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Design of a System that uses Air as a Source of Alternative Energy to Run CNG Three-Wheelers

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Abstract— It is now a banal truth that the environment is being subjected to plenty of environmental hazards. These are attributable to pollution that has completely overwhelmed the environment which in turn is also responsible for bringing about atrocious changes to the environment. The principle reason behind this change is increased carbon emission. Every day, a huge amount of carbon is released in the air because of burning fuel which results in Global Warming. People are gradually realizing this concern and have gradually started to use alternative sources of energy. This paper is about a design of an application which will help facilitate a revolution in Bangladesh. In this design Four Vane Air Motors act as the prime mover. Vane Air Motors contain vanes within an air tight body onto which air at high pressure is passed. The vanes are directly connected to a rotating shaft and hence any force on the vanes causes a torque, which can rotate the shaft helping to drive any load connected to it. Not only does this solve an age old question of finding an energy efficient fuel source, it also proves that efficient fuel can also be environment friendly. The Existing CNG Three-wheeler plying the roads of Bangladesh is scrutinized versus the proposed air powered model. Like any new technology, it still has its boundaries but after weighing out the pros and cons of this technology, it can be safely construed that compressed air technology is sure to dominate.

Index Terms— CNG, Vane Air Motor, Carbon fiber tank.

1 INTRODUCTION

THE ability to do work is called energy. While energy surrounds us in all aspects of life, the ability to harness it and use it for constructive ends as economically as possible is the challenge before mankind [1]. The burning of all kinds to fuel exhausts carbon dioxide gas. This gas together with other exhaust gases causes severe air pollution. Moreover, the fuels commonly used today (fossil fuels) are all limited such that as more fuel is consumed natural resources are decreasing [2]. There has been a steady movement towards developing higher fuel efficient machines and more contraptions based on alternative energy sources for consumers. In response, many smaller companies have started to rapidly increase research and development into radically different ways of powering consumer vehicles [3]. Alternative energy refers to energy sources which are not based on burning of fossil fuels or the splitting of atoms [4]. The renewed interest in this field of study comes from the undesirable effects of pollution (as witnessed today) both from burning fossil fuels and from nuclear waste. Among the renewable energy resources found so far the use of compressed air for storing energy is a method that is not only efficient and clean, but also economical. Compressed air is also used to run vehicles such as cars [5]. The power source of these kinds of cars is air and the emission product is also air. Cars using compressed air can travel 120 miles between refueling. The cost to operate is low, about one dollar per hundred miles. The compressed air only car will need to go to compressed air fueling stations for a compressed air refill. Once these retrofitted gas stations are in place, a refueling will take 3 minutes, will cost about $2 and will allow the driver to drive 125-175 before needing to refuel [5]. Alternatively, there are engines being developed that either switch over to electric or gas power allowing the car to continue to be driven, while at the same time operating the compressor to refill the tank with compressed air. Because there is no heat generating combustion in the engine, changing the oil needs to be done only once every 30,000 miles. The proposed system is designed in order to attempt to develop a system that uses air as an alternative fuel source to run Three-Wheeler vehicles instead of the conventional CNG fuel. Here it will be elucidated the components of the existing CNG Three-wheeler system and will be compared with the proposed system. This comparison is made based on hardware parts such as the motor, tank and fuel requirements. The proposed system will improvise using a revolutionary Vane Air Motor. Furthermore, a feasibility study is to being carried out to determine financial and environmental benefits of an Air powered System, over the CNG system.

The speed and power can also be controlled by installing a pressure regulator on the incoming air supply according to Figure 5. The pressure regulator reduces the air pressure to the motor. A pressure regulator is always fitted on the inlet port. By using a pressure regulator the torque on the output shaft will be affected, starting torque is best con-

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trolled with this method.The paper is organized as follows: In section II, the existing CNG. In section III, the proposed design was presented. Characteristics of Vane Air Motor and the Performance charts were presented at section IV and section V respectively. A brief discussion on Air Tank and Shuttle Valve was discussed in Section VI and VII. Section VIII presents a Comparison of cost of conventional CNG three-wheeler and air motor. Finally the paper was concluded in Section IX.

2 EXISTING CNG SYSTEM

The existing Bajaj CNG three-wheelers has been taken as the existing standard CNG three-wheeler as it is preeminently popular in Bangladesh. These have a four-stroke engine and can run on both CNG and petrol, and come with a host of safety measures. . The vehicle is also fitted with a 'bursting disc', which acts as a safety valve and releases gas into the atmosphere, if the pressure of the gas in the cylinder exceeds 300kg / cm ^{2}. Only one cylinder with a capacity of 2.2 liters of water (approx 3kg of gas at 200bar) is needed for such a system. The maximum net power of the engine is 6.53 HP at 5000rpm and the maximum net torque is 10.5 Nm at 4000rpm. The gross weight of the vehicle and maximum payload is 680kg and 335kg respectively [6] [7].

3 PROPOSED DESIGN

The proposed system that will replace the 4-stroke CNG three-wheeler must have performance characteristics comparable to or better than the existing CNG engine. As such, bearing in mind all the factors including the environment, a suitable Air-powered motor with compatible, or better, performance characteristics is the ideal choice. A block diagram of the proposed design is shown in fig. 1.

Initially (not shown in diagram), clean, filtered natural air will be externally compressed (via high pressure compressors) to a pressure of 300bar and stored in the air tank. It is necessary use very clean air to prevent damage to the vanes of the motor and also to ensure less power loss. The compression is isothermal which ensures maximum efficiency as the temperature will not rise in such a case. This, although seems to be optimum performance option, will result in longer refill times. Hence, a compromise must be struck between time to refill and the heat generated. The shorter the refill time, the larger the temperature rise, and vise versa.With the air tank filled to capacity when the throttle is released it allows the shuttle valve to start ejecting air at a reasonable rate just sufficient to produce the starting torque. The shuttle valve is a device that brings down the pressure from 300bar on the side of the air tank, to an operable pressure of about 2bar – 8bar on the motor side. It does this by allowing short bursts of air to be released. The released air is passed through pressurized tubing and carried to the air inlet of the Air motor. Once the potential energy in the incoming high pressure air is converted into rotational kinetic energy of the rotor, the outgoing air leaves via a silencer.

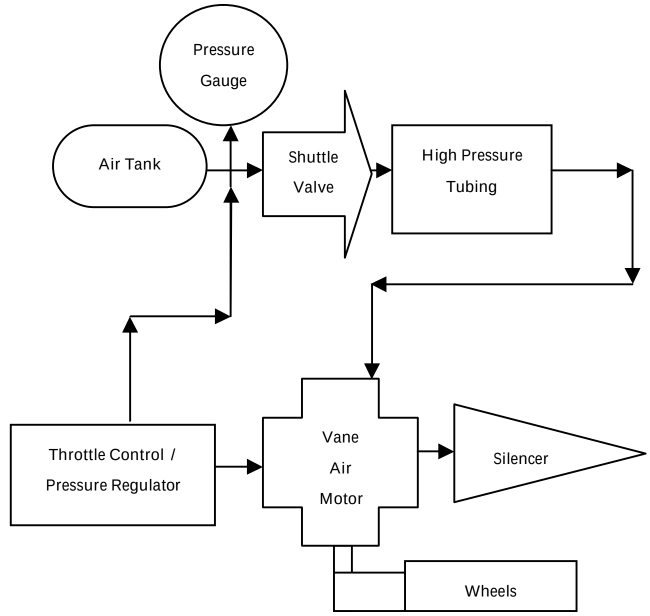


Fig. 1: Block diagram of the air powered design

The rotor is connected to the wheels via a cog-mechanism. A pressure gauge connected to the air tank provides visual reference of the pressure within the air tank.

4 VANE AIR MOTOR

The Vane air motor is based on a very simple process that is similar to the working of a drive motor of a boat. A motor boat runs its fan to push fluid in a direction opposite to its desired motion, while the vane air motor pushes air (fluid) on its vanes to create rotational motion of its drive shaft.

As highly compressed air is ejected from the high pressure air tank into the air inlet valve of the air motor it induces a force on the vane it first encounters.

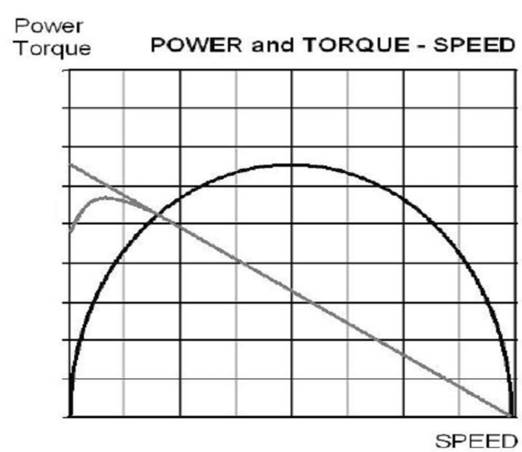


Fig. 2: Power and Torque – Speed Graph

From fig. 2 to fig. 5, the performance characteristics of the vane air motor are shown graphically [8].

The output power of a vane motor varies as a function of speed and torque. The relationship when the air supply is not externally regulated is shown in the graphs of fig. 2.

A typical characteristic of vane air motors is the variable starting torque for a given input pressure; a result of the varying vane position at start up. The minimum starting torque produced as indicated in the graph of fig. 3 has been used for our reference as our application involved the motor always being loaded.

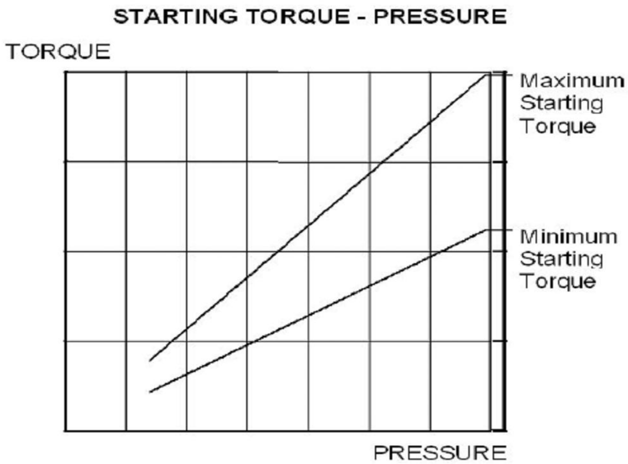


Fig. 3: Starting Torque – Pressure Graph

Speed regulation is another parameter. Controlling the speed and torque of an air motor is achieved by regulating the air supply; a relatively cheap and simple operation. Two methods are available, throttling and pressure regulation.

In throttling, the air flow is controlled by placing a flow control valve at the inlet port or the outlet port of the air motor. Throttling will reduce the maximum speed of the motor but will not affect the starting performance; the air pressure is unaffected at low flow conditions i.e. at starting. A difference in performance is achieved, as is evident in the graph of fig. 4, between throttling on inlet and outlet port.

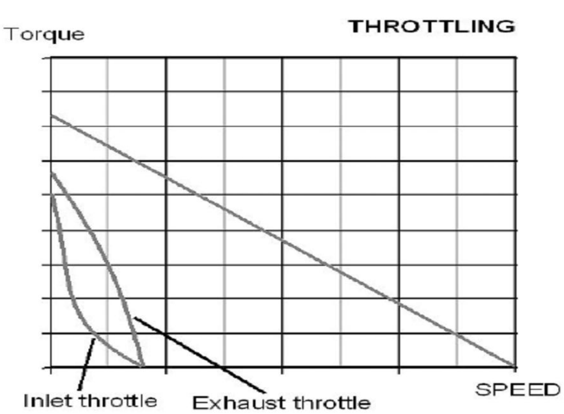
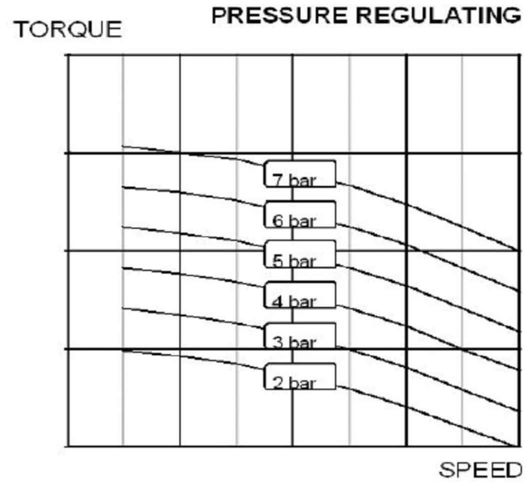


Fig. 4: Throttling Graph

The speed and power can also be controlled by installing a pressure regulator on the incoming air supply according to fig. 5. The pressure regulator reduces the air pressure to the motor. A pressure regulator is always fitted on the inlet port. By using a pressure regulator the torque on the output shaft will be affected, starting torque is best controlled with

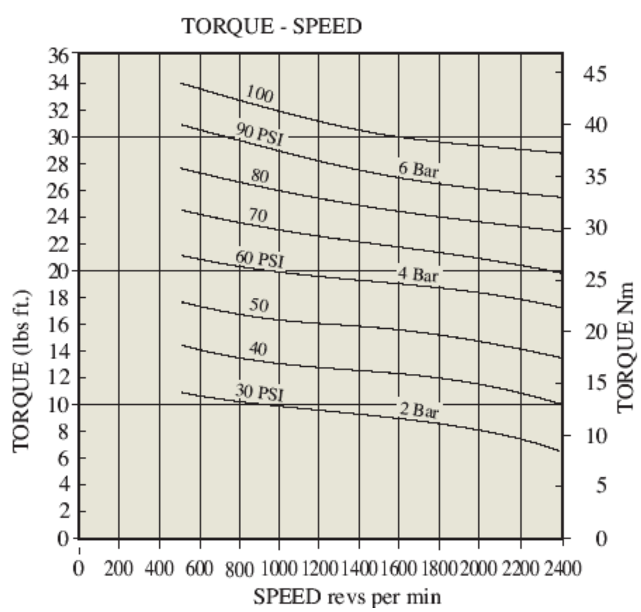


this method.

Fig. 5: Pressure Regulating

5 Performance Charts

In this section, from fig. 6 to fig. 9, the performance charts of the VA10C are provided [8]. The graph on fig. 6 is a comparison of the Torque vs Speed performance of the VA10C air motor. According to the requirement of the application, it is evident that at a pressure of 2 bar a required torque of 10.5Nm is achievable by the air motor at approximately



2000rpm.

Fig. 6: Torque - Speed Graph

The Starting torque vs Pressure chart of fig. 7 shows us once again that at approximately 2 bar, the required 10.5Nm torque is achievable.

This is read off the Minimum Starting Torque graph as it provides information about the motor when it is loaded.

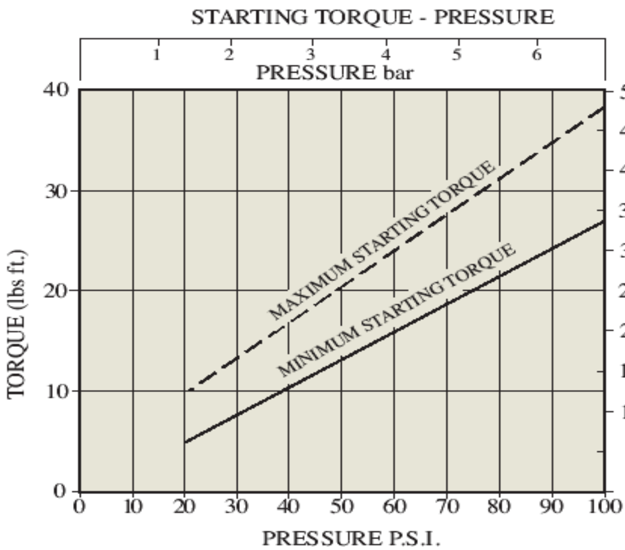


Fig. 7: Starting Torque - Pressure Graph

In fig. 8, Power vs Speed Chart gives the various power output in kW for various pressure and rpm values.

The proposed system will work at a pressure of approximately 2 bar or 4 bar at 2000rpm

This chart of fig. 9 shows the rate of consumption of air stored in the tanks during the period of operation.

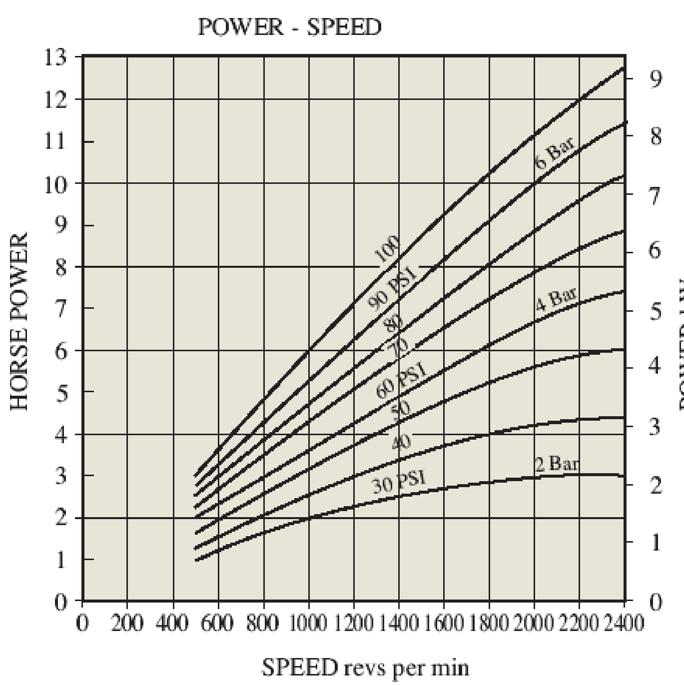


Fig. 8: Power - Speed Graph

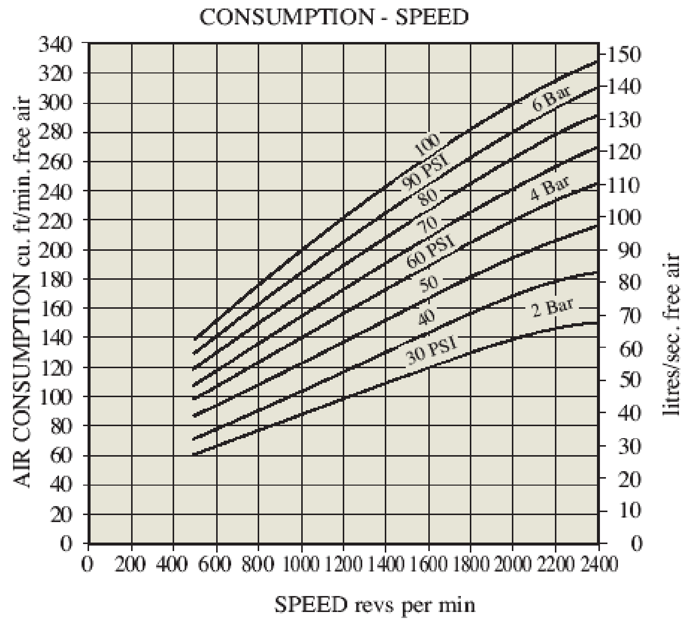


Fig. 9: Consumption - Speed Graph

Using air as an energy vector is viable and will pragmatically be tantamount (if not better) in performance to the conventional engine. Based on study of the air motor in this chapter it is quite clear that development of the idea of using air as an energy vector will lead to great challenges and setbacks. Despite the foreseeable drawbacks it is worth mentioning that the selected air motor – Vane Air Motor – deems itself suitable for the chosen application as the power, horsepower, RPM and air consumption rates all suggest harmonic compatibility. This is further explored in the chapter on feasibility.

6 AIR TANK

According to the principal of Air motors the thrust and supply of the air from the cylinder is the main driving force. So a vital part of the design is the air tanks. As the project is based on the Vane Air powered motor the capacity, pressure, flow rate and consumption rate of air are crucial to discuss.

Carbon fiber tanks are relatively new to the world of compressed air tanks [9]. The tanks are made out of composite materials developed by NASA for use in space exploration. This "space age" technology makes the tanks lightweight, strong and capable of accepting charging pressures of 4500 psi. As a result, they are just the perfect compressed air tanks for the vane air motor. Carbon fiber tanks are able to hold a massive 88 cubic feet of air charged to a working pressure of 4500 psi. Providing 40 plus fills, the carbon fiber tank is the equivalent of 5 or more standard scuba tanks. Typically at 26" in length and weighing less than 12 lbs., the carbon fiber tank provides light weight, compact and portable air storage. The tank package includes a DIN adapter with micro-line hose. The real value in a carbon fiber tank is its ability to hold pressure to 4500 psi.

7 Shuttle Valve

A Shuttle valve acts as if it directs the air at the inlet coming from either of two sources to a single destination. In certain fluid/air power systems, the supply of fluid to a subsystem must be from more than one source to meet system requirements. The main purpose of the shuttle valve is to isolate the normal system from an alternate or emergency system. It is small and simple; yet, it's a very important component [10].

A shuttle valve used to operate more than one actuating unit may contain additional unit outlet ports. Enclosed in the housing is a sliding part called the shuttle. Its purpose is to seal off either one or the other inlet ports. There is a shuttle seat at each inlet port.

This valve provides a means of interrupting a pressure line when a predetermined pilot pressure is reached in a normally open or normally closed form. The valve can be used in any pilot or small flow system as a remotely operated sequence valve.

8 Comparison of Cost of Conventional CNG Three-Wheeler and Air Motor

Cost of the total existing 4-stroke three-wheeler is Tk 2,81,500. The engine alone cost Tk 30,000 and the fuel cost is Tk 75,120 per year. In addition to the miscellaneous cost of Tk 5000 per year the annual cost of driving this three-wheeler is Tk 80,000 per year.

It is to be note that the vehicle is imported and induces a government tax on its overall price. Furthermore, the price of CNG is affected by globally inflating fuel costs and is presumed to rise to approximately Tk 55/ m^3. This will mean a staggering annual fuel cost of about Tk2,56,660/-.

In comparison to the existing system the proposed design has in a vantage position. The total cost of the proposed system is Tk 1, 15,000, which comprises of the cost of Air motor Tk 60,000, cylinder Tk 45,000 and a total miscellaneous cost of Tk 10,000.

It is to be noted that the expense on the part of the air powered system is a one-time cost. This amount is all that is required to convert a CNG three wheeler system to an air powered system.

The total annual cost of running the CNG Three-wheeler (Excluding the purchase price of the vehicle) is approximately Tk 80,120/-. Over a period of 5 years this amounts to Tk 4,00,600/- This amount is inclusive of the fuel cost (calculation of which is elaborated on the chart in chapter 6.3) and other miscellaneous maintenance routines.

In comparison, the total cost for the air powered system is initially Tk1,15,000/- which may seem much higher than CNG for a period of 1 year, but over a period of 5 years the cost is still the same, i.e., Tk 1,15,000! Thus, when long term is considered, the air powered system is a far cheaper alternative.

Hence when the two systems are compared numerically the proposed system is found to be around 3.5 times or 71.3% cheaper.

To add to this, it must be emphasized that there is no actual fuel cost to run the air powered motor. The fuel is air which is freely available in plentiful supply. The only cost that may be incurred is the cost of compressing the air into the tanks, which is minimal and may even be unaccounted for if the compressors are powered by solar panels.

9 Conclusion

It is now evident that a vehicle based on internal combustion may as well run on a compressed air powered engine efficiently that is supplied by air compressors. Most standard fossil fuel burning combustion engines can be suitably converted to be powered by compressed air pursuant to the present invention. The air compressors which supply the air "fuel" to the engine chamber where the air is used to provide the force for "pushing" rotors within the chamber where rotational movement turns the drive shaft, which operates through a transmission to turn the drive axle to move the vehicle. These air compressors may be electrically and/or mechanically driven. The fuel system of the disclosed invention is effective for basically any internal combustion engine, including both two-stroke and four-stroke engines. Many modifications and variations of the present design will be apparent to one of ordinary skill in the art in light of the above teachings. It is therefore understood that the scope of the design is not to be strictly confined to the literal limitations of the claims appended hereto.

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