

Nitro-Vacuum Engine

Lalit Ravindra Wale



Abstract: A “Nitro-Vacuum Engine” comprises of a nitrogen cylinder, an engine block and a vacuum pump. Pressurized nitrogen gas is used to drive the piston and vacuum pump is installed to assist the piston movement. In this paper, construction and working details of “Nitro-Vacuum Engine” are explained. Also, pressure of the nitrogen gas required to drive the piston and minimum time in which vacuum pump can evacuate the gas are calculated, along with the power produced by the engine and it’s comparison with modern conventional engines. The purpose of this engine is to eliminate the concept of combustion from engines and move towards a green and clean environment.

Key words: Specific Heat Capacity, Bernoulli’s Principle, Vacuum Pump.

I. INTRODUCTION

Besides many services IC engines provided to humankind, we all are also aware of the damages caused by them to humans and environment. Also the high fuel prices and its depleting resources are major concerns of worry in the recent era. Hence it is important that we find some other ways to run engine, which will be harmless to both the humans and the environment. The purpose of this paper is to discuss constructional and working details of “Nitro-Vacuum Engine” to avoid the problems mentioned above.

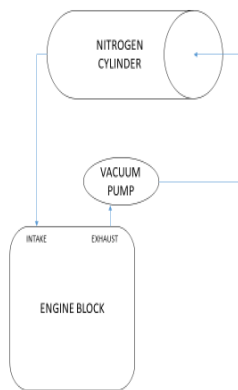


Fig 1. Block Diagram of Nitro-Vacuum System

In Nitro-Vacuum system, pressurized nitrogen gas is supplied to engine via nitrogen cylinder. This nitrogen gas is used for driving the piston downwards and vacuum pump is used to suck the nitrogen gas in the cylinder, thereby causing the upward motion of piston due to vacuum created.

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From vacuum pump, nitrogen gas is supplied back to the nitrogen cylinder. Also, power produced by the engine is calculated and compared with modern engines. “Nitro-Vacuum Engine” avoids the use of any combustible fuel, hence it might be able to prevent the inevitable damages caused by the conventional IC engines.

II. LITERATURE REVIEW

Engineers from Zhejiang University, Hangzhou-310027, China published “Theoretical study on the ideal open cycle of the liquid nitrogen engine” paper in “Journal of Zhejiang University” postulates characteristics of the liquid nitrogen engine’s ideal open cycle using cryogenic medium as a heat sink and the atmosphere as a heat source. A paper titled “Liquid nitrogen fuelled closed Brayton cycle cryogenic heat engine”, published in “Energy conversion and management” by C. A. Ordonez at University of North Texas reveals method to run engine on stored liquid nitrogen. Atmospheric heat is used to vaporize stored liquid nitrogen to compressed nitrogen gas. The compressed gas is used to run the engine and gas is released into the atmosphere. US patent application no. 11/344,050 named “Combustionless vapour driven engine and it’s method of operation from Clarence E. Harrison SR., Portsmouth, states method of operation of combustionless vapour driven engine. Heating element (at a temperature greater than flash point of liquid) is placed inside the engine to convert the liquid into vapour. As the liquid comes in contact with the heating element, it is converted to vapour causing internal pressure of the cylinder to rise. This increase in pressure is used to drive the engine. To the author’s knowledge, there is no work published on running engine using gaseous nitrogen and vacuum pump.

III. CONSTRUCTION

The “Nitro-Vacuum Engine” system will consist of a cylinder block, a high pressure nitrogen cylinder which will supply nitrogen gas at high pressure which will provide high pressure force for the piston to move downwards and a vacuum pump which will help the piston to move upwards. The size of KV20 vacuum pump of Kirloskar Company is approximately 0.02m³= 20 litres (here size means the volume occupied by the vacuum pump). This vacuum pump has power requirement of approximately 1 horse power (hp). In cars we use only one alternator to drive the electronics of the vehicle which produces approximately around 1hp. So, instead of using only one alternator, if we use two alternators by using complex belt and pulley arrangement,

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we can drive the electronics by one alternator and vacuum pump by the other one. In “Nitro-Vacuum” system there is no requirement of fuel tank, so the space of the fuel tank can be attributed to nitrogen cylinder. Nitrogen cylinder of Praxair Company of 2000 psig pressure has 2 cu. ft. volume which is approximately 57 litres. Modern conventional cars generally have fuel tanks with capacity of 45 to 65 litres. So, we can easily attribute the space of fuel tank of conventional cars to the nitrogen cylinder in “Nitro-Vacuum” system. In “Nitro-Vacuum Engine”, nitrogen from the nitrogen cylinder will be supplied from the nitrogen intake valve and exhaust valve will be connected to vacuum pump which will suck the nitrogen in the engine cylinder when the vacuum valve is opened. The construction of the engine block will be same as conventional block.

IV. REASON OF CHOOSING DINITROGEN GAS OVER OTHER GASES

In this system Dinitrogen gas is considered because it is very much less reactive and its availability and cost. Apart from these factors, Dinitrogen gas has high specific heat capacity (1.040kJ/kgK at 300K), so it will take longer time to heat as compared to oxygen or air.

V. WORKING

Now moving to the working of the system, like conventional IC engine, “Nitro-Vacuum Engine” will be started by a starting motor. Once it gets the required momentum, starting motor will become off and “Nitro-Vacuum” system will come into action. There will be a nitrogen cylinder which will supply nitrogen to the engine cylinder. Consider the piston at top dead centre (TDC), the nitrogen from the nitrogen cylinder will start coming into the engine cylinder when the piston is at TDC. Due to the pressure of the nitrogen gas and the momentum acquired due to the starting motor, the piston will move downwards. There will be a valve (analogous to intake valve in conventional engine) to regulate the flow of nitrogen into the cylinder. As the piston moves down the nitrogen will keep coming into the cylinder providing necessary force to the piston to go from top dead centre (TDC) to bottom dead centre (BDC). As soon as the piston reaches the BDC, the nitrogen intake valve will be closed and the vacuum valve (analogous to exhaust valve in the conventional engine) will be opened. As the vacuum has power of absorption, the nitrogen gas will be sucked into the vacuum pump and due to the vacuum created, the piston will move upwards to TDC. Thus, nitrogen coming from intake valve will help the piston to move from TDC to BDC and the vacuum pump will help the piston to move from BDC to TDC. After the piston reaches the TDC, the cycle will be continued. The motion of the piston will be given to the crankshaft through connecting rod and further the crankshaft will be connected to the flywheel and the gearbox to drive the vehicle. The nitrogen gas which is absorbed into the vacuum pump during the motion of the piston from BDC to

TDC, will be transferred to the radiator for cooling. The nitrogen gas after cooling from the radiator will be again supplied back to the nitrogen cylinder. And from the nitrogen cylinder, the nitrogen gas will be recirculated to the engine. The vacuum pump will be run by an alternator which will be driven by the crankshaft through belt and pulley arrangement or gears. This is the basic working of the “Nitro-Vacuum Engine”. Now, consider a cylinder of 200cc. Consider the cylinder to be oversquare, as undersquare cylinder has longer stroke. In oversquare cylinder maximum engine rpm (revolutions per minute) is possible at lower piston speed due to shorter stroke.

Let us assume bore to stroke ratio as 1.2.

$$\text{Hence, } D/L=1.2 \quad (1)$$

Where, D=diameter of the bore and
L=length of the stroke.

As volume of cylinder,

$$V = (\pi/4) * D^2 * L.$$

But, volume of engine is 200cc.

$$\therefore (\pi/4) * D^2 * L = 200$$

By converting 200 cm³ to mm³,

$$\therefore (\pi/4) * D^2 * L = 200000 \quad (2)$$

Hence, by solving equations (1) and (2), we get,

$$D = 67.3571 \text{ mm and}$$

$$L = 56.1309 \text{ mm.}$$

Suppose, we need to run the engine at 6500 rpm.

Hence, time required for one revolution will be = 0.0092 seconds.

One complete revolution consists of motion of piston from TDC to BDC and again back to TDC.

Consider, half revolution, which is motion of piston from TDC to BDC.

As one revolution takes 0.0092 seconds, so half revolution will take half time.

Time required for half revolution will be = $0.0092/2 = 0.0046$ seconds (3)

As the piston is at TDC, its initial velocity at the top most point will be zero.

Hence, $u=0$,

Where, u = initial velocity of the piston.

Therefore, from equation (3),

For complete downward stroke, time required= $t= 0.0046$ seconds.

Length travelled by the piston in complete downward stroke= $s=56.1309$ mm.

Now using the kinematic relation,

$$s = u \cdot t + \frac{1}{2} \cdot (a) \cdot (t)^2$$

Substituting the values of s , u and t ,

We get,

$$a = 5305.3781 \text{ m/s}^2$$

Where, a = acceleration of the piston.

Hence, for running the engine at 6500 rpm, acceleration of the piston should be 5305.3781 m/s^2 .

Now, let us move on and calculate the pressure of the nitrogen gas required to drive the engine at 6500 rpm.

For calculating the pressure, we need the mass of piston-connecting rod assembly.

Let,

Mass of piston = 1kg

Mass of connecting rod = 1.5kg

Mass of other accessories = 0.5kg,

Other accessories include mass of gudgeon pin and mass of volume of crankshaft that is fitted in lower end of the connecting rod.

\therefore Total mass on which pressure force will act = $m = 1 + 1.5 + 0.5 = 3 \text{ kg}$.

Now, force which will act on piston-connecting rod assembly is given by,

$$F = m \cdot a.$$

$$\therefore F = 3 \cdot 5305.3781 \text{ N}$$

$$\therefore F = 15916.13 \text{ N} \quad (4)$$

Hence, pressure acting on piston,

$$P = F/A \quad (5)$$

Where, A = area on which the pressure force acts = $(\pi/4) \cdot D^2 = (\pi/4) \cdot (67.3571 \cdot 10^{-3})^2 = 3.56 \cdot 10^{-3} \text{ m}^2$. (6)

\therefore From equations (4), (5) and (6),

$$P = 4.47 \text{ MPa} = 648.32 \text{ psig.}$$

Hence, 648.32 is the pressure of the nitrogen gas required to drive the engine at 6500 rpm. We can change the pressure of the nitrogen gas by guarding the intake valve. According to the Bernoulli's principle the pressure of a fluid increases as

the cross section of the opening of the pipe increases. So, by changing the cross section of the intake valve, we can change the pressure of the gas which in turn will change the speed of the engine as the engine speed is dependent upon the pressure of the gas. For regulating the engine speed, we also need to control the amount of vacuum reaching the engine cylinder. Now, we will calculate the minimum time in which vacuum pump can evacuate gas from the cylinder. The KV20 vacuum pump has ultimate vacuum up to 650 mm of Hg. According to 'Hydraulics and Pneumatics' (a global fluid power content provider), time required to pump a system down to a certain vacuum level, is given by,

$$t = (V \cdot n) / 4q$$

Where,

' t ' is time in minutes,

' V ' is system volume in ft^3 ,

' q ' is flow capacity in cfm (cubic feet per minute),

' n ' is a constant.

Values of ' n ' according to 'Hydraulics and Pneumatics' are as follows:-

$n=1$ for vacuum up to 15 in-Hg,

$n=2$ for vacuum >15 but ≤ 22.5 in-Hg

And

$n=3$ for vacuum ≥ 22.5 and up to 26 in-Hg.

For the 'Nitro-Vacuum' system,

$$V = 200 \text{ cm}^3 = 0.00706 \text{ ft}^3.$$

For the vacuum pump KV20,

$$q = 55 \text{ m}^3/\text{hr} = 32.3714 \text{ cfm.}$$

Now, ultimate vacuum of the KV20 vacuum pump is 650 mm of Hg which is equal to 25.5906 in-Hg. The value of ' n ' for this value of ultimate vacuum is 3 according to the above data for the values of ' n '. But if we keep the value of ' n ' as 3 in time calculation then the time of evacuation of gas from the cylinder will be high. So, in order to decrease the value of ' n ', we can set the vacuum at lower side. By adjusting the vacuum at 370 mm of Hg, which equals to 14.5669 in-Hg, the value of ' n ' from the above mentioned data becomes 1. Hence, time required to pump the system is given by,

$$t = (0.00706 \cdot 1) / (4 \cdot 32.3714)$$

$$t = 5.45 \cdot 10^{-5} \text{ minutes.}$$

Hence, $t = 0.00327$ seconds (by converting minutes into seconds).

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Hence, 0.00327 seconds is the minimum time in which 'KV20' vacuum pump can evacuate the gas from the cylinder. If we open the vacuum valve just a little bit, then

the amount of vacuum reaching the engine cylinder will be small and thus piston will take longer to reach from BDC to TDC resulting in low engine speed. If we open the vacuum valve more, then the amount of vacuum reaching the engine cylinder will be more and the piston will take short time to reach from BDC to TDC resulting in greater engine speed. Thus, by regulating the opening of the vacuum valve we can regulate the speed of the engine.

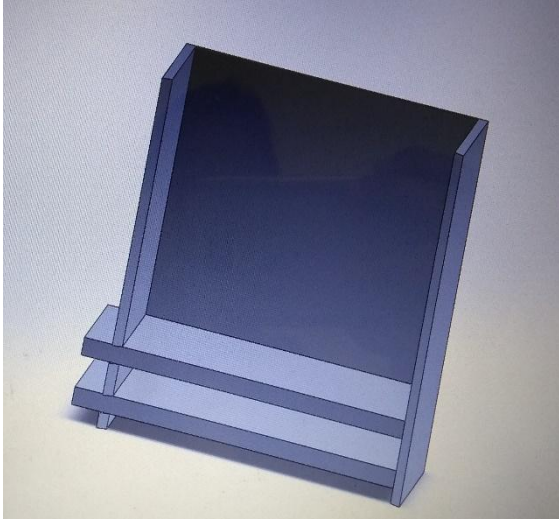


Fig 2. Valve mechanism (view 1)

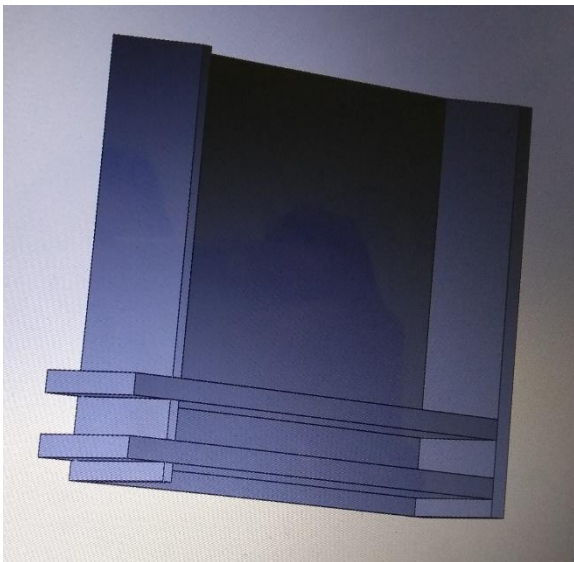


Fig 3. Valve mechanism (view 2)

The figures 2 and 3 show the valve mechanism which can be used in the "Nitro-Vacuum" engine for regulating the nitrogen intake and vacuum reaching the engine cylinder. There are two slits in the mechanism. The upper slit will be connected to the throttle paddle which will be operated by a driver. The lower slit will be electronically operated. The motion of the lower slit will depend on the position of the piston. Now consider it as a nitrogen intake valve. When the piston is at top dead centre (TDC) the lower slit will be

opened and when the piston reaches the bottom dead centre (BDC) the lower slit will be closed. So, the function of the lower slit is just to allow and block the entry of the nitrogen gas in the engine cylinder. The upper slit is connected to the throttle paddle. As we press the throttle paddle the upper slit will start to open more and more, increasing the cross sectional area, thereby increasing the pressure of the gas entering into the cylinder. If we release the throttle paddle the upper slit will start closing, decreasing the cross sectional area, thereby decreasing the pressure of the gas reaching the cylinder. Thus, function of the upper slit is to regulate the pressure of the nitrogen gas reaching the cylinder. Now consider this mechanism as vacuum valve. The upper slit will be connected to the throttle paddle as in case of intake valve. As the throttle paddle is pressed, the upper slit will be opened more and more, increasing the cross sectional area, thereby increasing the vacuum reaching the cylinder, which will reduce the time of evacuation of the gas and piston will take shorter time to travel from BDC to TDC. Thus, by pressing the throttle paddle we can increase the speed of the vehicle. If we release the throttle paddle, the upper slit will start closing, decreasing the cross sectional area, thereby decreasing the amount of vacuum reaching the cylinder, which will increase the time of evacuation of gas from the cylinder and the piston will take longer time to travel from BDC to TDC. Thus, we can decrease the speed by releasing the throttle paddle. The function and working of the lower slit will be similar to that in intake valve. Only the slit will be opened when the piston will be at BDC and closed when the piston is will be at TDC. Hence, the upper slit will be open all the time and its motion will be regulated by the throttle paddle and lower slit will be electronically operated and it will be opened and closed according to the position of the piston in the cylinder. Thus, if we synchronize the nitrogen intake valve and the vacuum valve properly, we can get the desired engine speed.

VI. ENGINE EFFICIENCY

For calculating the efficiency of the engine, we require input and output powers. Input power is also called as indicated power which is the power produced within the engine. Output power is also called as brake power which is the power available at the output.

Indicated power is given by,

$$I.P. = (P \cdot A \cdot L \cdot n) / (60 \cdot 1000) \text{ {kW}}$$

Where,

P = Mean effective pressure.

A = Cross sectional area of the cylinder.

L = Length of the stroke.

n = Number of strokes per minute.

$$n = 2 \cdot \text{RPM} = 2 \cdot 6500 = 13000.$$

$$I.P. = (4.421 * 10^6 * 3.56 * 10^{-3} * 0.056 * 13000) / (60 * 1000)$$

$$\therefore I.P. = 191.409 \text{ kW.}$$

Output power can be measured by rope brake friction dynamometer.

Brake power is given by,

$$B.P. = [(W-S) * R_b * 2 \pi N] / [60 * 1000] \text{ {kW}}$$

Where,

W = Dead weight.

S = spring balance reading.

R_b = Radius of the brake drum and flywheel.

N = Speed of the output shaft in rpm.

Thus, by measuring the value of N and with the help of rope brake dynamometer setup, we can calculate the brake power.

Efficiency of the engine is given by,

$$\eta = [\text{Output power}] / [\text{Input power}]$$

$$= [\text{Brake power}] / [\text{Indicated power}]$$

Thus, by measuring the brake power, we can calculate the efficiency of the engine.

VII. RESULTS AND DISCUSSION

Table- I: Results

1.	Pressure of the nitrogen gas required at 6500 rpm	4.47MPa= 648.32psig
2.	Minimum time in which vacuum pump can evacuate gas	0.00327 seconds
3.	Power produced within the engine	191.409kW

From the calculations, for running the engine at 6500 rpm, pressure of nitrogen gas required is 648.32psig. The most commonly used cylinder for nitrogen is rated at 2200psig. Other commonly used nitrogen cylinders are 2485psig and 2640psig. This shows that, the pressure required to drive the engine is achievable and we can easily create high pressures which will help to drive the engine at higher rpm. Minimum time for evacuation of gas by KV20 vacuum pump is 0.00327 seconds. Time required for half revolution of 'Nitro-Vacuum' engine running at 6500 rpm is 0.0046 seconds. The minimum time of evacuation of gas by 'KV20' vacuum pump is 0.00327 seconds. Hence, this vacuum pump can easily evacuate the cylinder within the time constraint for running the engine at 6500 rpm. Power produced within the engine is 191.409 kW (or 256.683 horsepower) which is comparable to many modern cars.

VIII. CONCLUSION AND FUTURE SCOPE

Though the "Nitro-Vacuum Engine" is in primary stage of development, the main objective of the present paper has been fulfilled. It is shown in the paper that, power produced by the engine is in correspondence with the present engines. Also, the pressure requirements of the engine can be fulfilled by the nitrogen cylinders available in the market. Alongwith that it is also proved in the argument that KV20 vacuum pump can be able to evacuate nitrogen gas within requisite time. So, "Nitro-Vacuum Engine" might be a solution to current engines which are producing many harmful effects to nature and humankind. Further experiments and case studies must be conducted to validate the results. Advanced studies will prove the efficiency, feasibility and reliability of the engine in depth.

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Lalit Ravindra Wale is a student at Maharashtra Institute of Technology, Pune, Maharashtra, India. He is currently studying in 4th year of engineering and pursuing his bachelors in Mechanical Engineering. The author has done internship in Maharashtra State Road Transport Corporation in Pune, learning about overhauling of the state transport buses engines. He has also participated in a workshop, organised by Elite Techno Group for the design and fabrication of electric ATV which was similar to the ones which are used in the SAE BAJA competitions. The author has also worked as a trainee at Shrisai Motors, where he studied about various problems encountered by sundry of petrol and diesel cars and how those problems are resolved.