulator consists of a control knob which works along with a spring to apply load onto the diaphragm assembly. The diaphragm inserts pressure onto the valve pin which is connected to the valve seat. This causes the seat to drop which in turn allows the downstream air flow from the inlet port to pass through and out of the outlet port. As the air passes through the outlet port, a breathe hole allows the air to enter a chamber below the diaphragm. As soon as the pressure on either side of the valve seat is balanced

the seat is closed with the help of the spring. The downstream airflow later causes a drop in pressure within the chamber causing the seat to open and as a result allowing the air to pass through again. This happens until the pressure is balanced again after which the seat then closes. This process is continuous and maintains a set value of the airflow through the outlet port.

Lubricator: the function of the lubricator is to control the amount of oil which passes into the downstream airflow. There are two types of such lubricators; oil fog lubricator and micro fog lubricator. The first one allows all the droplets of oil to pass into the air flow whereas the latter reduces the size of the droplets before entering the airflow. The size of the average particle is less than 2 micron and approximately only a tenth of the particles visible in the site dome are allowed to pass downstream.

d. Pneumatic Tubes (8mm diameter)

The pneumatic tubes are a major part of the mechatronic system as they help connect all the different components together. They act as wires in an electrical circuit would, only here the circuit comprises of pneumatic components and hence pneumatic tubes must be used. The thickness of the tubes in this case is 8 mm. However there is a variety of tube with different thicknesses available. Tubes come in 6mm, 8mm, 10mm, 12mm, 16mm etc. The thickness of the tubes is proportional to the size of cylinder/actuator that can be operated. For instance larger machines with huge cylinders would require a higher thickness of tubes. The function of the tube is to transport the supply of compressed air from one component to the other all the way to the output device. Thicker tubes can carry higher volumes of air particles which explains why thicker tubes are needed for the actuation of heavy cylinders. In this case the tubes are 8mm thick so every component of the system must have 8mm fittings. The tubes can only be connected via fittings so the fittings must be of the same thickness as the tubes. To ensure there is no leakage of airflow, Teflon tape can be wrapped around the fittings.

e. Distribution manifolds

Distribution manifolds sometimes referred to as air and steam headers are used mainly to divert the airflow from a single feed line to several locations/components. It functions as a combination of multiple connectors which allows the input airflow passing into a single inlet to be divided and equally distributed through multiple outlet ports. These devices also help prevent corrosion within the valves and allow the air to pass through smoothly by removing the unwanted fluids or condensation from the vent valve. The manifolds basically function as extension sockets enabling multiple connection options for isolation. It is important that these manifolds are robust and reliable hence they are made from materials such as stainless steel and carbon steel.

f. Directional Control Valves (DC Valves)

Fluids or gases flow into different pathways from valve ports with the help of directional control valves. These valves allow the air to flow through a passageway leading to or from other components and sources. Hence directional control valves are of great significance to pneumatic systems.
The valves comprise a spool within a cylinder which is either electrically or mechanically actuated. The flow of the air is dependent on the position of the spool. The position can be changed in order to either allow or restrict fluid flow through a passageway, this process takes place instantly causing the air to accelerate and decelerate swiftly.
There are several different types of DC Valves which can either be manually or mechanically operated. What differentiates the valves from each other are the way in which they are operated and the number of ports and positions. Valves have different ports/position orientations where the number of ports is how many connections can be accommodated and the number of position refers to the number of flow paths provided by the valve. The following are types implemented in the setup:

1) 3/2 24 V Solenoid Valve

When a solenoid valve operates, an orifice in the valve body is either opened or closed, allowing or preventing flow through the valve. By activating the coil, a plunger raises or lowers the aperture by elevating or lowering it within a sleeve tube. An assembly of a coil, plunger, and sleeve makes up a solenoid valve. We can turn ON and OFF with DC power supply which is connected to solenoid valve.

2) 3/2 Pilot Air Operated Normally Open Valve

The primary force needed to open the valve during pilot operation is supplied by the medium pressure. As it just regulates the flow of a small diameter impulse line that enables the fluid to open the main diaphragm or piston, the pilot can be quite small. When the pressure at the inlet is higher than the outlet, the valve is said to be "normally open," allowing fluid to flow from the inlet to the outlet. The internal valve components move and the valve closes when pneumatic pressure is applied to the pilot.

3) 5/3 Pilot Air Operated Normally Closed Valve

Pressure relief valves known as pilot-operated valves regulate the inlet and output ports of the main valve. Although they resemble spring-loaded valves, they offer the finest alternative for achieving the highest pressure and capacity. These valves provide exceptional overpressure protection performance. Normally close describes a valve that is closed, preventing fluid from flowing from the intake to the outlet. As long as the pressure is higher at the inlet, the internal valve components move when the pilot pressure is applied, and the media flows from the inlet to the outlet.

4) 5/2 Mechanical Push Button Valve

When fluid needs to be quickly stopped from flowing through a pipe or changing direction, a push button valve is designed for simple manual operation. When the button is pushed, normally open valves close, and when the button is released, they spring open. When the button is pushed, normally closed valves open, and when it is released, they return back to their closed position.

5) 5/3 Mechanical Hand Lever Valve

5-way 3 position hand lever valves allow to creep the cylinder forward or back and then hold it one spot by controlling manually through lever. These valves are generally used for double acting pneumatic actuator/cylinder.

6) Pedal Valve

Pneumatic pedal valves are used to remotely control other pneumatic components of a system. For instance, they can drive pneumatic cylinders that secure workpieces, allowing machines to be operated without the need for a human operator.

g. Flow Control Valves

The main function of control valves is to open or close internal pathways for regulating the flow of a fluid. Control valves are part of a control loop that controls a process. Control valves adjust internal openings in response to instructions from the controller.

Control valves are the most commonly used final control components in process control engineering. Control valves alter flowing fluids such as gases, steam, water, or chemical compounds to counteract load disturbances and bring the controlled process variables as close as possible to their intended set points.
Control valves are used to control the flow of fluids by changing the size of the flow path according to control, allowing direct control of the flow rate. This allows you to control process variables such as fluid level, temperature and pressure. In automatic control terminology, it is called final control element. A control valve can control the flow of fluid based on a control input. There are many different types of control valves. The following are types implemented in the setup:

1) Speed Control Valve

This valve is used to control the flow rate of fluid manually through the throttle mechanism in the valve. We can increase or decrease the flow rate based on our needs.

2) Flow Cum Check Valve

This check valve helps in preventing the back flow of fluid. A check valve essentially functions as a one-way valve, allowing the flow to pass freely in one direction but blocking it in the other.

3) Shuttle Valve

It is possible for fluid to pass through a shuttle valve from one of two sources. A shuttle valve is typically found in pneumatic systems, though it can also be found in hydraulic ones on occasion. A shuttle valve's fundamental design resembles a tube with three openings: one at each end and one in the center.

4) Quick Exhaust Valve

The quick exhaust valve is usually mounted above the pneumatic cylinder or near to cylinder to quickly drain the trapped air inside the cylinder after operation.

h. Valve Fittings (8mm)

Every valve has different threading, based on this threading appropriate fittings must be selected. It is essential that all fittings are of same diameter and correspondent to the diameter of the pneumatic tube. These fittings act as junctions which enable connectivity between the valves and the tube. To remove the tube from the fittings the fittings must be pushed inwards.

i. Stoppers (8mm)

When a valve is not in use its fittings must be closed to keep the dust or unnecessary air away. Stoppers help close the fittings. This is especially useful when the control unit being operated but certain valve ports are not required, in this case if not closed air will leak through the outlets and this will affect the functionality of the whole control unit. To avoid such a nuisance stoppers can simply be inserted into the fittings of all the valves not in use and can be removed at will. The stoppers must be of the correct size based on the diameter of the fittings and the tube.

j. Push Button Switch

Most push button switches work in the same way. Pressure is applied to the button or actuator, depressing the internal spring and contact, touching the solid contact on the underside of the switch. This action closes or opens a circuit. The
Push-to-make switch allows current to flow between the two contacts when held down. The circuit is broken when the button is released.

k. Double Acting Cylinder

A double-acting pneumatic cylinder is a cylinder in which thrust or power is generated in both the extension and retraction directions. Double-acting cylinders have ports on each end, and changing ports moves the piston back and forth similar to opening and closing a gate.
Air pressure is alternately applied to both ends of the piston. Applying air pressure produces thrust on the positive (push) stroke and thrust on the negative (pull) stroke.
Double-acting cylinders are typically used in all applications where the required thrust and stroke length exceed those available with single-acting cylinders. Small double-acting cylinders are also used in applications where positive end positions are required on both strokes.

l. Pneumatic Jack operated by Cylinder

This is a device which functions with the help of the double acting cylinder. The two ends of the cylinder are connected to the jack and so as the cylinder moves into its positive (push) stroke the jack elongates and moves up and as the cylinder moves into its negative (pull) stroke the jack is compressed and moves down. The purpose of this device is to simply demonstrate how any pneumatic device consisting of a cylinder can be operated using this pneumatic control unit.

4. EXPLANATION IN DETAIL

As mentioned above the aim of this project was to create a setup which could integrate mechatronics and pneumatics and could be used for demonstrations and also be used to operate any basic pneumatic device. In order to successfully create such a setup a number of procedures and concepts had to be followed. The first step was to conduct the appropriate research to find out which components would be necessary to

showcase and implement the concepts of mechatronics and pneumatics to accomplish the task of making a control unit. After completing the research and purchasing all the vital components, the next step was building the base and platform for the setup. Once the base and platform were assembled, the next step was to create a small hole on the platform for the push button switch after this all the mechatronic and pneumatic devices/components had to be attached to the platform in the appropriate manner in the correct order and pattern. After all the components had been fixed to the board the next step was to cut out and connect pneumatic tubes to the components forming multiple different circuit connections. The final step was to test the control unit on an output device to check its functionality and derive different possible results due to the several different connections possible. The following is the elaboration and details of all the procedures mentioned above:

a. Research

The first step of conducting research was crucial in providing information as to which components would be useful for a mechatronic control unit. After completing the research we realized that the following components would be needed:-

1) Compressor with tank: to compress air and keep it stored for when it is needed.
2) FRL: a unit consisting of a filter for removing large air particles, a regulator for controlling the pressure of the air and a lubricator for providing a controlled quantity of oil to the air.
3) Pneumatic tubes (8mm): to carry the airflow from one component to another.
4) Valve fittings (8mm): for the connectivity between valves and tubes.
5) Stoppers (8mm): for blocking valve outlets not in use.
6) Push button Switch: for the activation and deactivation of the electrical circuit implemented while using the solenoid valve.
7) Distributor manifold: for increasing the range of outlets/ports in order to connect several different valves.
8) 24 V DC power supply: a power supply converting AC to DC which provides power to the solenoid valve.
9) Switch: to activate and deactivate the power supply.
10) Set of DC Valves: valves for directional control include 3/2 24 V solenoid valve, 5/3 hand lever valve, 5/2 push button valve, pedal valve, 3/2 pilot air operated normally open valve and a 5/3 pilot air operated normally closed valve.
11) Set of flow control valves: valves for controlling airflow include speed control valve, flow cum check valve, shuttle valve and quick exhaust valve.
12) Double acting cylinder: used as output for demonstration of a cylinder.
13) Pneumatic Jack operated by cylinder: used as output device for demonstration of a pneumatic machine.

b. Board Assembly

The control unit comprises a number of valves and components hence the base and platform would need to be enormous in order to accommodate all the components of the unit. We decided to make a portable table as the base and an attachable/detachable board as the platform. In order to do this we cut out four pieces of wood and attached them together using carpentry methods and adhesives. The top of the table was made leaving a groove in the centre so that the board could be inserted and removed at will. Wheels were attached to the table for increased mobility.

A large piece of wood with dimensions 80 x 120 cm and a thickness of 1 inch was cut out. This piece of wood along with the pieces used to form the table were all painted white.

Once the board and platform were assembled and attached, a hole big enough to accommodate a push button switch was to be made on the platform using a drilling machine. Once this was done the final

procedure of the assembly was to attach a clamp to the backside joining the platform to the base and keeping it sturdy.

c. Attaching the Components

Before attaching the components it is important to anticipate different possible arrangements for the components. Once we were certain of which arrangement was best we decided to proceed. Based on our arrangement the DC power supply was to be fixed behind while the rest of the components would be attached to the front side. The push button switch was also to be inserted into the front side of the board but through the hole present on the board. So it was important to use a clamp for this attachment. The arrangement of the remaining components would have the FRL and distributor manifold placed beside each other at the bottom leaving some room on the right bottom side for the pneumatic jack which is not to be fixed but rather placed on the table. All the directional control valves would be placed on the left hand side one above the other forming a column except for the pedal valve which would be placed at the center. Meanwhile all the flow control valves would be placed in line at the right hand side making sure there is room at the bottom for the pneumatic jack and room above for the double acting cylinder which also would be attached to the board. Since the DC power supply was to be attached at the backside we first had to drill a small hole on the left side of the board so the wire connecting the solenoid valve and the power supply could pass through. Once this was done and the arrangement was made the next step was to insert Teflon tape to the threading of all the valve fittings to prevent leakage, along with this we also had to tighten the fittings of each valve using a spanner, then we could fix everything onto the board. For doing this we used screws and a power screw gun. While most components were attached this way some components such as the DC power supply, quick exhaust valve and double acting cylinder were attached using double sided tape since there were no holes within these components for screwing.

d. Cutting the Pneumatic Tube

The pneumatic tube was cut into many smaller pieces based on the circuit connections that were to be implemented. The cutting was done by a pair of scissors. Once the tubes were cut they were connected to the components based on the circuit connections required.

e. Different Possible Circuit Connections

As the control unit consists of several DC valves and flow control valves many different connections are possible. Each connection has a different effect on the output. The following are all the different possible connections that can be implemented on this control unit:

1) **FRL------Manifold Distributor------3/2 24V Solenoid Valve------Output Cylinder**

2) **FRL------Manifold Distributor------3/2 24V Solenoid Valve------Speed Control Valve------ Output Cylinder**

3) **FRL------Manifold Distributor------3/2 24V Solenoid Valve------Flow Cum Check Valve------ Output Cylinder**

4) **FRL------Manifold Distributor------3/2 24V Solenoid Valve------Quick Exhaust Valve------ Output Cylinder**

5) **FRL------Manifold Distributor------3/2 24V Solenoid Valve --------- 3/2 Pilot Air Operated Normally Open valve------ Output Cylinder**

6) **FRL------Manifold Distributor------3/2 24V Solenoid Valve --------- 3/2 Pilot Air Operated Normally Open valve------ Speed Control Valve------ Output Cylinder**

7) **FRL------Manifold Distributor------3/2 24V Solenoid Valve --------- 3/2 Pilot Air Operated Normally Open valve------ Flow Cum Check Valve------ Output Cylinder**

8) **FRL------Manifold Distributor------3/2 24V Solenoid Valve --------- 3/2 Pilot Air Operated Normally Open valve------ Quick Exhaust Valve------ Output Cylinder**

9) **FRL------Manifold Distributor------3/2 24V Solenoid Valve --------- 5/3 Pilot Air Operated Normally Closed Valve------ Output Cylinder**

10) **FRL------Manifold Distributor------3/2 24V Solenoid Valve --------- 5/3 Pilot Air Operated Normally Closed Valve------ Speed Control Valve------ Output Cylinder**

11) **FRL------Manifold Distributor------3/2 24V Solenoid Valve --------- 5/3 Pilot Air Operated Normally Closed Valve------ Flow Cum Check Valve------ Output Cylinder**

12) **FRL------Manifold Distributor------3/2 24V Solenoid Valve --------- 5/3 Pilot Air Operated Normally Closed Valve------ Quick Exhaust Valve------ Output Cylinder**

13) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- Output Cylinder**

14) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- Speed Control Valve------ Output Cylinder**

15) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- Flow Cum Check Valve------ Output Cylinder**

16) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- Quick Exhaust Valve------ Output Cylinder**

17) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- 3/2 Pilot Air Operated Normally Open valve------ Output Cylinder**

18) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- 3/2 Pilot Air Operated Normally Open valve------ Speed Control Valve------ Output Cylinder**

19) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- 3/2 Pilot Air Operated Normally Open valve------ Flow Cum Check Valve------ Output Cylinder**

20) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- 3/2 Pilot Air Operated Normally Open valve------ Quick Exhaust Valve------ Output Cylinder**

21) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- 5/3 Pilot Air Operated Normally Closed Valve------ Output Cylinder**

22) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- 5/3 Pilot Air Operated Normally Closed Valve------ Speed Control Valve------ Output Cylinder**

23) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- 5/3 Pilot Air Operated Normally Closed Valve------ Flow Cum Check Valve------ Output Cylinder**

24) **FRL------Manifold Distributor------5/3 Hand Lever Valve--------- 5/3 Pilot Air Operated Normally Closed Valve------ Quick Exhaust Valve------ Output Cylinder**

25) **FRL------Manifold Distributor------5/2 Push Button Valve --------- Output Cylinder**

26) **FRL------Manifold Distributor------5/2 Push Button Valve --------- Speed Control Valve------ Output Cylinder**

27) **FRL------Manifold Distributor------5/2 Push Button Valve --------- Flow Cum Check Valve------ Output Cylinder**

28) **FRL------Manifold Distributor------5/2 Push Button Valve --------- Quick Exhaust Valve------ Output Cylinder**

29) **FRL------Manifold Distributor------5/2 Push Button Valve--------- 3/2 Pilot Air Operated Normally Open valve------ Output Cylinder**

30) **FRL------Manifold Distributor------5/2 Push Button Valve --------- 3/2 Pilot Air Operated Normally Open valve------ Speed Control Valve------ Output Cylinder**

31) **FRL------Manifold Distributor------5/2 Push Button Valve --------- 3/2 Pilot Air Operated Normally Open valve------ Flow Cum Check Valve------ Output Cylinder**

32) **FRL------Manifold Distributor------5/2 Push Button Valve --------- 3/2 Pilot Air Operated Normally Open valve------ Quick Exhaust Valve------ Output Cylinder**

33) **FRL------Manifold Distributor------5/2 Push Button Valve --------- 5/3 Pilot Air Operated Normally Closed Valve------ Output Cylinder**

34) **FRL------Manifold Distributor------5/2 Push Button Valve --------- 5/3 Pilot Air Operated Normally Closed Valve------ Speed Control Valve------ Output Cylinder**

35) **FRL------Manifold Distributor------5/2 Push Button Valve --------- 5/3 Pilot Air Operated Normally Closed Valve------ Flow Cum Check Valve------ Output Cylinder**

36) **FRL------Manifold Distributor------5/2 Push Button Valve --------- 5/3 Pilot Air Operated Normally Closed Valve------ Quick Exhaust Valve------ Output Cylinder**

37) **FRL------Manifold Distributor------Pedal Valve------Output Cylinder**

38) **FRL------Manifold Distributor------ Pedal Valve ------Speed Control Valve------ Output Cylinder**

39) **FRL------Manifold Distributor------ Pedal Valve ------Flow Cum Check Valve------ Output Cylinder**

40) **FRL------Manifold Distributor------ Pedal Valve ------Quick Exhaust Valve------ Output Cylinder**

f. Testing of Circuit Connections

The final step was to test as many circuit connections as possible while also testing the functionality of the control unit. To do this the compressor was turned on, the DC power supply was plugged in and turned on as well. We had to make sure that none of the outlet ports were left open meaning when certain components are not in use during the operation and testing of a connection, all the ports of these components must closed. The stoppers are meant for these scenarios. Every valve has fittings, while the threading of the fittings of different valves may differ the diameter of all fittings must be same and correspondent to the diameter of the pneumatic tube in use. In this case the tube was of 8mm so we made use of 8mm stoppers to block all the open fittings of valves not in use.

5. RESULT & DISCUSSION

The main objective of this project was to endeavor in creating a setup which follows the principles of mechatronics and pneumatics and is able to actuate any basic pneumatic machines/cylinders in multiple ways. In order to increase functionality and possible outcomes several different valves each with unique working principles were attached to the unit. Every valve/component has a different function and can be used in different ways to affect the output and each component has a different impact on the output device.
As mentioned above several different circuit connections were possible due to the number of different valves/components present within the setup. It was very important to determine exactly which types of connections would be feasible and the different outcomes they would generate. Hence several different circuit connections were implemented and tested. First using the double acting cylinder and then using the pneumatic jack as the output devices.

a. Circuit Connections Using Pneumatic Jack

1) **FRL------Manifold Distributor------3/2 24V Solenoid Valve------Speed Control Valve and Flow Cum Check Valve------ Output Cylinder**

Result: - Here two flow control valves are connected to the solenoid valve. One to each end of the cylinder hence both the forward and backward motion of the cylinder can be controlled. This obviously causes the jack to incline and decline. The push button switch is used to control the device.

2) **FRL------Manifold Distributor------5/3 Hand Lever Valve------Speed Control Valve and Flow Cum Check Valve------ Output Cylinder**

Result: - Here two flow control valves are connected to the hand lever valve. One to each end of the cylinder hence both the forward and backward motion of the cylinder can be controlled. This obviously causes the jack to incline and decline. The lever is used to control the device. The first motion causes the jack to slightly rise, the second motion causes it to incline to the fullest and the third motion causes it to decline.

3) FRL------Manifold Distributor------5/2 Push Button Valve------Speed Control Valve and Flow Cum Check Valve------ Output Cylinder

Result: - Here two flow control valves are connected to the push button valve. One to each end of the cylinder hence both the forward and backward motion of the cylinder can be controlled. The push button is used to control the device. The pushing motion causes the jack to incline and the pulling motion causes it to decline.

b. *Basic rules and Concepts*

1) All inputs such as FRL and DC valves must be connected to the Distributor manifold when in use.
2) When in use all outlets of components such as manifold and valves must either be connected to another component or the outlet must be blocked using a stopper to avoid leakage.
3) Pilot valves are DC valves which need to be connected to other DC valves for being controlled and operated. Connecting two DC valves together is not possible unless one of them is a pilot valve. This helps increase intensity and speed of airflow causing cylinders to move faster.
4) Flow control valves act as output valves and need not be connected to manifold however must be directly connected to the cylinders and DC valves. The flow control valves can be connected to either or both ends of a cylinder to control the speed at which the cylinder moves.
5) Speed control valves and flow cum check valves have similar properties and impact the cylinder in similar ways.
6) Quick exhaust valves allow the air pressure from the cylinder to be released quickly and help increase the speed of cylinder movement.
7) The number within the name of a valve represents the ports present and the number of positions possible for the cylinder. For example a 5/3 valve has five ports and three positions in which cylinder can stop.
8) Before disconnecting tubes make sure the compressor valve is closed and no air pressure is present within the tubes.

6. CONCLUSION

As seen above several procedures such as conducting research, assembly of board and platform, drilling, clamping, attaching components and testing of circuit connections were all followed and several components such as compressor tank, DC power supply, FRL, distributor manifold, DC valves, flow control valves, pneumatic tubes and pneumatic output cylinders were used in order to achieve this objective.
Based on all the information provided and the results obtained from testing multiple circuit connections it is evident that the following unit is able to operate pneumatic cylinders and machines in multiple ways. Not only can this particular setup be used for basic demonstrations of how mechatronic control units function in industries but this unit itself can be utilized for operating basic pneumatic machines such as a pneumatic jack. The setup can be upgraded furthermore to increase its functionality so that it is able to operate machines requiring a higher magnitude of pressure. Therefore it can be claimed that the aim of this project was successfully fulfilled.
The following report can be used to enlighten the readers about the basics of mechatronics and pneumatics and can also act as a guide for those looking to operate or create a pneumatic control unit. This report also

highlights the functions and applications of several different mechatronic and pneumatic components and hence can also act as a guide for those interested in creating and operating basic mechatronic and pneumatic devices.

7. APPENDICES

8. REFERENCES

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