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Study on Energy Storage System for 21st Century and Uses of Compressed Air as an Alternative to Fossil Fuel for Light Transport Engines

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ABSTRACT:

The worldwide current problem is to find out the non-conventional resources as best alternative to fossil fuel and make sustainable energy future. Present paper deals with the study of alternative fuel for automobile engines with a special emphasis on compressed air driven engine. A proposal has been put forward for 21st century energy storage system & its uses for running the compressed air engines / turbines.

1.0 INTRODUCTION:

Since worldwide conventional energy resources is depleting very fast, it necessitates the search of alternatives resources such as Non-Conventional Energy Sources and Renewable Energy Sources, for sustainability to fossil fuel and other available resources of energy. As per recent study, about 80 % of fossil fuel is being consumed in transport (e.g., Cars, Buses, Trucks, Trains, Power houses, Room heating devices etc.).

In 1956, an US based Chief Consultant and Oil Geologist **Marion King Hubert** predicted that if oil is consumed with high rate, US Oil production may peak in 1970 and thereafter it will decline. He (Hubert M. K..-1956) also predicted that other countries may attain Peak Oil day within 20-30 Years and many more may suffer with oil crises within 40 years, when Oil wells are going to dry. He illustrated the projection with a bell shaped "Hubert Curve" based on the availability & its consumptions of the fossil fuel. Large fields are discovered first, small ones later. After exploration and initial growth in output, production plateaus and eventually declines to zero.

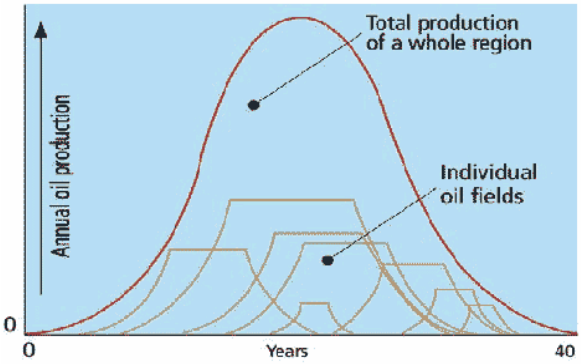


Fig. 1 Hubert Curve

India's vehicular pollution is estimated to have increased eight times over the last two decades. This source alone is estimated to contribute about 70 per cent to the total air pollution. With 243.3 million tons of carbon released from the consumption and combustion of fossil fuels in 1999, India is ranked fifth in the world behind the U.S., China, Russia and Japan. India's contribution to world carbon emissions is expected to increase in the coming years due to the rapid pace of urbanization, shift from non-commercial to commercial fuels, increased vehicular usage and continued use of older and more inefficient coal-fired and fuel power-plants.

Thus, peak oil year may be the turning point for mankind which in turn led to the end of 100 year

of easy growth, if self-sufficiently & sustainability of energy I s not maintained on priority. It may end up a better world **[15]**. Thus the study of the paper is going to cover Non-Conventional Energy resources such as Solar Energy, Wind Energy, Bio-mass & bio-gas, Hydrogen, Bio-Diesel and specially Compressed air as storage of energy to maintain sustainability to 21st Century for running the air turbine / engine for lighter vehicles. This may also leads to environmentally & ecologically better future.

2.0 WHAT IS SUSTAINABILITY TO FOSSIL FUEL?

Sustainability is the extent to which the positive effects are likely to last after the intervention has terminated. In general *"Sustainability is meeting the needs of current and future generations through simultaneous environmental, social and economic improvement"* **[16].** The "Sustainability to fossil fuel" is nothing but to preserve the oil & make brighter future of mankind by adding alternative energy sources such as "Non-Conventional and or Renewable Energy" which is going to overcome current problem. Now worldwide researchers, inventors are paying full attention towards this issue. The Energy Storage System or Power Conversion System is the only solution for 21st century energy sustainability.

2.1 AVAILABILITY OF WORLD ENERGY RESOURCE [21]:

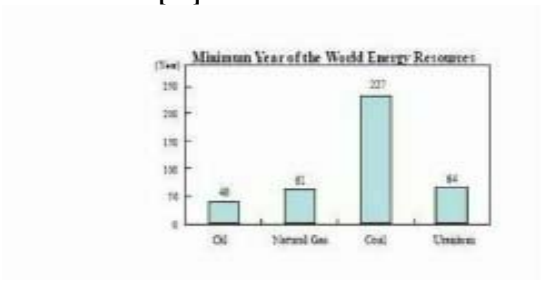


Fig. 2 Energy Availability

2.2 INFLUENCE OF FOSSIL FUEL ON ENVIRONMENT & ECOLOGY [15]:

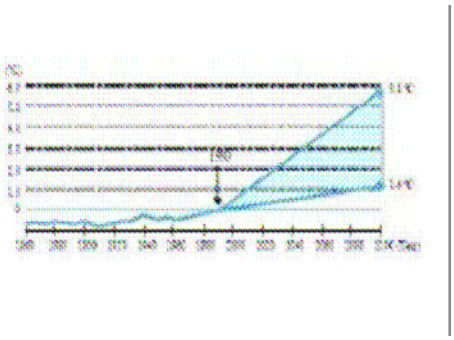


Fig.3 Global Warming Forecast

From above it is evident that by greater use of fossil fuel, there are two distinct reasons to go for Sustainability and make alternative to fossil fuel. The first one is Depletion of Oil resources and second one is High rate of Emission.

2.1Depletion of Fossil fuel:

It is known fact that about 100 years ago our researches had gone towards hydrocarbon energy (i.e. petroleum product) as main energy source and now causing civilization vulnerable by its depletion in supply. Many researchers, technologists and scientist have spoken as to **why alternative to fossil fuel is sought? [16]**

2.2 Influence of fossil fuel on environment and ecology: [15]

It is observed that with increasing pace of civilization, uses of transport have become essential part of life and increasing in geometrical progression. This is leading to very hazardous condition due to high rate of pollution.

2.2.1 Automobile Emission: Emissions from an individual car are generally low, relative to the smokestack image many people associate with air pollution. But in numerous cities across the country, the personal automobile is the single greatest polluter, as emissions from millions of vehicles on the road add up.

2.2.2 Automobiles & Ozone: Ozone in the upper atmosphere (the "ozone layer") occurs naturally and protects life on earth by filtering out ultraviolet radiation from the sun. But Ozone at ground level is a noxious pollutant. Ozone is not emitted directly but is formed in the atmosphere through a complex set of chemical reactions involving hydrocarbons, oxides of nitrogen, and sunlight.

2.2.3 Automobiles and Carbon Monoxide:

Carbon monoxide (CO) is a colorless, odorless, poisonous gas. A product of incomplete burning of hydrocarbon-based fuels, carbon monoxide consists of a carbon atom and an oxygen atom linked together. Carbon monoxide results from incomplete combustion of fuel and is emitted directly from vehicle tailpipes. Incomplete combustion is most likely to occur at low air-to-fuel ratios in the engine, causing health hazards.

2.2.4 Auto Emission Control Act: Air pollution and cars were first linked in the early 1950's by a California researcher who determined that traffic was to blame for the smoggy skies over Los Angeles. At the time, typical new cars were emitting nearly **13 grams per mile hydrocarbons (HC), 3.6 grams per mile nitrogen oxides (NOx), and 87 grams per mile carbon monoxide (CO)**. Since then, the Federal Government in 1995 has set standards to bring down levels of these pollutants to **0.25 gram per mile HC, 0.4 gram per mile NOx, and 3.4 grams per mile CO.** The standard for evaporative HC emissions is 2 grams per test.

2.2.5 Wasteful Uses of Fossil fuel: It is essential to reduce carbon emissivity due to higher rate of utilization of transport and to increase thermodynamic efficiency of energy usage. For this, the ecological tax reform should be advanced, harmonized internationally step by step, and be a part of the WTO treaty. Energy prices should be sufficiently high to punish wasteful behavior while honoring efficient energy use across the board, and especially in the road transport sector.

3.0 NON-CONVENTIONAL ENERGY SOURCE:

Many researches are being carried out to find the alternative to fossil fuel. Apart from them non-conventional energy such as Photocell battery operated vehicles, hydrogen cell, windmill operated power-generating devices and its storage capacitors, **C**ompressed air operated vehicle, Bio diesel and Di-methyl Ether are also being used as an alternative to fossil fuel.

3.1 Use of Wind Energy:[20]

Windmills are being used very effectively for irrigation as well as power generation, where high velocity air is running in atmosphere, due to geological conditions. Wind power is the kinetic energy of wind, or

Fig.4 Wind Farm

the extraction of this energy by wind turbines. In 2004, wind power became the least expensive form of new power generation, dipping below the cost per kilowatt-hour of coal-fired plants. Wind power is growing faster than any other form of electrical generation, at about 37%, up from 25% growth in 2002. In the late-1990s, the cost of wind power was about five times what it is in 2005, and that downward trend is expected to continue as larger multi-megawatt turbines are mass-produced.

3.2 Bio-Diesel: Biodiesel is a renewable fuel obtained from vegetable oils, animal fats, and recycled cooking oils. Biodiesel offers many **[13,17,18]** advantages. It can be used in several different ways such as use 1% to 2% Biodiesel as a lubricity additive, which could be especially important for ultra low sulfur diesel fuels (ULSD, less than 15 ppm sulfur), which may have poor lubricating properties. It can blend 20% Biodiesel with 80% diesel fuel (B20) for use in most applications that use diesel fuel. It can even be used in its pure form (B100) while taking proper precautions. The word Biodiesel in this report refers to the pure fuel B100 that meets the specific Biodiesel definition and standards approved by ASTM International.

Fig.5 Jatropha

The use of Bio diesel are tested for various parameters and blending of Bio Diesel up to 18-20 % is found most efficient for the running of the vehicle and also pollution limits due to hydrocarbon (HC), Carbon-

mono oxide (CO) and nitrogen (NOx) are found well within the emission limits prescribed by EPA in 1995.**[15]**

3.3 Dimethyl Ether: Demonstration on Dimethyl Ether while carried out it was found that CO emission is lower than Propane and n-butane over a broad range. No production from DME is less than or similar to Propane & nbutane. DME burns with a non- luminous flame
& flame is much compact. It is also noticed that oxygen blending 4 % wt in the fuel blend and it is observed that the emissions can be reduced by as much as 28 % when compared with premium diesel.

3.4 Hydrogen Cell Vehicle: Hydrogen gas does not occur naturally in the Earth's atmosphere and the gas must be artificially produced. Currently hydrogen used in the manufacture of ammonia is produced by reacting steam with methane. Hydrogen may also be extracted from fossil fuels by using fuel `reformers'. Both these processes produce pollutants. They cannot be used to generate the gas for storing electrical energy. Therefore the most practical method of generating hydrogen is the electrolysis of water. This process is about 65% efficient and because of this hydrogen will always be more expensive than the energy used to produce it. The recent development in Hydrogen cell car (Honton E. J-2004) was done by USA based inventor who has demonstrated the Hydrogen Fuel Cell Car at 15th Annual US Conference & Hydrogen Expo, USA and projected the scope of its market in different country.

3.5 Photovoltaic Cell: Non-conventional energy is the source available in nature and do not effect imbalance in atmospheric ecology. Worldwide uses are being made for electric photocell to generate electric power and power so generated are utilized to be stored in batteries, which finally gives power to use for light, run small electric motors and in US photo Cell car has also been developed to run on roads emission free. A research works
Solar Cell Spectral Response Setup are also going on to make cluster of photocell operated device to generate power, which can be utilized in many ways. Solar PV, or photovoltaic -- panels on roofs -- are what most people think of when they think of solar power. The largest PV array in the world, located in Germany, produces 10 megawatts of electricity. But Nevada Solar One will produce 64 megawatts -- enough to power 40,000 homes in the Las Vegas area during the hottest part of the day.

3.6 Solar Thermal Power Generation:
When the price of oil is high, talk turns to alternative forms of energy, including wind, biofuels and solar. One kind of solar energy isn't getting much publicity. But solar thermal power is quietly becoming a significant source of electricity in the Southwest. In the desert south of Las Vegas, crews working on a project called Nevada Solar One are assembling a parabolic trough

Fig. 7 Solar Power Plant

of curved mirrors connected in a huge array. At the center, a closed-loop tube will be filled with oil that will be heated by the sun. The hot oil will flow around the 400-acre project and into a building where it will turn water into steam. It, in turn, will turn a steam turbine, which will make electricity.

3.7 Compressed Air: Sterling air engine was developed in 1790-1810, but due to its limitation much work was not carried out. Keeping in view of fire problems in Coalmines and other volatile places where high flammable fuel like fossil fuel vehicles are not advisable, compressed air engine operated vehicle are normally started to use. Thus in 1979 to 1998 much work was not carried out, with limitation.

4.0 ENERGY STORAGE SYSTEM OR POWER CONVERSION SYSTEM:

The Power Conversion System (PCS) is a vital part of all energy storage systems[24]. It interfaces the energy storage, the energy storage device and the load (the end-user). PCS cost is significant and it can be greater than 25% of the overall energy storage system. PCS cost range from $100/kW for UPS markets to $1200/kW for Standalone markets have been seen. Some of the major PCS markets include:

• Motor drives
• Power supplies
• UPS (uninterruptible power supply)
• Electric vehicles
• Inverters/Converters for solar-hybrid systems, Micro-turbines, Fuel cells, Wind turbines

However, Power Conversion System technology has been evolving slowly due to the limited Distributed Energy Resources (DER) market. As a result, Energy Storage System cost has been high with low profit margins and the manufacturing volume has been low impacting reliability and quality of the Power Conversion System designs. What is needed is a significant reduction in overall cost with improved reliability, development of state-of-the-art Power Conversion System with multiple uses, which increases production volumes for DER applications, improve controls and adaptability, and improve manufacturing.

4.1 Batteries:
SNL has a broad technical base of battery expertise focusing on integrated storage systems. These storage systems operate in varying environments and electrical conditions. In these storage systems there are many different types of battery technologies. With the different designs having advantages under specific operational conditions. It is important to understand the capabilities and limitations of each storage technology.
4.1.1 Lead-Acid Battery: Lead-acid is one of the oldest and most developed battery technologies. It is a low cost and popular storage choice for power quality, UPS and some spinning reserve applications. Its application for energy management, however, has been very limited due to its short cycle life. The amount of energy (kWh) that a lead-acid battery can deliver is not fixed and depends on its rate of discharge.
4.1.2 Li-Ion -Lithium Ion Battery: The cathode in these batteries is a lithiated metal oxide (LiCoO2, LiMO2, etc.) and the anode is made of graphitic carbon with a layer structure. The electrolyte is made up of lithium salts (such as LiPF6) dissolved in organic carbonates. When the battery is being charged, the Lithium atoms in the cathode become ions and migrate through the electrolyte toward the carbon anode where the combine with external electrons and are deposited between carbon layers as lithium atoms. The main advantages of Li-ion batteries, compared to other advanced batteries, are:

- High energy density (300 - 400 kWh/m3, 130 kWh/ton).
- High efficiency (near 100%).
- Long cycle life (3,000 cycles @ 80% depth of discharge).

4.1.3 NaS -Sodium Sulfur Battery: A NaS battery consists of liquid (molten) sulfur at the positive electrode and liquid (molten) sodium at the negative electrode as active materials separated by a solid beta alumina ceramic electrolyte. The electrolyte allows only the positive sodium ions to go through it and combine with the sulfur to form sodium polysulfides. 2Na + 4S = Na2S4 .During discharge, as positive Na+ ions flow through the electrolyte and electrons flow in the external circuit of the battery producing about 2 volts. This process is reversible as charging causes sodium polysulfides to release the positive sodium ions back through the electrolyte to recombine as elemental sodium. The battery is kept at about 300 degrees C to allow this process.
4.1.4 PSB - Polysulfide Bromide Flow Battery: Polysulfide Bromide battery (PSB) is a regenerative fuel cell technology that provides a reversible electrochemical reaction between two salt solution electrolytes (sodium bromide and sodium polysulfide). Like other flow batteries, the power and energy ratings of Regenesys are independent of each other. PSB electrolytes are brought close together in the battery cells where they are separated by a polymer membrane that only allows positive sodium ions to go through, producing about 1.5 volts across the membrane. Cells are electrically connected in series and parallel to obtain the desired voltage and current levels. The net efficiency of this battery is about 75%. This battery works at room temperature. It has been verified in the laboratory and demonstrated at multi-kW scale in the UK. Compared to lead-acid batteries, EC capacitors have lower energy density but they can be cycled tens of thousands of times and are much more powerful than batteries (fast charge and discharge capability).
4.1.5 VRB -Vanadium Redox Flow Battery: VRB stores energy by employing vanadium redox couples (V2+/V3+ in the negative and V4+/V5+ in the positive half-cells). These are stored in mild sulfuric acid solutions (electrolytes). During the charge/ discharge cycles, H+ ions are exchanged between the two electrolyte tanks through the hydrogen-ion permeable polymer membrane. The cell voltage is 1.4-1.6 volts. The net efficiency of this battery can be as high as 85%. Like other flow batteries, the power and energy ratings of VRB are independent of each other.

4.2 Super Capacitor: Electrochemical capacitors (EC) store electrical energy in the two series capacitors of the electric double layer (EDL), which is formed between each of the electrodes and the electrolyte ions. The distance over which the charge

separation occurs is just a few angstroms. The capacitance and energy density of these devices is thousands of times larger than electrolytic capacitors. The electrodes are often made with porous carbon material. The electrolyte is either aqueous or organic. The aqueous capacitors have a lower energy density due to a lower cell voltage but are less expensive and work in a wider temperature range. The asymmetrical capacitors that use metal for one of the electrodes have a significantly larger energy density than the symmetric ones and have lower leakage current.

4.3 Flywheels:[24] Most modern flywheel energy storage systems consist of a massive rotating cylinder (comprised of a rim attached to a shaft) that is substantially supported on a stator by magnetically levitated bearings that eliminate bearing wear and increase system life. To maintain efficiency, the flywheel system is operated in a low vacuum environment to reduce drag. The flywheel is connected to a motor/generator mounted onto the stator that, through some power electronics interact with the utility grid. Some of the key features of flywheels are little maintenance, long life (20 years or 10s of thousands of deep cycles) and environmentally inert material. Flywheels can bridge the gap between short term ride-through and long term storage with excellent cyclic and load following characteristics. The choice of using solid steel versus composite rims is based on the system cost, weight, size, and performance trades of using dense steel (200 to 375 m/s tip speed) vs. a much lighter but stronger composite that can achieve much higher rim velocities (600to 1000 m/s tip speed). Actual delivered energy depends on the speed range of the flywheel as it cannot deliver its rated power at very low speeds. For example, over 3:1 speed range, a flywheel will deliver ~90% of its stored energy to the electric load.

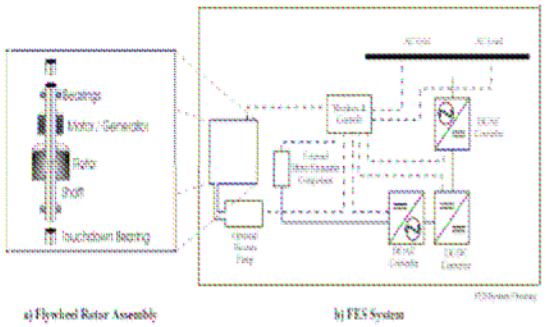


Fig. 8 Schematic Diagram of Flywheel

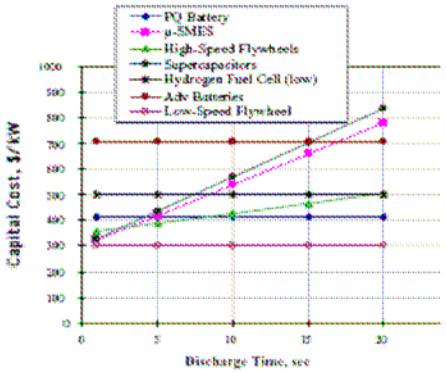
Development / Deployment Status:

While high-power flywheels are developed and deployed for aerospace and UPS applications, there is an effort, pioneered by Beacon Power, to optimize low cost commercial flywheel designs for long duration operation (up to several hours). 2kW / 6kWh systems are in telecom service today. Megawatts for minutes or hours can be stored using a flywheel farm approach. Forty 25kW / 25 kWh wheels can store 1MW for 1 hour efficiently in a small footprint.

The stored energy can be approximated by:

$$E = (I\omega^2)/2 \quad = \quad (mr^2\omega^2)/2 \quad = \quad (m\,v^2)/2$$

where w is the rotational velocity (rad/sec), I the moment of inertia for the thin rim cylinder, m is the cylinder mass and v is linear rim velocity.



Graph 1 Capital Cost vs Power Quality

5.0 COMPRESSED AIR AS ENERGY STORAGE:

Air is natural source and available freely in atmosphere, which can be stored after compressing it to desired pressure such as 90- 350 psi. This is the only source, which can be stored at very high pressure and can be retained without any loss after lapse or with passage of time. Compressed air can drive many domestic appliances such as vacuum cleaner, mixers, pumps, electric generator when electric power fails instead of using inverter to have clumsy arrangements of battery etc.

5.1 Influences of Air on Environment and Ecology

The light vehicles presently running on fossil fuel releases tail pipe emission and creates imbalances to ecology, ultimately hazardous to public health. Compressed air as an alternate for running light vehicles using air turbine will have no ill effect on ecology and reduce the health hazards.

5.2 Sustainability, Economics and Advantages

Compressed air is most sustainable. It has no volatility or temperature or much weather effect. Once compressed air is stored through compressor, it

will be available at any time without any loss of pressure. Thus sustainability of compressed air is much better compared to other available alternate of fossil fuel. Battery needs constant maintenance even for charging & discharging cycle. Hydrogen Cell (Rose et al. -2004) is very costly due to its storage problems. Wind Mills (ABI Research-2004), Photo Cells also need some storage devices may be of high bank capacitors or batteries, which will need constant and recurring expenditures on its upkeep.

6.0 USES OF COMPRESSED AIR AS AN ALTERNATIVE TO FOSSIL FUEL:

India is developing country and per capita income of average person is very low to meet out the minimum requirement of person. Maximum population of country is still living in villages where transport is still either bi-cycle or motorbike. Current hike of fossil fuel are increasing tremendously up to 30-40 % every year. With this pace by 2010 prices may go double than what is today and by 2030-40, it may touch to Rs.1000 per litre. A time will come when common person would not be able to purchase fuel to run the motorbike. It is not only due to rate of increase of vehicles in India, but it is a worldwide problem due to the 80 % of fossil fuel being consumed in transport with increasing mobility of persons and transportation of daily consumable materials through road transport. Thus, it is the need of the day to explore possibility of alternatives for fossil fuel to make environment free from emission & make children healthy(Singh Onkar & Singh BR-2006).

Since the last two decades lot of researches are being made to tap down air freely available in atmosphere and compressing it for storage in cylinders for its further use. This compressed air can be used to run combustion engine with mixture of gas and air getting fired at compression stroke at TDC. Compressed air helps for fire stroke when ignition takes place. Thus efficiency of IC engine gets improved and without running all four stroke cycle it runs on two stroke cycles. But air engines so far developed (Guy and Negre Cyril-2004, Rocha Beau de-2005) are basically running on hybrid such as compressed air and gases and are not 100% zero pollution.

6.1 Model of Air Turbine

Present objective is to develop an air engine using air turbine with output of 6.85 HP to 7.50 HP at 5500 to 7500 rpm, which will be suitable for a motorbike. Various steps involved in the development of engine are as given separately. A cylinder of compressed air is proposed to have minimum capacity of storing air for requirement of 30 min running at initial stage and maximum pressure of 200-300 psi. The Air Turbine with dual inlet and exhaust has been taken into consideration to produce high rpm to match 7500-8000 rpm. Compressed air storage cylinder is designed so that it produces constant pressure for minimum variation of torque at low volume of compressed air(Singh onkar & Singh BR-2008).

A spring loaded baffle is installed into the cylinder to regulate the constant air pressure. The Air Turbine is designed with spring-loaded vanes to maintain regular contact with elliptical bore, to produce optimum torque (Faglsang-2004, Selig-2004, Reddy Gorla-2005, Schreck & Robinson-2004). Above air turbine is being designed to meet out the all-minimum parameters of motorbike to have efficient and fossil fuel free running.

6.2 Design considerations for Air Turbine

6.2.1 Empirical Requirements

Required Air pressure:	60-150 psi (assumed)
*Speed:	3000 rpm
*Torque:	9.6-10 Nm
P-V Ratio:	4 / 5

Note: - *Data based on Performance of commercially available motorbike (7.2 HP)

6.2.2 Principle

For novel air turbine the high pressure air is the driving force at ambient temperature. The impulse and dynamic action of high pressure are responsible for the shaft work from air turbine.

It is reverse process of vane type air compressor. Considering the isotropic expansion of air entering the Air Motor having n vanes, theoretical work is given as under: -

$$w = n\left(\frac{\gamma}{\gamma-1}\right) p_1 v_1 \left\{\left(\frac{p_4}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right\} - n\left(p_4 - p_5\right) v_4$$

→ **(1)**

Where W= Theoretical Work done,

p_1 & v_1 are Pressure & Velocity respectively at which air strike the Turbine,

p_4 & v_4 are Pressure & Velocity, respectively at which maximum expansion of air takes place,

p_5 is the Pressure at which Turbine releases the air to atmosphere.

6.3 Single Inlet & Exhaust model for Air Turbine

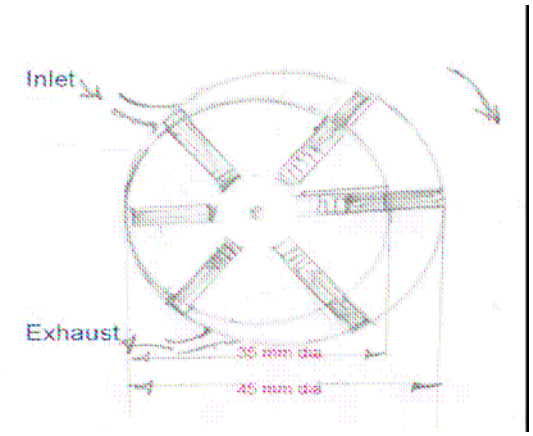


Fig. 9 Compressed Air Turbine –Concept & Cycle

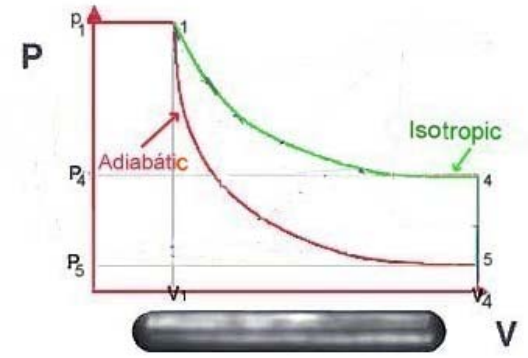


Fig.10 Polytropic cycle for Air Turbine

From equation (1)

$$w = n\left(\frac{\gamma}{\gamma-1}\right)p_1v_1\left\{\left(\frac{p_4}{p_1}\right)^{\frac{\gamma-1}{\gamma}}-1\right\}-n\left(p_4-p_5\right)v_4$$

Let $\frac{\gamma-1}{\gamma}$ = k (constant)

$$w = \frac{n.p_1.v_1}{k}\left\{\left(p_4{}^{k}.p_1{}^{-k}\right)-1\right\}-n\left(p_4-p_5\right)v_4$$

→ **(2)**

Applying Lagrange's Multiplier, the Optimum value of Shaft-Work will be obtained when:-

$$\frac{\partial w}{\partial v_4}=0 \qquad \rightarrow \textbf{(3)}$$

$$\frac{\partial w}{\partial p_4}=0 \qquad \rightarrow \textbf{(4)}$$

Applying Equation (3),

$$\frac{\partial w}{\partial v_4}=0,$$

$$-n\left(p_4-p_5\right)=0$$

or

$$\boxed{p_4=p_5\cong 1.0\,Atm\,\mathrm{Pr}\,or\,1.0132bar} \rightarrow \textbf{(5)}$$

Applying Equation (4),

$$\frac{\partial w}{\partial p_4}=0\ ,$$

$$n.\frac{p_1.v_1}{k}\,p_1{}^{-k}.k.p_4{}^{k-1}-n.v_4=0$$

or $n.p_1{}^{1-k}.v_1.p_4{}^{k-1}-n.v_4=0$

Let $c=p_1{}^{1-k}.v_1$,

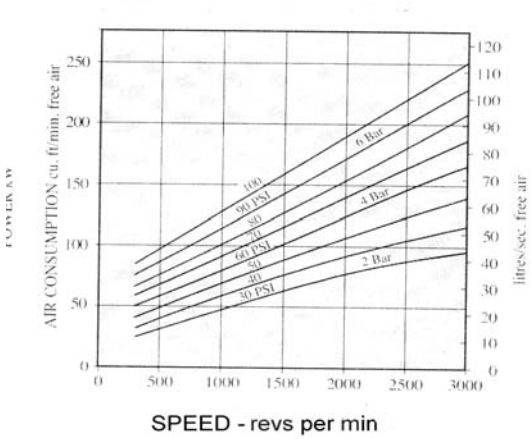
then $n.c.p_4{}^{k-1}-n.v_4=0$

Therefore $\boxed{p_4=\left(\frac{v_4}{c}\right)^{1-k}}$ →**(6)**

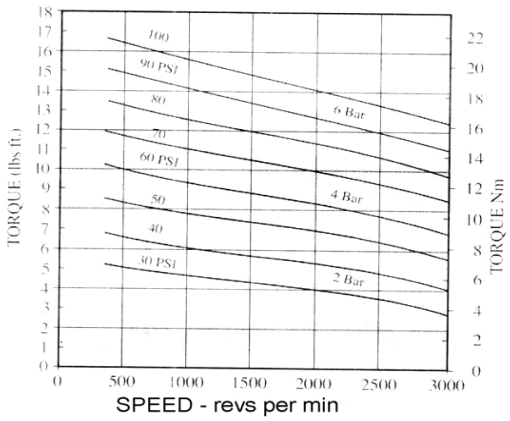
From the above, it is clear that for optimal shaft work, p_4 has direct relation with v_4, p_1 & v_1, where $\left(p_1{}^{1-k}.v_1\right)$ is taken as a constant.

6.3.3 Results and Discussions

From the theoretical calculations, results obtained at different pressure and rpm relations between "Air Consumption & Speed" as well as "Torque & Speed" are drawn.



Graph-2 Air Consumption versus Speed



Graph-3 Torque versus Speed

Here it is evident that better speed can be achieved at lower Consumption of Air, if the negative forces acting due to higher difference in pressure between P_4 to P_5 are almost eliminated.

7.0 CONCLUSIONS:

In view of fast depleting fossil fuel reserves and growing energy requirements, it has become inevitable to look into for alternative sources of energy. Biodiesel, Solar Energy, Wind Energy, Photovoltaic Cell, has immense potential for being used as an alternative to fossil fuel. Following conclusion drawn from present study:-

7.1 Peak oil is turning point for mankind and the 100 year of easy growth may end, if self sufficiently & sustainability of energy is not maintained on priority.

7.3 Future technological developments are required to be aggressively taken up to develop Photo voltaic electric powered, hybrid powered, fuel cell operated, compressed air engines and Biodiesel renewable energy for automobile vehicles.

7.4 Solar Energy Power Stations, Wind Power Stations and Nuclear Power Stations will also become future Power generation source in big way.

7.5 The air having enormous potential as working fluid, can be compressed and stored as in a portable cylinder as Energy Storage.

7.6 An Air Turbine having dual inlet and exhaust can be designed to run efficiently on compressed air at 90-100-psi air pressure.

7.7 Such Air Turbine is under close test run and expected to be most efficient than the currently available one, as negative workforces are eliminated and ultimately it is going to be the best alternate to the fossil fuel driven prime-over / engine.

Thus the atmospheric air when compressed at 200-300 psi and stored in cylinder can be utilized as working fluid to run primover required for domestic appliances as well as light vehicle, will definitely be the 21st century energy storage system and alternate to fossil fuel.

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