Design and Fabrication of Air Brake System Using Engine Exhaust Gas

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Abstract
The focus of this project is to review the latest development and technologies on waste heat recovery of exhaust gas from internal combustion engines and new developments on turbocharger technology. The study looked into the potential energy savings and performances of technologies. In this paper, a comparative study among exhaust turbocharging, steam turbocharging and steam-assisted turbocharging was conducted on a passenger car gasoline engine, and the effects of various boosting pressure were analyzed. In this project, we are placing a turbine in the path of exhaust from the engine which is coupled to dynamo which converts the kinetic energy into electrical energy. The generated power is stored in the battery to apply pneumatic braking system

***Keywords:** Turbocharger, engine,* UID, *cylinder.*

INTRODUCTION

A number of irreversible processes in the engine limit its capability to achieve a highly balanced efficiency. The rapid expansion of gases inside the cylinder produces high temperature differences, turbulent UID motions and large heat transfers from the UID to the piston crown and cylinder walls .These rapid accession creates exhaust gases with pressure which overreach the atmosphere level and get released while gases are expanding to prepare the cylinder for different actions. By doing so, the heated gases produced from the combustion process can be easily channeled through the exhaust valve and manifold. To increase the work output of engine. We can use huge amount of energy stream from the exhausted gases. Consequently, higher efficiency, lower fuel consumption by improving fuel economy, producing fewer emissions from the exhaust, and reducing noise pollution have been imposed as standards in some countries. It was stated that the waste heat produced from thermal combustion process generated by gasoline engine could get as high as 30–40 percent which is lost to the environment through an exhaust pipe. In addition, 12–25 percent of the available energy in a fuel will be used to drive the wheels and other accessories which technical descriptions.

A huge of amount of energy is consumed through the exhaust gas in internal combustion. It was investigated that the percentage of fuel energy converted to useful work only 10.4 percent and also found the thermal energy lost through exhaust gas about 27.7 percent. In the given second law states that fuel energy.is converted to the brake power about 9.7 percent. And the exhaust about 8.4 percent. In another research the value of exhaust gases mentioned to be 18.6 percent of total combustion energy. It is also found that by installing heat exchanger to recover exhaust energy of the engine could be saved up to 34 percent of fuel saving.

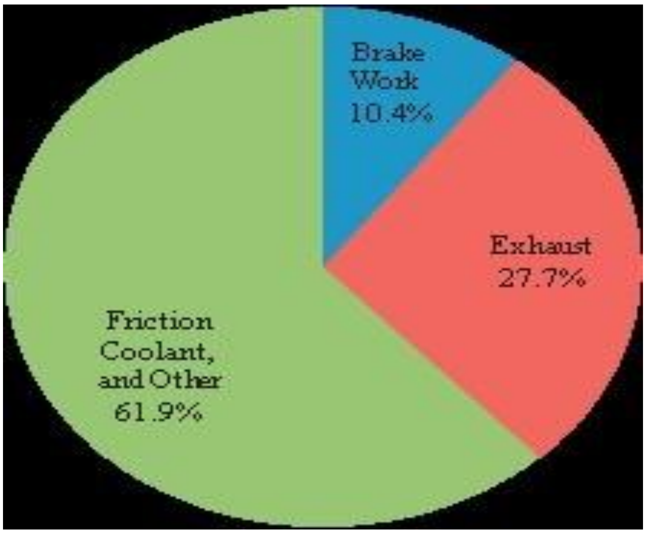


Figure 1: *energy distribution.*

Literature Review

[1] R. Saidur (2012) reviewed the latest developments and technologies on waste heat recovery of exhaust gas from internal combustion engines (ICE). It was hoped that with the latest found on exhaust heat recovery increased the efficiency of ICEs, world energy demand on the depleted fossil fuel reserves would be reduced and hence the impact of global warming due to the GHG emissions would fade away. [2] J. Yang (2013) in this paper, two kinds of novel boosted pressure approaches of steam turbocharging and steam-assisted turbocharging were proposed. Steam Turbocharging had higher energy saving potential than the other two turbocharging approaches. Steam turbocharging would achieve the target intake pressure in the entire IC engine speed area. Steam-assisted turbocharging would be improved to IC engine intake pressure at the low-speed operating conditions. With the increased IC engine speed, the exhaust gas energy recovery efficiency of steam turbocharging system decreased and its maximum value was 6.5 percent while the exhaust gas energy recovery efficiency of steam-assisted turbocharged and exhaust turbocharged first increased and then decreased. [3] S. Rajoo (2017) this paper presented the development of a Micro Gas Turbine (MGT) as range extender (RE) engine for electric vehicles (EV)A computer related vehicle model was created to analyze the I if driving condition for driving range of EV and the sizing of range extender of the REEV, specially for MUDC Malaysia Urban Drive Cycle that the driving range of an EV was greatly reduced When operating in MUDC condition. [4] A. Fazlizan (2015) reviewed that it was possible to recover energy in air that was being discharged from an exhaust system without negatively affecting its performance. The discharged air from the system had the quality of being able to generate steady and predictable energy. With the correct wind turbine positioned and size matched, an optimum amount of energy recovery can be obtained. Based on the result, when the turbine was spinning at a high rotational speed, the cooling tower model experienced an increment in air flow rate and a reduction in fan motor power consumption. [5] S. Kumar (2015) in this paper we had modified an automobile for producing power using turbines. Nowadays in automobile field many new innovating concepts had being developed.

We had used the power from vehicle exhaust to generate electricity which can be stored in battery for the later consumption. In this project, we had demonstrated a concept of generating power in a moving vehicle by the usage of turbines. Here we had placing a turbine in the path of exhaust in the silencer. [6] V. Nivethan (2016) in this paper we had placed a turbine in the path of exhaust from the engine. The turbine was connected to a dynamo by means of coupling, which was used to generate power. Depending upon the airflow the turbine would start rotating, and then the dynamo would also start to rotate. A dynamo is a device which is used to convert the kinetic energy into electrical energy.

Problem Statement

The exhaust gas from the internal combustion engine is directly connected to the air tank and stored. Then it is connected to the double acting pneumatic cylinder through a solenoid valve. The pneumatic cylinder is connected to the brake pedal to apply brakes. The figure is shown below. This system creates a back pressure to engine as it is not directly left out to the atmosphere. So there is no pressure difference between the high and low pressure for these gases to flow out. And this system has high amount of heat from the exhaust gases which can damage the air tank and other systems.

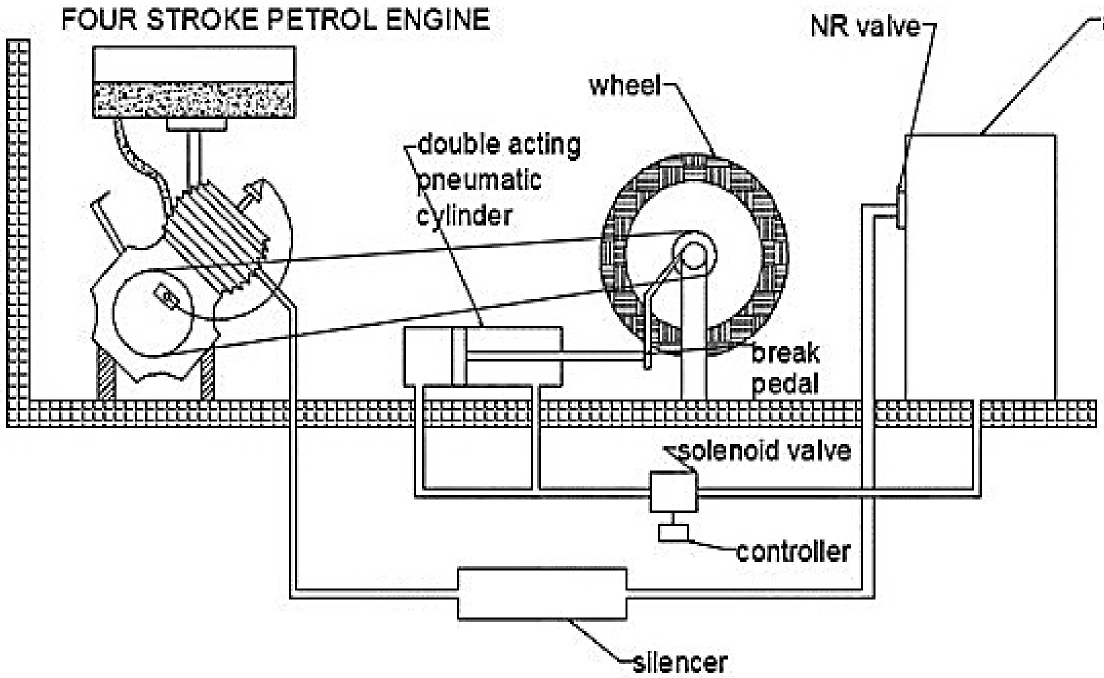
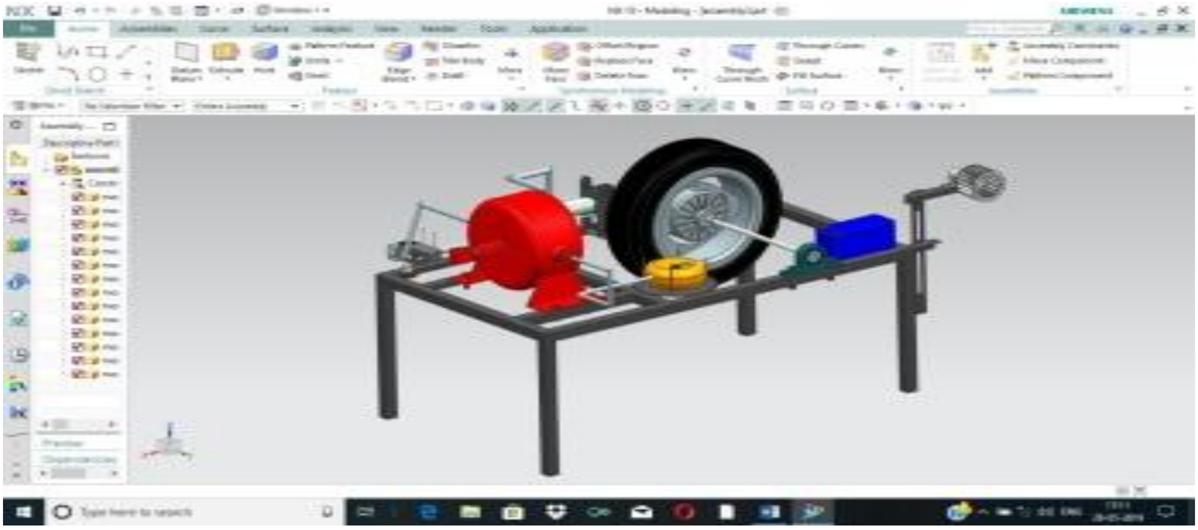


Figure 2: *Internal system.*

Working

An internal combustion engine powered vehicle is used to produce exhaust gas. Here we are placing a turbine in the path of the exhaust gas from the silencer. The turbine is connected to a dynamo. Depending upon the flow of exhaust gases, the turbine will start rotating thus rotating the dynamo, which is used to generate electricity. A dynamo is a device which is used to convert the kinetic energy into electrical energy. The battery is used to store the electricity generated from the turbine. Thus, the stored electric power is used to run the DC air compressor. The air compressor is used to compress the atmospheric air from the surrounding. It is connected to the air receiver tank which stores the compressed air in the air receiver. The air receiver tank is connected to the pneumatic actuator through 3/2 solenoid valve. The pneumatic actuator is connected to the brake lever of drum brakes. When brake is applied, the solenoid valve is opened which allows the compressed air to actuate the brake lever through pneumatic cylinder and thus brakes are applied to the wheel.



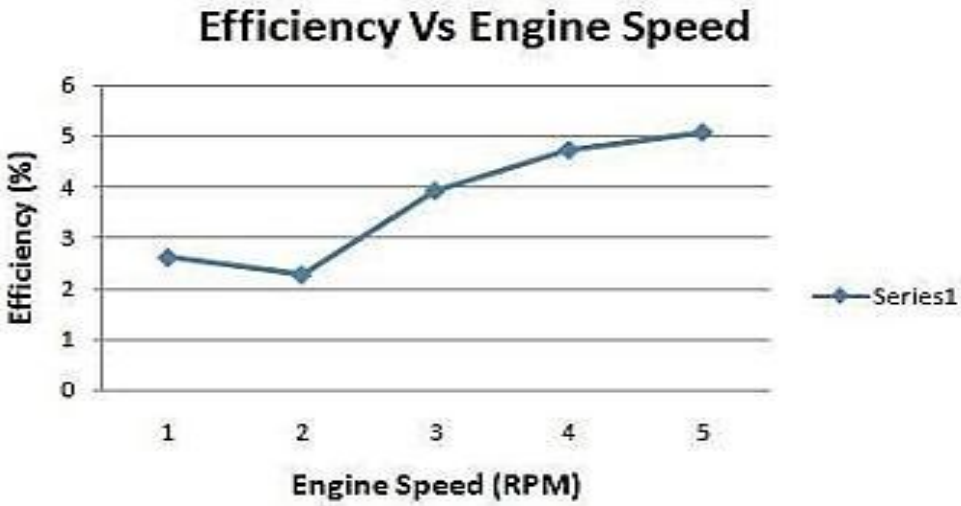


Figure 3: *Efficiency vs. engine speed.*

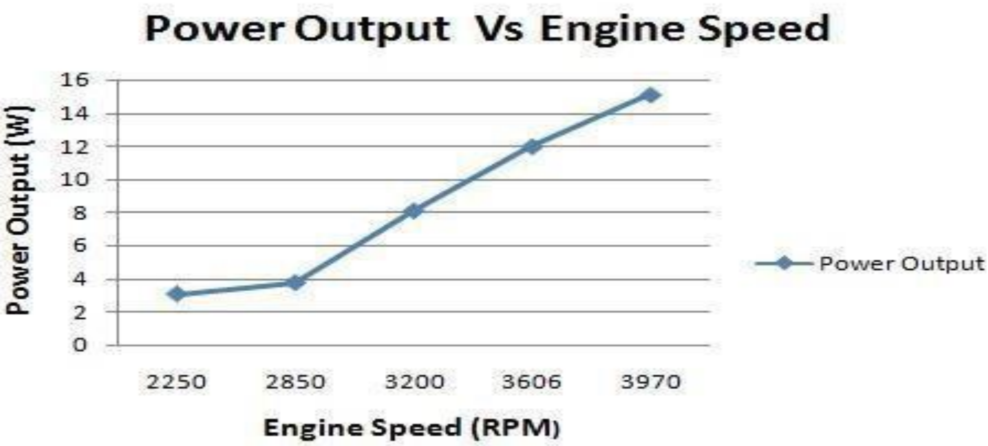


Figure 4: *Power output vs. engine speed.*

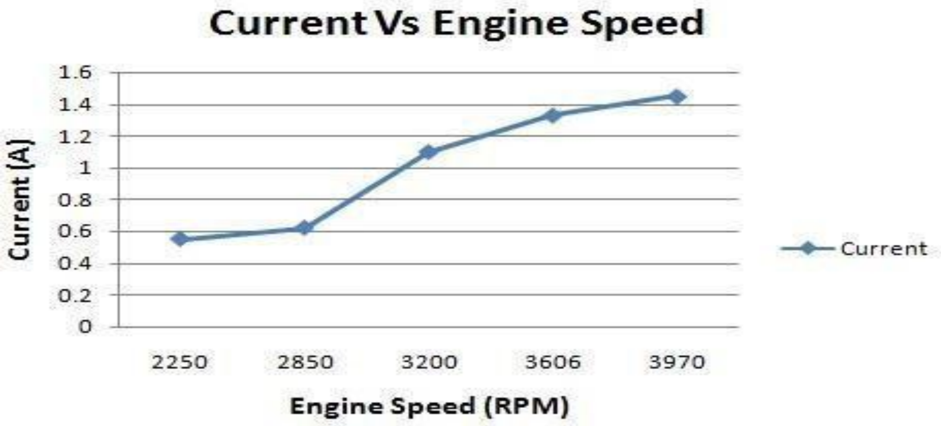


Figure 5: *Current vs. engine speed.*

Design Calculations

TURBINE: - Number of blades = 22 Diameter = 0.08m Formula to be used: - Area of Swept, A = π x (radius of turbine) 2 = π x (0.04) 2 = 5.024 x 10$^{(}$3) *metresq.* = 0.005026*metresq. F or N* = 45, *V elocityof theT urbine, V* = (*pxDxN*)⁄60 = (*p*x0.08*x*45)⁄60 = 0.1884*m/s*

Where,

D=diameter of turbine, N=number of revolution per minute Power available at the turbine = 1/2 x density x area x (velocity) 3 x Cp = 1/2 x 1.23 x 0.005026 x (0.1884) 3 x Cp

= 3.1141 x 10-6 Watt.

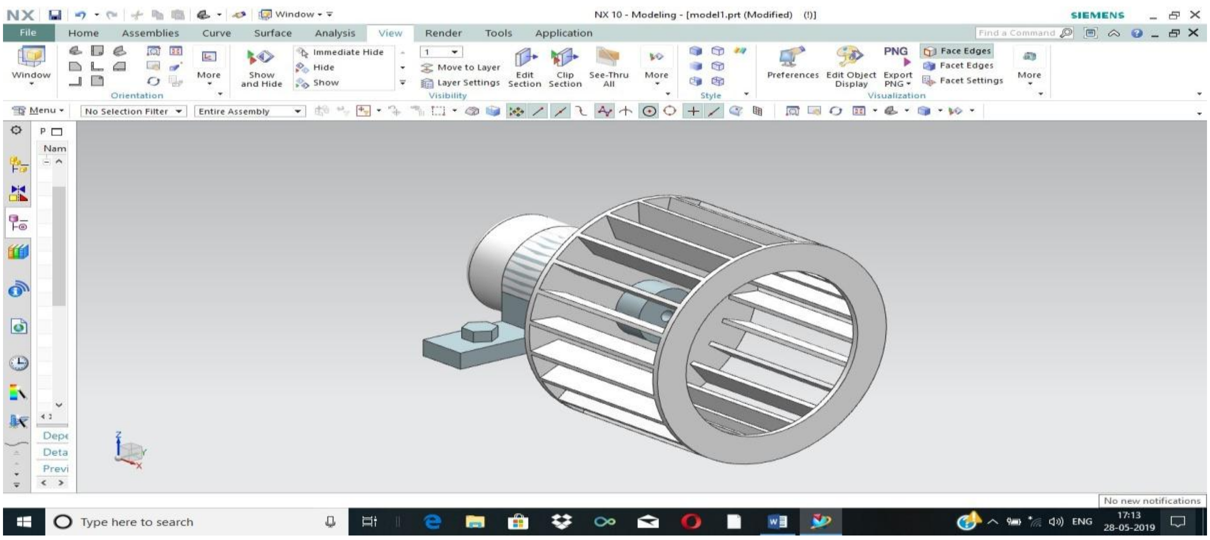


Figure 6: *Model of turbine.*

RPM of Turbine Velocity of Turbine (m/s) Power at Turbine (W) 45 0.1884 3.1141x 10-6 48 0.2010 1.0021 x 10-5 54 0.2261 1.4266 x 10-5 57 0.2386 1.6787 x 10-5

Difference in Power, P (48) – P (45) = 6.9069 x 10-6 W P (54) – P (48) = 4.1791 x 10-6 W P (57) – P (54) = 2.5221 x 10-6 W

BRAKING FORCE

Mass of vehicle = 150 kg Velocity of vehicle = 10 m/s Distance = 10 m. Kinetic energy = 1/2 x M x V2 = 1/2 x 150 x (10)2 = 7500 J. As, W = F x S Where, W = Kinetic Energy F = Braking force required to stop the vehicle S = Distance So, W = F x S 7500 = F x 10 F = 7500/10 F = 750 N. This is the force required to stop the wheel of vehicle.

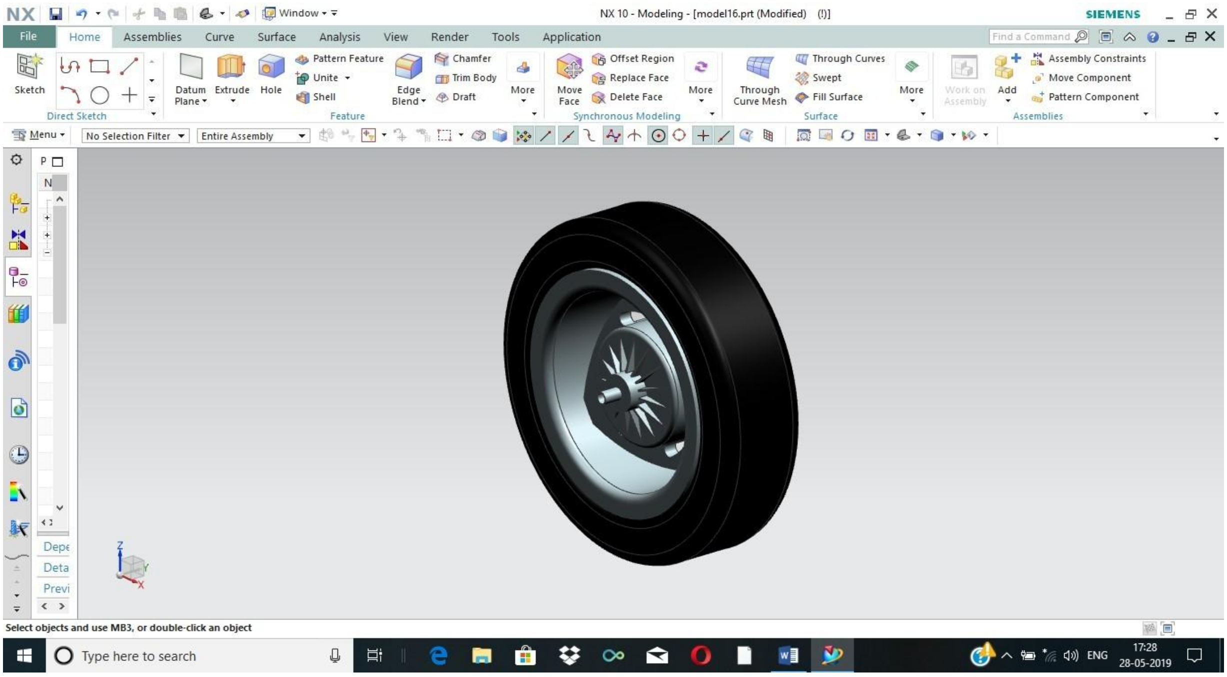


Figure7: *Model of wheel.*

AIR TANK

Diameter of Tank = 0.32 m. Length of Tank = 0.115 m Area of Tank = π x R = 0.5026 m2 Volume of Tank = A x L = 0.5026 x 0.115 = 0.0578 m3 Pressure required applying brakes, 1 PSI = 6894.757 Pascal. (PSI= Pound Force per Square Inch.) Pressure = Force/Area = 750/0.5026 = 1492.24 N/m2 = 0.2164 PSI = 0.0745 Bar

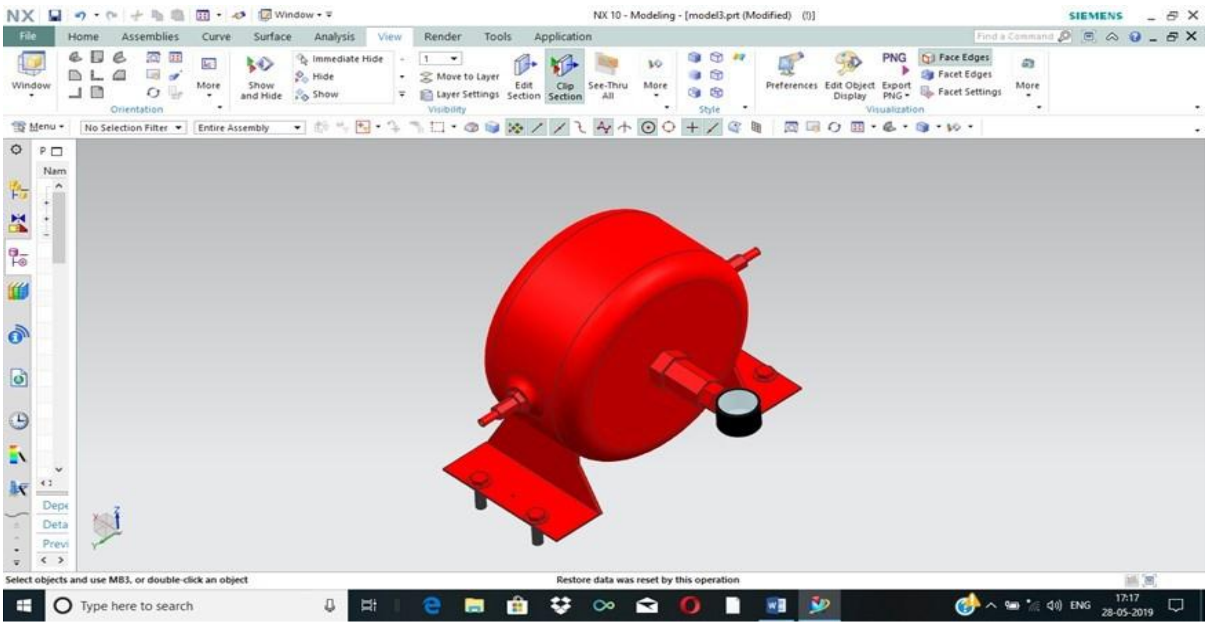


Figure 8: *Model of air tank.*

ACTUATOR

We are using double acting cylinder for pneumatic brake system. Area of piston = Braking force required/ Maximum working pressure Braking force required = 750 N. Maximum working pressure = 7450 N/m2. Area of piston, A = 750/ 7450 A = 0.0604 m2.

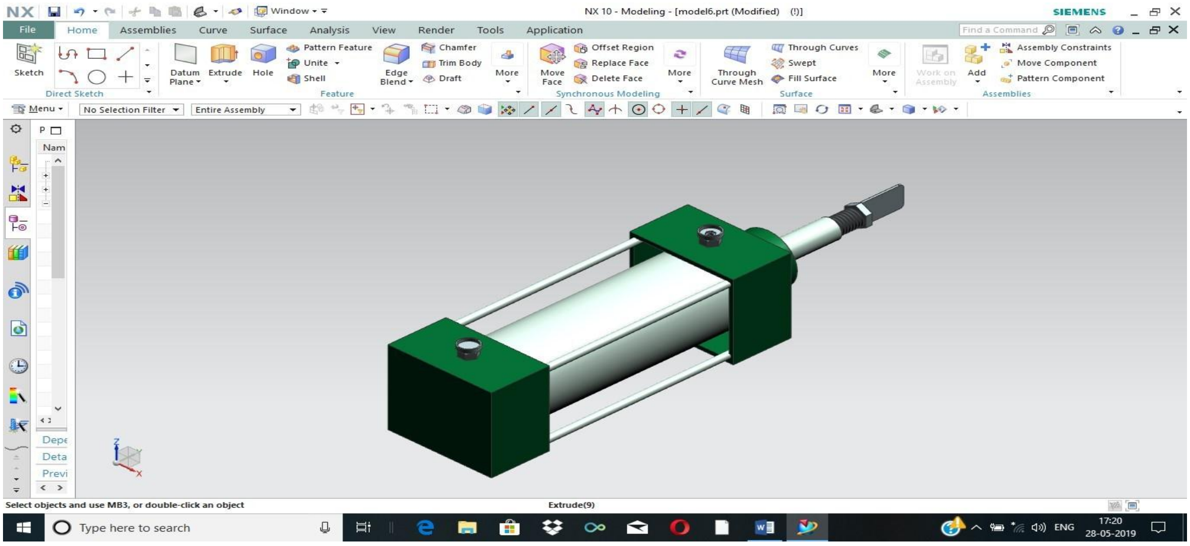


Figure 9: *Model of actuator.*

Frame

The frame must be rigid and strong to carry the components of electricity generation and air brake system. The components must be statistically balanced. The rotating part such as the wheel must be dynamically balanced on the shaft which is mounted on the frame by pedestal bearing for Supporting the shaft.

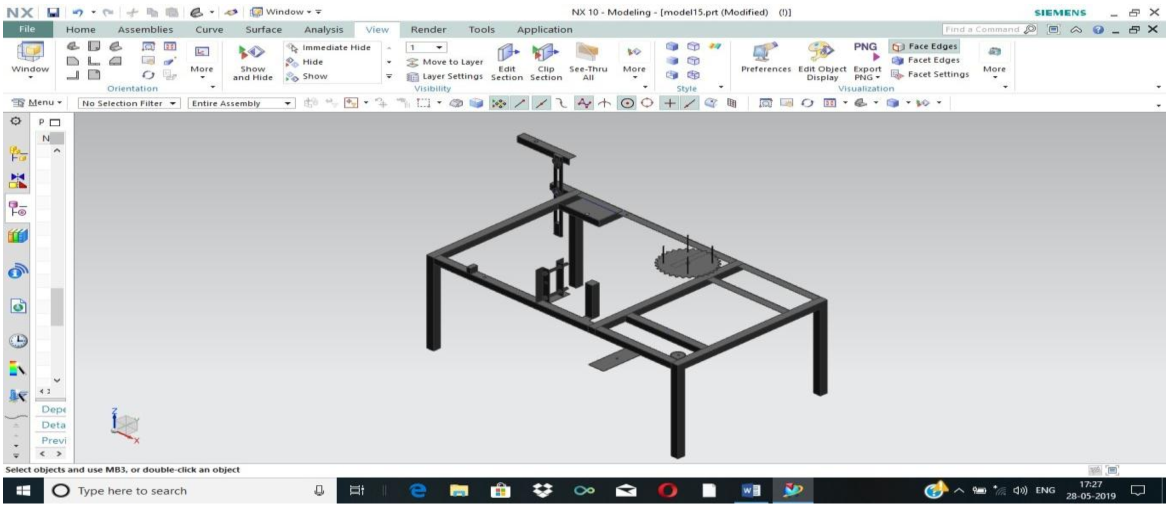


Figure 10: *Model of frame.*

Motor

High torque rated voltage current: DC12V No load current: 0.2Amps (Max 1.2 Amps) No load Power Consumption: 2.4 Watts (Max 15 Watts) No Load Speed: 4000RPM. Great for the rusty or damaged DC motor on the machine. It comes with magnetic shield. To run this motor, you would need a 12 Volt DC Power Supply. The Amperage rating on it should be 1 Amp or above. Alternatively, you can also directly connect it to a 12Volt Battery. It is perfect for various DIY applications.

AIR COMPRESSOR

The selection of air compressor is based on the following factors: Discharge pressure of compressor required. It is determined based on the requirement of cylinder, air motor and pressure drop in the circuit. Sometimes two compressors are used if a part of the pneumatic circuit needs high pressure air and remainder pneumatic circuit requires low pressures. Vane and lobe type compressors are used for pressure requirements up to 2 bars at high flow rates. Volume flow rates are to be ascertained with the consideration whether the compressed air is needed continuously or for intermittently.

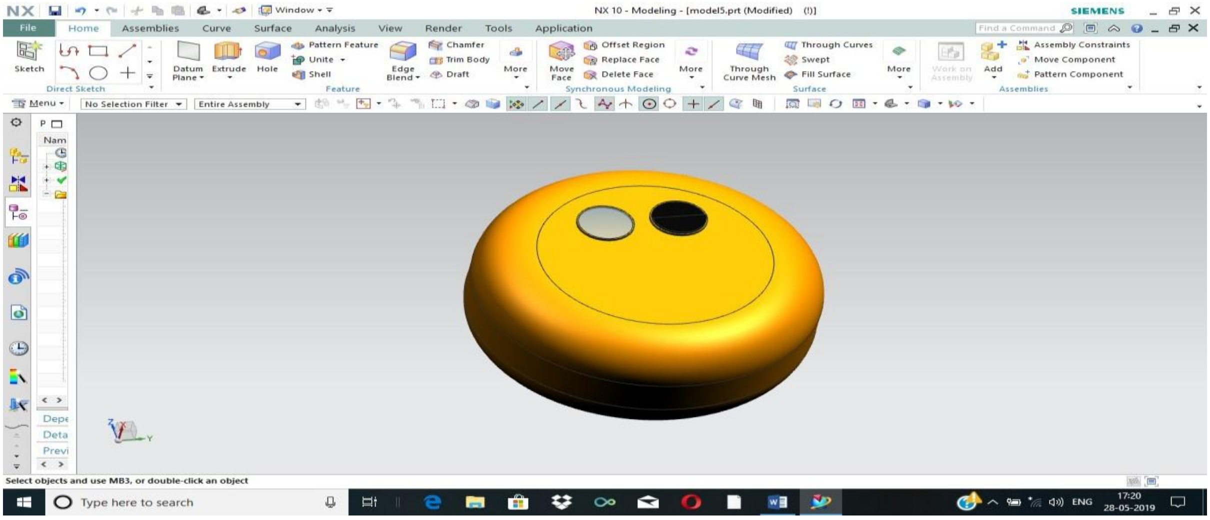


Figure 11: *Model of air compressor.*

PNEUMATIC FILTERS

Air filters are used to filter the air taken into the compressor. The important functions performed by a filter are: Filter all the suspended impurities in air such as dust and other particular matter. Filter helps in condensing the excess water vapor.

TYPES OF FILTERS

1. Fine mesh wire cloth filter: to remove foreign materials.
2. Synthetic material filters: to remove small particles.
3. Cartridge filters: these filters remove 99.9 percent of particles down to 0.01m.

PRESSURE REGULATOR

Air coming out from the source and moving into pneumatic system needs to be supplied at constant pressure irrespective of the source pressure.

Therefore, the regulators are pressure control valves which are normally open type of valve.

Lubricator: -Air entering into the pneumatic system is not completely dry. It always contains a certain percentage of lubricant to ensure that the moving parts operated by the air are properly lubricated. Lubrication of air is done by mixing a fine mist of lubricant into the air stream. This mist will be carried along with the compressed air into the system and will keep all the moving parts lubricated. Lubricator is not installed in special application where 'oil free' air is required. In all other cases, lubricator is essential and it is Standard accessory of a pneumatic system.

FILTER, REGULATOR AND LUBRICATOR (FRL) UNIT

-Since the three components viz. filter, regulator and lubricator are essential components of any pneumatic system; the present trend is to combine all three components into one unit called as FRL (filter- regulator-lubricator) unit.

Mufflers: There are also called pneumatic silencers. The rapid exhaust of air into the atmosphere causes noise. The intensity of such noise could be very high and its

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frequency is in the audible range. It causes very high noise pollution. Exposure to noise for prolonged period can cause many health related problems. Hence it is essential to use mufflers at all air exhausts, thereby reducing the effects of noise pollution.

Dryers: -Air contains moisture (water vapour). The percentage of water vapour in air depends on the ambient conditions. The air has to be dried before supplying to the pneumatic systems. It involves the removal of the moisture content from air. Generally, depending on the method of drying they are classified as:

- Mechanical dryers- also called refrigerated dryer
- Chemical dryers- also called as desiccant dryers and Absorption dryers.

Pressure Control Valves

Pressure Control Valves used in pneumatic are basically “Normally Open (NO) type”. They are mostly pressure regulators or “Regulators”. Pressure is controlled based on the outlet pressure. A feedback is given from the outlet to control the mechanism which is normally open type. When there is a change in the outlet pressure, this is communicated to the diaphragm. The diaphragm will move upwards or downwards depending on the outlet pressure. The movement of the diaphragm will open or close the valve opening thus regulating the pressure. When the outlet pressure increases, the valve gets closed more and the flow of the air is reduced. This will bring down the outlet pressure. In case the outlet pressure reduces, then the valve will increase the flow rate of air. This will bring up the reduced pressure to the desired pressure at outlet.

Solenoid Operated Direction Control Valve: -Solenoid valve is an electro-mechanical valve that can be used to control the flow of liquid or gas. The solenoid converts an electrical signal in to a mechanical movement. The signal is sent to a coil and the movement occurs inside the valve. Solenoids valves are usually described as pilot operated or direct operated (or direct acting). Direction control valves are used in pneumatics to serve the same functions as in hydraulics.

They are used for diverting the compressed air to various parts of the system. There is no difference in the type, classification and method of functioning. The most commonly used DCV’s are of the spool type.

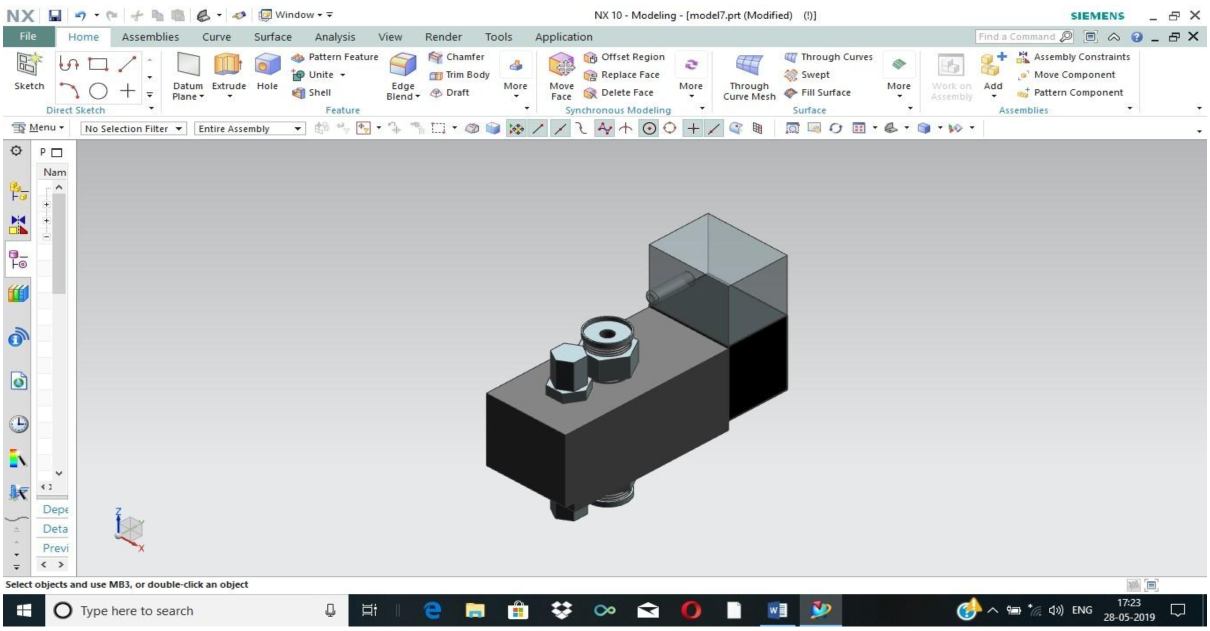

Figure 12: *Model of solenoid valve.*

PIPING

Piping's are selected based on the pressure dropsand maximum fluid velocities. The standard limits of fluid velocities are as follows: Suction line, Vs =0.5 m/s to 1.5 m/s Return line, Vf = 2 m/s

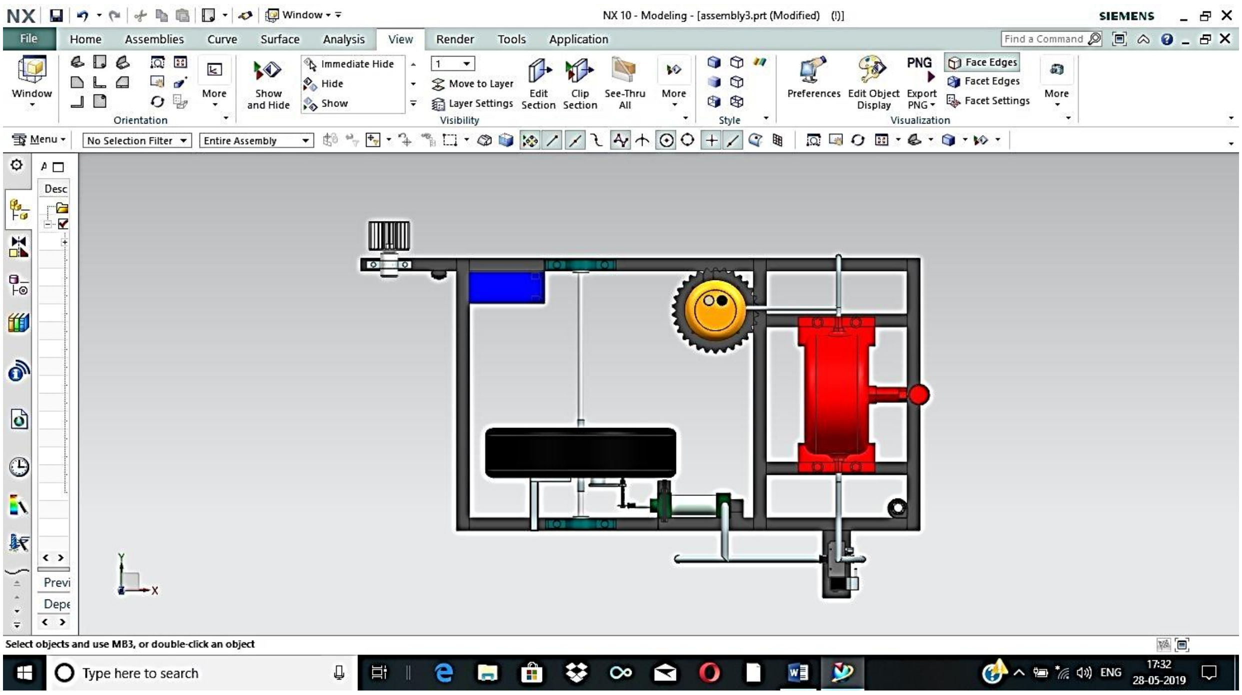

Figure 13: *Model of component setup.*

ADVANTAGES OF AIR BRAKE SYSTEM

Air brake can transfer high braking effort with ease.

1. The system is flexible to mount on the chassis.
2. Air from compressor can be utilized for other pneumatic accessories.
3. The response of air brake is very fast.
4. The working principle of an air brake system is similar to that of a hydraulic system except that in air brakes, the medium used to transmit braking effort is compressed air.
5. Air brakes are faster in response and can transmit high braking effort
6. They are employed on heavy vehicles such as trucks, buses, etc.

BRAKING PERFORMANCE

It is the most important in consideration to vehicle safety. Brake system design is an important parameter for braking force. Fb=Tb/rw Where, Fb = braking force Tb= braking torque rw= wheel radius As Tb increases Fb also increases but up to the limit of road adhesion. So, Fb max = ubW Where, ub= coefficient of road adhesion Braking performance test provides the intuitive knowledge of braking distance and stability of vehicle during braking. Generally, best braking performance is referred to the condition where vehicle stops within minimum possible distance without diverting from its original course. There is dynamic transfer of weight due to acceleration and braking. To counter act the effect of weight transfer we need to design braking system in such a way that will enable us to distribute the force required to apply the brake.

RESULT

Power generated at turbine = 1.6787 x 10-2 KW (for 57 rpm) 2. The maximum working pressure of system = 0.0745 Bar 3. Force required to apply brakes = 750 N

CONCLUSION

From this project, it is possible to recover energy that is being discharged from engine exhaust system without negatively affecting its performance. There are large potentials of energy savings through the use of waste exhaust gases which are released to atmosphere. It involves capturing and reusing the waste exhaust gases from internal combustion engine and using it for generating electrical work. This electrical work can be used for various uses. It can be used for air brake system for heavy vehicles. This system can also be used for hybrid vehicles. The shaft power was mostly limited by the turbine operating pressure, indicated that modification on the turbine was needed for performance improvement.

FUTURE SCOPE

1. A generator mounted on the shaft of the turbocharger can generate electricity from exhaust gases from the engine and later stored in battery.
2. This system can be used in hybrid combination vehicle with internal combustion engine and battery.

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