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DESIGN AND FABRICATION OF AN ELECTROMAGNETIC PISTON ENGINE

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ABSTRACT

The electromagnetic piston engine is a kind of reciprocating engine that works on the principle of electromagnetism i.e like poles attract and unlike poles repel each other. The engine consists of the same basic parts as that of a conventional engine, the piston, the connecting rod, the cylinder and the crankshaft. The electromagnet used in this paper is an AC solenoid magnet and the crankshaft, connecting rod are made of mild steel. The piston has a neodymium magnet attached to the top as this magnet is extremely powerful. When the magnet and the solenoid are of opposite poles, the piston attracts moving the solenoid from BDC to TDC. Once the solenoid changes poles and become the same pole as that of the magnet, it repels and pushes the piston from TDC to BDC. The engine built in this paper is a 4 cylinder V4 configuration engine. The results of this experiment and project is that as of now, this engine cannot be used to lift high power loads and cannot be used for large vehicular aspects. However, this engine can be improved in all aspects and with sustainable developments to the engine, This can soon be used as a viable alternative to the actual engine. The advantage of doing so is that companies will not have to change any existing designs and principals in both the planning and manufacturing phases. With just a few updates to their existing manufacturing lines, They can move to an all electric engine setup in the car as the future of automobiles lie in electric vehicles and this engine will help the companies reduce the costs of manufacturing and setup by a huge margin hence increasing profits.

Keywords: Crankshaft, Solenoid Analysis, Connecting rod, Neodymium magnet research.

I. INTRODUCTION

Conventional Engines use fossil fuels as a base for power supply. Currently, about 81 percent of the world's vehicles run on conventional IC engine technology. Also, in hindsight, 78 percent of the world's global warming happens because of fossil fuels. The cost of fossil fuels is also extremely high considering the time, energy and cost to extract them and refine them.

Fossil Fuels are used to power all modes of transportation around the world and are also used to generate electricity.The waste generated by the use of fossil fuels are causing great amounts of harm to the environment and are a major cause of climate change. Most of this energy is used to power any type of mechanical component that uses a particular type of fossil fuel to run. Renewable energy is a continuous supply of energy that does not cause any harm to the environment. This type of energy is also known as clean energy and can be used as an alternative to fossil fuels.

Keeping this in mind, there is a need to come up with an engine that does not harm the environment, is cheap to manufacture and is also sustainable. One such engine is electromagnetic piston engine. Like any normal IC engine, this electro magnetic engine too has all the components such as piston rings, cylinder, connecting rod, crankshaft, etc. However, there is no piston rings, the inlet port and exhaust ports are absent and there is no spark plug to generate spark. This engine uses a solenoid and permanent magnet attached to the cylinder head and piston head respectively. The solenoid acts exactly like a normal magnet when electricity is provided to it. [1]

This engine works on the principle of magnetism, i.e the attraction and repulsion property is used to create reciprocating motion that converts it into mechanical work using connecting rod and crankshaft. This engine should perform exactly like a conventional internal combustion engine. [1]

The mechanism of power generation is however, different from a normal IC engine. It uses electro magnetism instead of fossil fuels. Electro magnets are powered using a battery with a specific voltage and power output. The piston contains a powerful neodymium magnet that reciprocates using attraction and repulsion property when the electromagnet is powered and provided with an opposite and similar polarity respectively. This motion is converted to the required circular motion using the crankshaft.

The advantage of the electromagnetic engine is that it is free from any pollution. It is also easy to design as it lacks any complicated parts. Keeping this in mind, we have decided to base our experiment on this system. The details of the experiment is as explained below

II. STATEMENT OF THE PROBLEM

1. The alarming rise of global warming has been a primary concern in the world. Most of this is due to fossil fuels. It is necessary for countries, especially like India, China and the United States to switch to renewable sources of energy.

2. Conventional IC engines use fossil fuels that are inefficient, cause high amounts of emissions and are non-renewable energy resources.

3. There is also another problem that is increasing exponentially. There is currently un-certainity in the world with regards to fossil fuels due to the heavily unstable prices of fossil fuels.

4. The world has a limited oil resource. Different types of fuels have different deadlines to extinguish. However, one thing common to all these fuels and their extracting organizations, that is they all are in agreement that the worlds limited oil source will come to an end. In the year 2002, according to ExxonMobil, an oil&gas company, they estimated that oil around the world will end around the year 2040.

5. The percentage of energy losses in an IC engine is about 6 percent. They are very inefficient at around 40 percent, meaning most of the fuels consumed is wasted.

6. The weight of the engines, considering all its complex components also cause some amount of inefficiency in the vehicle.

III. LITERATURE REVIEW

According to a paper by Kala Butler [1], on the topic electromagnetic reciprocating engine, it states that the electromagnetic engine consists of a magnetic cylinder and piston with a cylinder with that has an electro magnet attached on top. The cylinder has an inner wall that is magnetizable to one magnetic pole.

According to Manoj Anto A et al [3] in the paper "Design and Fabrication of Electromagnetic Engine", the electromagnetic engine should be performing exactly like an internal combustion engine. The strength of the field is controlled by the number of windings given to the copper coil in the electromagnet. The advantage of this report is that it is pollution free and the extra internal parts such as piston rings, oil rings, fins, etc is eliminated.

Referring to the paper "Electromagnetic Engine" by Vishal Abasaheb Misal Et al [4], it is said that they had changed to principle of the IC engine to satisfy this engine by replacing fossil fuels with electromagnetic energy. The engine works on the principle of electromagnetic attraction and repulsion between magnets. This engine has an electromagnet located at the top of the engine in the location of the spark plug and cylinder head and a permanent neodymium magnet attached to the piston. The electro magnet is powered by a battery in such a way that the polarity of it is opposite to that of the permanent magnet. When the piston travels to the Bottom Dead Center, the supply of current to the Electromagnet is cut off by means of timing or relay. This causes the permanent magnet which is at the Bottom Dead Center to travel back to it's initial position i.e. the Top Dead Center. This causes one complete revolution of the crank shaft which causes the output work. The electro magnet is witched on using a CAM and follower mechanism.

As stated by Kala Butler in the paper "Electromagnetic Engine White Paper" [1], In a world that has severe climatic change due to the excess carbon dioxide produced due to the burning of fossil fuels and an overly dependant society on the oil supply, which has given the monopoly to certain countries over others, we face a deadly problem that screams for an immediate solution. This electromagnetic engine is one of those solutions to this problem.

IV. WORKING PRINCIPE

1. There is a piston magnetization unit that magnetizes the piston to one magnetic pole, i.e north or south pole according to requirement. This unit magnetizes the piston in a fixed time.

2. The piston is moved in one direction by creating a magnetic attraction force between the cylinder and piston by exciting the electromagnet that is placed in the cylinder head. This causes an attraction force between the piston and cylinder head causing the piston to get attracted to the Top Dead Center.

3. The piston is then sent to the opposite direction by creating an opposite force field in the electromagnet causing it to repel the permanent magnet on the piston. This causes the piston to move in the opposite direction towards the bottom dead center, thus causing a reciprocal motion.

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4. The current system of engine can be arranged in multiple ways such as inline, radial, V8, V12, etc. according to power requirements. One such system is developed and they are arranged together according to the requirements based on the type of vehicle it needs to power. [10]

5. The electromagnet is an attractive electromagnet that is a solenoid with uniform winding and a plunger. The solenoid is a wire coil and the plunger is made of an attractive material. When the solenoid is energized, it gets magnetized and applies a force to the plunger which makes it reciprocate. The plunger stops moving when the forces on it are balanced.

CAD LINE DIAGRAM -

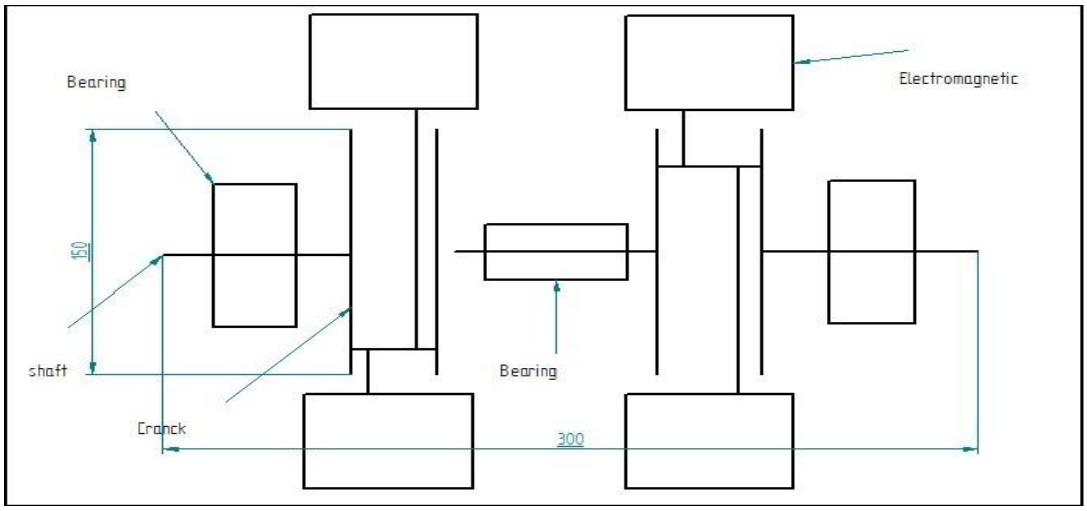

Figure 1: 2D CAD Model of V4 Solenoid Engine

V. OBJECTIVES OF THE PROJECT

The main objectives of the project are to replace the conventional IC engines with a more cheap, efficient engine that is the electromagnetic piston engine.

The Specific objectives are as follows –

1. To review previous papers on the engine, to identify the problems faced by the authors and to identify steps to solve these problems.

2. To design an engine taking into consideration the papers design aspects and the disadvantages in these papers and to come up with a final design.

3. To calculate the parameters in the design of the engine and to identify the parts and materials to be brought and fabricated.

4. To build a prototype of the engine and identify the problems that we would face during the fabrication and overcome these problems.

5. To fabricate the engine according to requirements and to analyze and tabulate the data obtained and compare it with previous data of previous engines.

VI. SCOPE OF THE PROJECT

1. With energy resources depleting and pollution rising at an alarming rate, it is important to look for alternative resources to power vehicles. These sources should not only be renewable but should also be sustainable

2. The scope of the project is such that the industries spend no extra time, manpower or money in upgrading their existing engines but rather, can build the engine with the existing machinery and data.

3. In the future, these cylinders can be arranged in various ways like radial, V shape, Inline, V8, V12 arrangement, etc. based on the power output required by the vehicle.

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4. One can further enhance the project to be more sustainable by charging the battery that powers the electromagnet by means of solar power and a dynamo attached to the wheels. [1]

VII. METHODOLOGY

1. All the previous papers have been collected and have been studied. The literature review has been done and we have to identify the problems and advantages in each paper and a concise review has to be made. The design aspects in each paper and the calculations have to be included in the review.

2. A design of the engine has to be made and the CAD models and diagrams have to be made. The CAD models should be made keeping in mind the advantages and disadvantages in all the papers and must include the advancements to be made by the team.

3. The parts to be fabricated and the parts to be brought are to be identified and a market survey has to be done in order to identify the cost of these parts. The required parts to be brought are obtained using the calculations made.

4. A small-scale prototype is built to identify the problems if any that will be faced during fabrication and the problems if any are overcome before the final fabrication of the engine.

5. The final fabrication of the engine is done taking into consideration all the advantages and disadvantages in the prototype and all the design calculations are kept in mind.

6. The fabricated engine is analyzed and various power and speeds are taken into consideration. The results are tabulated.

VIII. CONSTRUCTION OF ELECTROMAGNETIC PISTION ENGINE

PART DESCRIPTIONS -

1. Cylinder: Here we use AC solenoids as a cylinders. Solenoids are placed at 60 angle to replicate a 4 cylinder V engine. The Heat dissipated by the engine is comparatively low so we do not need external cooling mods or fins for heat transfer.

2. Connecting rod: We used aluminum rods for its light weight to act as a connecting rod.It serves as a link between the piston and the crankshaft. It helps in converting the reciprocating motion into rotary motion of the crankshaft.

3. Fly wheel: It regulates the engine's rotation to makes its operation at a steady speed. The flywheel has a very high moment of inertia and thus helps in regulating fluctuation in rotational speed and is also used to reduce the vibrations in the engine .

4. Crank shaft : It helps convert the reciprocation motion of the neodymium attached pistons into rotary motion of the crank shaft.

5. Permanent magnet (NdFeB): These neodymium magnets are placed on top of the the connecting rood to act as the pistons.

WORKING PRINCIPLE-

This engine is based off of the attraction & repulsive property of the magnet. The electromagnetic engine works on the same principle as that of a two stroke engine. To understand it's working, we assume that the piston is at the Bottom Dead Center in the first stroke. The solenoid is connected to a suitable electric supply. The power of the solenoid depends on the power output required by the engine. When it is energized, the solenoid reciprocates from the BDC to the TDC and when the connection is lost, it is reversed back to it's original position. This power control is made using contact switches that are connected to the crankshaft and this rotates with rotation of the crankshaft. The switches are placed in different positions to ensure maximum efficiency and output from each solenoid that is used. This motion is repeated on all four solenoids and the solenoid moves from the top dead center to the bottom dead center continuously throughout the power cycle, similar to a 2 stroke engine. Electromagnetic engines work on the principle of electromagnetism where like poles repel and unlike poles attract. This continuous process rotates both the crankshaft which rotates the flywheel. This is used to energize the vehicular or transportation needs and the power depends on the power of the solenoid.

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CONSTRUCTION OF PROTOTYPE -

We made a final CAD model for the engine and have decided to go for a V4 engine. The solenoid will be a 2-3kgs AC solenoid with 15mm radius that powers 4 pistons of stroke length 20mm with neodymium magnets attached to it. The crankshaft diameter is 30mm and crank diameter is 150mm. The material being used is mild steel and there will be a fly wheel attached to it. The engine will be partly machined and partly fabricated as 3D printed plastics cannot withstand so much heat and is very costly.

To check the working of the engine, we built a small prototype using wood, a syringe and copper coils. The copper coil was wound around the syringe and a magnet was attached to the plunger. The engine is in a 2-cylinder inline configuration and we found the places we have to keep maximum focus on and where we can provide improvements to the engine. Maximum emphasis must be kept on the crankshaft and the clearance of the piston inside the cylinder to ensure smooth flow of the engine. The engine was given a basic electrical connection and smooth operation was ensured.

From our calculations and analysis, we have found out that DC solenoids cannot be used to lift heavy weight pistons and it will have low power. Hence, we decided to use AC solenoids with high lifting capacity. These solenoids are available ready made in the market and are available for cheap rates as well as compared to the DC solenoids where we have to build the entire solenoid from scratch by deciding the thickness, number of turns, etc. of the copper wire and have to provide all the necessary electrical connections to it as well. Hence, the AC solenoids overcome all these disadvantages and we have decided to use them. It also reduces the cost of the entire build by a substantial amount not only in terms of money but also in terms of manpower and time.

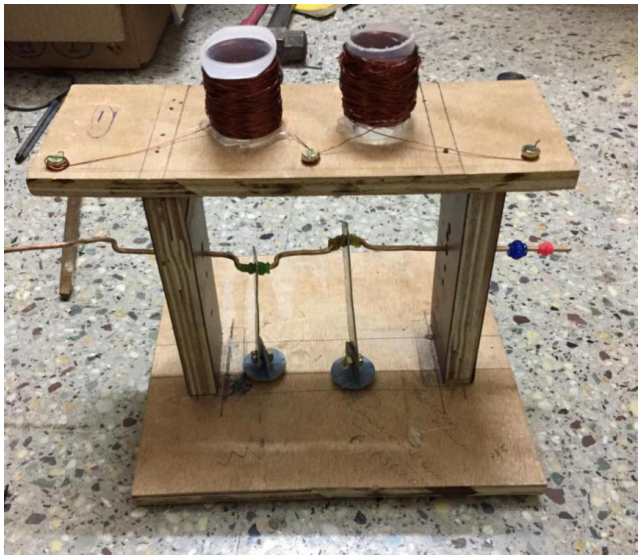

Figure 2: Prototype of a Solenoid Piston Engine

Once the prototype was constructed and the focus areas were identified, the construction of the actual project began. The crankshaft was designed by using mild steel as the material. Mild steel had high corrosion resistant properties and allowed for maximum temperatures in operation. Mild steel also allows for easy machining and is the most ideal material for construction of the engine. The crankshaft was designed and fabricated using a CNC machine. The process took some trial and error and finally, the working crankshaft was designed. The pistons were designed first using large heavy iron material. Later, it was found that these pistons could not be lifted with full force by the solenoid, hence smaller pistons using light weight steel was designed. The piston resembled a thick sheet of metal that was bolted to the crankshaft and could be removed if needed.

We attached a neodymium magnet to the other side of the piston and placed it inside the AC solenoid. The arrangement of these solenoids was relatively easy as it was according to the design and previous data from the prototype helped in the easy assembly of these solenoids. The electrical connections were given using a fairly basic method. The connections were given by connecting it to the crankshaft and using the crankshaft rotation, the timing was given to the piston. As the crankshaft rotated, after 180 degrees, it would trigger a switch located close to the crankshaft and it would respectively turn the electric supply to the solenoid on or off. This would cause the solenoid to attract the magnet to the TDC when the current was supplied and as the piston reached the TDC, it would turn off the power supply, hence demagnetizing the solenoid causing the piston to go back to the BDC. The electric supply was made alternate such that when one solenoid turned off, the other one

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turned on, this producing an alternate movement of the pistons, and hence causing a continuous rotation of the crankshaft.

On construction of the engine, it was found that the energy supply was not even and the engine made too much noise and provided a lot of vibration. This led to a conclusion that fitting a fly wheel to the engine would reduce this problem to a huge extent. Hence a flywheel was attached to one end of the engine and this reduced the vibrations and noise to a huge extent. The solenoid piston engine was now ready for testing and result analysis.

CONSTRUCTION OF ACTUAL MODEL

As discussed in the working, this model of engine is constructed mainly on the cylinder. To make our main cylinder block we used 4 solenoids as our electromagent and placed them in V configuration to replicate a 4 cylinder 'V' engine. Each solenoid carries a piston which is made up of aluminium and has a permanent magnets attached to it. The piston is attached to connecting rod using screws and further the connecting rod is attached to the crank shaft. We have used a relay and timers to pass current to different solenoids to create a magnetic field so that the piston is attracted and repelled. This whole assemble is mounted on to a frame to provide stability and DC current is used to supply power to the solenoids and the relay. Now when the , D.C current of around 24 Volts is supplied to the coils, it gets magnetized. Strong magnetic field is created inside the cylinder. Two poles are formed at the either ends of cylinder. When permanent magnet is placed pointing its north pole upwards, to get attracted to the top of the cylinder which is set as the opposite pole using the controller. Now, piston moves to TDC and when direction of the current is changed, north pole is formed at the top of the cylinder and north pole of the piston gets repelled downwards. Piston now moves to the BDC. This is the resultant Reciprocating motion which converted to the rotary motion of the flywheel, using Connecting rod assembly.

Figure 3: Actual model of a V4 electromagnetic piston engine

VIII. RESULTS AND DISCUSSIONS

An electromagnetic piston engine is an engine that works on the principle of magnetism where like poles attract and unlike poles repel each other. Based on this, an engine was constructed using a V4 configuration. This engine used an AC solenoid magnet. On testing of this engine and on analysis of it from the parts used in its construction, the following results were obtained –

1.The engine in itself is not capable of carrying large loads. The solenoid used was a 2-3kgs AC solenoid and had little load carrying capacity.

2.The engine had heavy amounts of vibrations and noise which as reduced considerable on addition of a fly wheel. When the fly wheel was added, the engine ran considerable smoother and had more constant RPM's.

3.The engine has a low power input to power output ratio, mainly because of the solenoids load carrying capacity. A higher load carrying capacity solenoid can provide higher power to the engine, but this would mean that the components would increase in size and the overall size of the engine will increase considerably.

4.As there are no valves and ports in this engine, the design of this engine becomes significantly simpler and significantly lighter. The lesser components mean lesser maintenance and lesser parts to replace. This reduces the overall long-term cost of maintaining the engine. Lubrication is also significantly reduced in the engine.

5. The DC solenoid requires an accurate number of turns and accurate thickness in copper wires. Even with these turns and thicknesses, there is a higher chance of the engine having low load carrying capacity. The coils need to be properly fastened and there are a greater number of electric connections needed. The DC solenoid also has a reliability problem where the solenoid can be highly unreliable if not built accurately. The DC solenoids also have very low rpms compared to the AC solenoids.

6. To improve the load carrying capacity of this engine, one method would be the introduction of gears. The gears can increase the speed and reliability of the engine. An addition of a flywheel also ensures that energy is not lost in the engine and the engine operates smoothly under constant rpm's, this also increases the efficiency of the engine considerably.

7.With the above points being said, the solenoid engine can be said to have lower operating range and also a lower power delivery. It can be used in vehicles with considerable developments such as developments in the solenoids, developments in the crankshaft and development in the types of magnets used. Another way to increase the efficiency and power delivery of the engine would be to use two solenoids at the top and bottom of the piston.

8. The efficiency of the engine stands low at 20% compared to the 40% efficiency in IC engines. This being said, the solenoid engine operates on electricity which is a renewable energy source and also has a 0-carbon emission footprint. With the global temperatures rising significantly, one can say that the solenoid engine, with healthy developments, can be used to replace IC engines in the future without manufacturers changing significant changes to machines and equipment manufacturing them.

9. Another solution to the efficiency problem is to look at it from an alternative perspective. Rather than trying to make too many adjustments and complications in the engine, one can find a way to generate more electricity renewably in the vehicle itself. When the vehicle can generate renewable energy, a concern of efficiency is sizably reduced. The developers of the engine can work hand in hand with the developers of renewable energy generators and come up with an innovative solution to the current global problem of global warming.

10. As it stands, the engine can be used to power light weight unmanned vehicles where speed is not a factor, but it is long term usage. It can be used in places where solar power and other green energy sources is of abundance but there is very low availability of fossil fuels. Such applications would be in deserts and marine applications where it can be used to power unmanned vehicles that perform simple tasks that are not performable by humans or is hazardous to humans.

11.There is a high scope of improvement in the engine as every part of the engine, i.e. the solenoid, the electricity source, the magnet, the crankshaft, the flywheel, the configuration and the design have scope for improvement.

IX. CONCLUSION

The solenoid piston engine incorporates the design of the normal IC engine for most parts of the engine. The cylinder of the engine is replaced by the solenoid and the piston is fitted with a high-power neodymium magnet. The engine operates similar to the IC engine and the configuration of the engine can be done in any configuration that the IC engine uses. This engine is in its infancy stage and has a huge scope for development as almost all of its parts can be developed to provide a higher power and efficiency along with reliability.

As it stands, the engine provides low rpm's and has a lower efficiency than the IC engine, around 20%. But the main factor to be considered is the engine uses electricity as a source of power and it is safer than conventional IC engines in terms of environmental factors. Electricity can be generated renewable and forever by harnessing the solar energy, wind energy, tidal energy, etc.

The engine has all of its components identical to the IC engine. The piston lacks piston rings and the cylinder head replaces the conventional valves and ports with a solenoid. The other components such as the crankshaft, the configuration and the flywheel remain same. The engine can be used to power unmanned low speed vehicles and has a large scope of improvement in the future. This can be seen as one of the potential replacements for IC engines with sufficient developments made to improve power and reliability.

The solenoid piston engine can be considered to be a part of the list of future engine replacements for the IC engine, with an exception that this engine costs the manufacturers less time and money developing the engine and updating their machinery to come up with a new engine.

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