Design and Development of Pneumatic Air Engine using Linear Actuator

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Abstract. A study was performed to produce a pneumatic air engine using two linear actuators and then the linear motion was converted to a rotating motion using a crank shaft. This study aims to increase the use of linear actuators in pneumatic air engines as well as to apply pressurized air as an efficient and convenient transportation mechanism in line with the development of technologies developed through products available in the market. Two units of linear actuator such as pneumatic cylinders with two units of 5/2 way directional control valve with double solenoid actuation are used to control the cylinder movement. The cylinder will rotate the crank shaft when receiving a signal from the solenoid valve with 5 bar air pressure.

In conclusion, the system can travel up to 153 meters for a 24-liter air-pressure with 5 bar pressure when the test is run for a charging cycle by the compressor motor. If the compressor motor able to charge the compressor continuously, the movement distance can be increased.

1. Introduction
In today’s modern era, there has been many automation systems created and built all around the world. It has grown rapidly and still arising making almost the human life system dependent on it due to the capability and its production capacity. Various operations used manual concepts have changes abruptly [1]. We usually see how many of the manufacturing sector such as factories or companies had produced high quality products of engine. However, there are still several weaknesses in the system and still should be improve.

Amongst the causes for making this pneumatic air engine is that all other products of mechanism transports such as tow trucks, forklifts and others which is on the market is using electric-powered engine for lower long-term fuel costs, the upfront costs for batteries and chargers can be expensive although the batteries for electric transport can be re-charged. Furthermore, some of that is using Compressed Natural Gas (CNG) powered forklifts also require the appropriate refilling requirement in order to operate, but this type of fuel provides some distinct advantages. CNG is better for the environment and for overall air quality due to fact that it produces less emissions and the natural gas dissipates into the air as water vapour and carbon dioxide in the event of a leak. The CNG tank is never removed, but actually refilled which can reduce downtime and operator strain. Infrastructure for CNG refuelling stations, however, can be expensive due to the large amount of land required and
general cost of equipment and installation. This, along with other barriers to entry such as obtaining the proper permits and having an adequate natural gas supply make CNG an unpopular choice in the current material handling market. So, an invention of pneumatic air engine using linear actuators were decided which can be used for indoor activities such as in factory and outdoor movement for transportation. This pneumatic air engine is using the compressor to provide maximum air pressure for the pneumatic cylinder to move the engine. Worker who always involved in indoor or outdoor activities, such as towing the broke-down car and to lift-and-move materials over short distances, is the main user group targeted with this designation concept.

Vital objective for this project is to design and develop a pneumatic air engine for towing and to lift and to move materials over short distances by using linear actuator. The invention is to improve pneumatic air engine with which is simple in construction and which is reducing air pollution. In addition, objective of this invention to provide an improved pneumatic air engine, which is using materials such as pneumatic components and other that are easily available in the market.

This project aims to provide a convenient solution in process improve transport mechanism functioning in smart way. The importance of cost and times of production still did not get many attentions from the manufacturer. So, in this project, the aim is would be a good help to create something to design and develop the pneumatic air-powered engine which using linear actuator and improve its efficiency by several techniques by changing its components material, design of the air engine, the direction of the air flow and amount of air pressure. As result, the pneumatic powered air engine manufacturing is fully performance proven by researches [2-4]. The efficiency of the pneumatic air-powered engine using linear actuator was evaluated mainly based on the performance calculation result of the total tires rotated that can reach from the air pressure generated by the compressor.

Mostly, the tow transportation that available in market has now been provided with combustion gas engine is widely used but is limited to internal use as it is causing air pollution and long-term fuel cost. Therefore, in this project more focused on designing and making a mechanism transport with pneumatic powered air engine using linear actuators. Pneumatic system can be used to replace rotary movement because it is good control as a linear motion [5]. Besides, developing the uses of pneumatic system that can ensure the pneumatic powered air engine is can be simplified the way it works and. It also has lower installation and maintenance cost, provides reliable operation, and suitable for industrial applications [6]. This will help the users to get more assurance in using a fully automated system in a simpler and more flexible way. Besides, it can improve performance quality and efficiency, reduce labour intensity and bring huge economic benefits [6-7, 13-15, 20].

2. Detail Design

Detail drawings may be confused with ‘detailed design drawings’ which might describe the drawings produced during the detailed design stage, (sometimes referred to as ‘developed design’ or ‘definition’). Detailed design is the process developing the design so that it is dimensionally correct and co-ordinated, describing all the main components of the building and how they fit together [8-11, 12,16]. Not all drawings produced during this stage will necessarily be detail drawings. They are also distinct from the definition of ‘working drawings’ which provide dimensioned, graphical information that can be used by a contractor to construct the works, by suppliers to fabricate components of the works or to assemble or install components [11, 17-19]. Again, not all working drawings will necessarily be detail drawings.

2.1. Technical Drawing

When the final design was selected, the technical drawing which is a detail product is beginning in this chapter. Every single part of the part was making and then assembles the part to make it into a product. To make the technical drawing clearer, the assembly view will be separated again by creating an exploded view [21]. The following are two figures of technical drawing of pneumatic air engine using linear actuators that were shown with each dimension of it. Figure 1 shows the assembly view of
the product which was front view, back view, side view and the last one is isometric view. Next, Figure 2 shows exploded view with the name list of parts that already label in the isometric view.

Figure 1. Assembly View of Design Pneumatic Air Engine Using Linear Actuator

Figure 2. Exploded View of Design Pneumatic Air Engine Using Linear Actuator
2.2. Schematic Design
In this section, Figure 3 shows all significant components, parts, or tasks (and their interconnections) of a circuit, device, flow, process, or project by means of standard symbols. Schematic diagrams for a project may also be used for preparing preliminary cost estimates.

![Electro-Pneumatic Circuit Diagram](image)

Figure 3. Electro- Pneumatic Circuit Diagram.

2.3. Mode of Operation
The mode of operation for this product is starts with electrical energy from batteries which are 12V per battery which replacing power supply. This electrical energy is passed into the system causing the compressor and the cart to function. The actuators rotate the shaft when it receives a signal from the solenoid valves and enough air pressure is required for the actuator to operate. 5/2 bistable solenoid valves are used for controlling double acting pneumatic cylinders. They have 2 output ports, commonly designated A & B or 2 & 4. They have one inlet port, designated P or 1, and two exhaust ports, designated R & S or 3 & 5. The output port 2 is connected to the push-pull connector located on front of top of cylinder. Then the port 4 is connected to the push-pull connector located at back on top of cylinder. Same step goes to the other one cylinder. Then, the inlet port 1 relates to the second cylinder inlet port 1 through the one-way flow control valve. The blue pneumatic wire is connected from the valves and cylinder, while the red wired of signal port 14 relates to the red wires of signal port 12 and this get connected with the black wire of cylinder. Same step goes to another cylinder. Then, the rest wires are connected and connected to batteries charge of positive (+) and negative (-) charge. If the signal from first cylinder is turns on at port 12, so that the signal at port 14 of second cylinder will also turning on. This means the valve is received enough electrical power from batteries to make the cylinder move. The compressor is used for air compressing and through the connector tubing from the solenoid valve directly to the cylinder. This air pressure enables the generator to operate and the speed of the generator depends on the air pressure provided by the compressor.
3. Results and Discussions

3.1. Performance
Based on the result calculation, theoretical result and experimental result are different. The differences can be seen in the experimental result when the low air pressure of the compressor and the volume of the compressor are reduced. This causes the solenoid valves to fail to provide enough signals to the cylinder causing the piston movement to slow down due to insufficient air pressure. Even size of cylinders used also affect the volume of air pressure that can be achieved. The number of tire rotating can be determined at the end of the calculation. The test result data is based on the comparison of theoretical calculation and experimental calculation was made to prove the performance of the product.

3.2 Theoretical Calculation Gas Law
Below shown the theoretical calculations using Boyle’s law equation

\[ V_1 P_1 = V_2 P_2 \]  
(1)

Where;  
Compressor tank size = 24 liter  
Compressor working pressure, \( P_1 \)=7.5 bar  
Pressure set, \( P_2 \) = 5 bar

From Boyls’s law equation (1) we can determine the value of air \( V_2 \) is equal to 36 liter. The maximum usable quantity of air can be used to drive the cart for single cycle or charge is, 36 liter – 24 liter = 12 liter of compressed air.

3.3 Theoretical Calculation for Advance Force, \( F_{adv} \) of double acting cylinder

\[ \text{Pressure, } P = \text{Force, } F / \text{Area, } A \]  
(2)

\[ \text{Force Advance, } F_{adv} = P \times A \]  
(3)

Where;  
Cylinder diameter piston size \( d= 10 \text{ mm} \)  
Cylinder stroke length, \( L = 100 \text{ mm} \)  
Cylinder piston area, \( A = 78.55 \text{ mm}^2 \)

\[ \text{Cylinder Volume, } V = A \times L \]  
(4)

From equation (4) we can determine the cylinder volume; \( V \) is equal to 7855mm\(^3\). Cart will move in one cycle with two cylinders in advance position, so the quantity of compressed air required for one complete rotation of wheel is 15710mm\(^3\) from the equation (5).

\[ \text{Quantity of compressed air required per rotation, } V_{\text{Total for piston}} = 7855 \text{mm}^3 \times 2 \]  
(5)

If, we have 12 x 10\(^{-4}\)mm\(^3\) of air, so we can conclude that the crank shaft will rotate.

\[ = 12000000 \text{ mm}^3 / 15710 \text{ mm}^3 \]
\[ = 763.84 \text{ mm}^3 \]

Cart will move for 1 complete rotation = 0.2m @ 200 mm  
For 763.84 rotation, the cart will move = 763.84 x 0.2 m  
\[ = 152.76 \text{ m} \]

So, 152.76 meter is the limit distance for the cart to move for using 12\(^{-4}\) volume of air pressure.
3.4 Experimental Calculation

Based on the distance expected from the theoretical result, 152.7m is divided with the distance used for testing the cart. Testing distance is 9m and experimental cycle = 152.76m / 9m is equal to 17 cycle. The following figure 4 shows the experiment cart testing is conducted.

![Figure 4. Distance of 9m with 17 cycle for total distance 152.76 meter.](image)

When the actual experiment is conducted, the cart is achieved the 152 meter distance of travel. The result from the theoretical and real experiment shown that the cart will move around 152 meter for single charge of compressor tank. If the cart is achieved the 152 meter distances, it means that the theoretical calculation is correct and testing process is successful.

4. Conclusions

The theoretical and experimental calculation had been recorded to prove this objective is achieved. Among the scopes carried out are literature research to find the information on material transport mechanism without combustion gas that are already in market. At the end of this project, prototype product had been tested and calculations have been provided for the product performance. In conclusion, the system can travel up to 153 meters for a 24 liter air-pressure with 5 bar pressure when the test is run for a charging cycle by the compressor motor. If the compressor motor able to charge the compressor continuously, the movement distance can be increased.

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