Study on Improvement of Fuel Economy and Reduction Emission for a Gasoline Engines by Homogeneity Enhancement of the Charge

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Abstract: One of the common problems of the SI ICE that depends on a carburetor is that the fuel and air are mixed inhomogeneous. Such a problem leads to weak performance and low efficiency of the engine. This work is a part of researches that tried to increase the efficiency of the combustion by improving the mixing process. A suggested design has been given that provides the engine with a homogeneous mixture by initiating swirl motion during the mixing process in the intake manifold. The proposed device can be installed at the entrance of the engine to improve the mixture quality by converting the straight flow entering the engine into a spiral or swirling form. It also helps in breaking the fuel particles into smaller parts as a result of continuous collision with the device loops. This process increases the number of particles in the mixture producing a homogenous flow which is easy to evaporate on combustion chamber at all engine speeds. Such type of a homogeneous mixture is easy to burn and to be consumed effectively by the engine. As a result of integrating the device to real life engines, the specific fuel consumption has been reduced and the air pollution decreases. The results showed a significant increase in the combustion efficiency that reduces the fuel consumption by (10-15 %) and also reduces the exhaust temperature that reduces pollutants.

Key words: Internal Combustion Engine, Gasoline Engine, Fuel Combustion, Air-Fuel Mixture, Swirl Flow, Exhaust Gas Temperature and carburetors

INTRODUCTION

In the last few years, studies for improving the performance of the internal combustion engine have been developed at Mutah University laboratories that include all stages before, inside and after the combustion chamber. This work is part of these studies and it deals with the mixing processes before the combustion chamber. This study is directed to the engine that occupied with a carburetor system or indirect injection. These two areas have many applications in markets. The carburettor system is not found in the new car engines nowadays, but, it still used in old make car and in many other fields. It is used with small engines like those used in motorcycles, scooters and small standstill engines (Leonard J. et al, 2007). Etissa et al. in 2008, stated that “in major cities in East Asia, Africa, Southern Europe, and Latin America, 2-stroke scooters gasoline engines that occupied with carburetor are used in significant numbers” (Etissa, D., et al, 2008). Yang et al., 2005, studied the motorcycle industry and application for both 2-stroke and 4-stroke carburetor engine. They, also, stated that motorcycle is one of the most important transportation means for many countries in Asia and Europe. Motorcycles are very popular in both urban and suburban areas in Taiwan for their mobility and convenience. They mentioned that there are over 12 million motorcycles, which account for 67% of all motor vehicles in Taiwan (Hsi-Hsien Yang et al, 2005; Hsi-Hsien Yang, Lien-Te Hsieh, 2005). Hydrogen-powered lawn mower is another example for small engine that used carburetors (Yvon, K. and J.L. Lorenzoni, 2006). A recent work of Volckens et al. in 2008 was directed to the small, handheld two-stroke engines used for lawn and garden work (e.g., string trimmers, leaf blowers, etc.) that can emit a variety of potentially toxic carbonaceous air pollutants. They maintained that Lawn and garden machines emit 6 million tons of pollutants annually, accounting for 5-10% of total US emissions of carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxides (NOₓ), hydrocarbons (HC), and fine particulate matter (PM2.5) (John Volckens, et al, 2008).

Open literatures in the Internet and in the other resources (Tony's Guide to Fuel saving, 2007; Cenk Sayin, et al, 2005) show the importance of improving the mixing process and the various problems that face internal combustion engines, and in particular gasoline engines. In carburetor system, in specific, there is difficulty in mixing the elements inside the intake manifold. This issue was putting a burden on the automotive industry,
as such problem was making it more and more costly to own and operate a vehicle. Solutions for the internal combustion engine were necessary, and have become available; it has been implemented effectively starting in the late 1980s. (The Direct Injection System). Such solutions provided efficient mixing of the elements inside the intake manifold, and it also contributed to the overall saving in fuel consumption. As for the carburetor problem, it was never rectified or resolved, but replaced all together with a new solution, (The Direct Injection System). The research for a proficient mixing of elements is still in progress for the carburetor System, as it remains easier to repair and maintain. The on going research and work has provided a solution for this problem that will establish a relatively efficient mixing of elements that results in more optimum fuel efficiency, which was in high demand as petrol products continued to climb in price. As a part of this work, a device has been designed and tested by installing it on actual engines. Many advantages were gained after installing the device behind the carburetor of the engine. These include and not limited to the following: a relatively efficient mixing of the elements inside the Intake Manifold, improved fuel economy, increased stability of the engine and reduced emission.

The layout of this paper is as follows. This section gives a general introduction of this research, its importance and the methodology used. The next section will explain the theoretical background of the subject. A brief summary of the previous works that deal with similar subject has been presented. Section three will explain the proposed device. Section four is devoted to deals with experiments. The first part of the section describes the experimental rig and its set-up. The second part contains the experimental results. Finally, the last section details the conclusions of the work.

Theoretical Background:

Turbulence of the air in the combustion chamber is vital to the operation of all modern gasoline engines. The main effect of the turbulence is to speed up the burning of the fuel/air mixture. A gasoline vapor/air mixture actually burns quite slowly, in the order of a few meters per second. So a flame starting at a central spark plug would take about 10 milliseconds to reach the edge of the combustion chamber, if the air in the combustion chamber is moving rapidly, it will "stir up" the flame and help it to propagate much faster [7]. Turbulence is generated whenever air flows quickly past a stationary surface, but rapidly decays away through viscosity once the bulk air speed reduces. So modern thinking is to use careful design of the engine's inlet ports. By aiming the intake flow correctly, rapid air motion is set up during the induction stroke. This rapid motion breaks down into turbulence as the piston rises on the compression stroke, and if the engine is correctly designed, hits just the right level at the point of ignition. This "swirl" technology has been standard on engines for decades and is well understood [8]. Most "fuel saving devices" that claim to speed up the burn says that this improves fuel economy. To some extent that's right, but only at levels lower than found in most production engines. A very slow burn gives bad economy because the fuel is still burning when the exhaust valve opens! Theoretically the best efficiency would be obtained by an instantaneous burn, but this would produce an extremely high in-cylinder temperature and so the heat loss to the cylinder walls would be much higher (Tony's Guide to Fuel saving, 2007). The second and more fundamental point is that turbulence speeds up the burn, which is generally a good thing. But the ignition must be retarded by a corresponding amount, or the burn will occur too early. Ignition advance is carefully mapped, based on the engine's burning speed, to give the burn peak at exactly the right point in the piston's stroke (generally just after top dead centre),(Tony's Guide to Fuel saving, 2007).

The present paper relates to an air intake system for an internal combustion engine and more particularly relates to an air intake system adapted for use in generating an adequate swirling motion of intake air introduced into combustion chambers gasoline engine. It is known that, generating a swirling motion of intake air about the cylinder axis when the intake air is introduced into the combustion chamber of the cylinder is extremely effective for obtaining a well blended mixture of the intake air and fuel within the combustion chamber and thereby causing complete combustion of the mixture. It is also known that the intensity of the swirling motion of the intake air must be regulated so as to be suited for a given shape of the combustion chamber and for a specific type of fuel injection system employed in the gasoline engine. Further, the intensity of the swirling motion must be performed without decrease in weight flow of the intake air flowing into the combustion chamber, so that increases in output power and combustion efficiency of the gasoline engine are achieved. The modern engines industry different forms of intake pipes can be found which helps finding a homogeneous mixture. As an examples here is Honda Company which made these pipes shape look spiry for getting a homogeneous mixture. And for the same purpose, Peugeot made spiry intake pipes. On other hand, Mercedes-Benz company, it formed intake pipes for the modern gasoline engines having a shape that helps getting a mess in the mixtures to help having a homogeneous mixture.
Swirl flow has been used in many different kinds of internal combustion engine because of their effects in increasing efficiency, reducing of noise and other emission pollutants, and improving combustion instability (Gupta, A.K., et al., 1989). Heywood gives an excellent review of pollutant formation and control in SI engine (Heywood, J.B., 1976). He presents, in his paper, a graph for the effect of equivalence ratio on emission pollutants that show the complexities of emission control. Swirl motion may used before or inside the combustion chamber and, also, before or after combustion In Switzerland, May M., (1977), patented a high compression, high turbulence chamber. The induction swirl is generated clockwise by the inlet valve port and on compression this accelerates in the head cavity below the exhaust valve. Dyer et al (1982) presented a study of the effect of spark location on flame speed in swirling flow. A more recent work given by Edgar and Ashwani (199) treated the effect of high pressure and temperature. These combined effects act to influence fuel-air mixing, combustion stability, flame stability and generation of unwanted emissions.

In spite of the huge advancement in the field of internal combustion engines, the problem of mixing air with fuel in a homogenous way is still exist. A homogeneous fuel-air mixture is the mixture in which the fuel particles are surrounded by the air particles with equidistance between the particles based on the air-to-fuel ratio. (Ø) Such type of a homogeneous mixture is easy evaporate, burn and be consumed by the engine. As a result, the specific fuel consumption will be reduced as well as the air pollution resulting from incomplete combustion. Many patents all around the world have been invented in this field and few of them, as examples, will presented here. It is known that Mangion (1972) patented a device to improve the mixing process of air and fuel in gasoline engines in which the fuel evaporates inside the intake manifolds through closed tiny tubes inside there. On starting the engine, the high temperature exhaust gases penetrate through the closed tiny tubes causing a rise in its temperature. When fuel-air mixture enters the engine through the intake manifold, the fuel particles that exist in the mixture will collide with the high temperature tiny tubes causing it to evaporate. As a result, the mixing process becomes smoother and the mixture becomes homogeneous for faster burning. The evaporation of this mixture inside the intake manifolds will cause an increase in the mixture volume. As result, the volumetric efficiency $\eta$ of the engine will drop down causing a reduction in the effective efficiency $\eta$ of the engine.

One more example from the US patents is the fuel vapor generator (1975). It is in the form of a heat conductive member having an elongated U-shaped passageway formed through it. The member is mounted at the exterior of a carburetor venture. A first open inlet end of the passageway extends through the venture walls and receives atomized fuel from the main fuel nozzle and a portion of the incoming air. This fuel and air mixture is directed through the passageway where it is heated and the fuel is vaporized. The fuel and air are drawn from the passageway and returned into the venture at a location downstream from the main nozzle. A series of mesh screens extending across the passageway and spaced along its length assist in atomizing the fuel and assuring efficient conductions of heat to the entire mixture of fuel and air within the passageway.

On the other hand, the Russian prototype (1977) which is mainly a carburetor installed on gasoline internal combustion engines, mixes fuel with air at the venture then pushing it into the vertical chamber at the bottom of the carburetor to start a rotational movement inside there. During this process, the mixture will go through another remixing process and becomes more homogeneous before entering the intake manifolds. In such process, the homogeneity of the mixture is an air-flow-speed (engine speed) based process such that the mixture may become homogeneous at a certain speed and may not at another speed because of the change in the mixing time. The faster the engine runs, the shorter the time needed for the mixing process. This concludes that it is impossible to maintain a homogeneous mixture on all engine running speeds. Shablin, also, in his second invention (1982) change this technique into a tangential channel. This design has a problem that is the homogeneity is change in high speeds. One more example from the Russian patents is the work of Yakobov (1972). He inserts an additional device after the carburetor. This new device is provided with inclined channels with an angle of 14° in order to increase the swirl of the flow, improve the mixing efficiency and decrease the engine pollutants. The problem of this design is the relatively big space that occupied by the device that decrease the volumetric efficiency. The Australian prototype (2007) is another device used to improve the mixing process by installing it directly next to the air filter at the entrance of the intake manifolds. This device converts the straight airflow or the mixture to a swirling airflow by means of blades and holes installed in a tangential position at the device axis. The airflow or the mixture gets into the engine through the blades and the holes and gets out in whirling motion. This airflow then gets mixed with the fuel producing a homogeneous mixture that can burn and evaporate quickly. They claim 15-20% fuel savings, but some old cars have achieved figures higher than 35% fuel savings. This device works efficiently under low engine speeds and is not recommended for high speeds because the centrifugal forces increase as the speed increases causing the fuel particles to accumulate on the intake manifolds’ walls which produce an inhomogeneous mixture (in
some places the mixture is rich and in some others is lean). The last patent to be presented here is taken from a local institute (Al-Rousan, A.A., 2008). This invention is a new device to improve the mixing process in the gasoline engines that operate either by carburetors or indirect injection with many advantages. This prototype is made of steel with no moving parts and can be installed without any modifications to the engine and requires no chemical additives. The device is also small in size so that it will not block the entrance of the intake manifolds and it will improve the mixing process inside the intake manifolds. The proposed device, that will be called loop afterward, has a coil shape and can be attached to the walls of the intake manifolds in a spiral form along its entrance. The aim of this work is to study and test this loop in order to extract its performance and introduce it to real life. For this purpose one of these loops has been designed, manufactured and tested. The details of this study will be presented in the following sections.

Description, and Preliminarily Tests of the Loop:

Inserted a loop inside the intake manifolds will increase the swirling motion because a big portion of the mixture starts to move around the loop axis that has been called the main stream. Such kind of motion helps in mixing the air and the fuel in a homogeneous way at the exit. The rest of the mixture, that has been called the swirl stream, enters through the device to help controlling its homogeneity. At low or medium speeds, swirl stream get homogenized by the device then exits to join the other homogenized main stream at the exit. The mixture then enters the engine in a swirling form as a new homogeneous mixture. On high engine speeds the fuel particles in the mixture accumulate on the walls of the intake manifolds entrance as result of big centrifugal forces on the mixture. This mechanism improves the mixing process and also controls the homogeneity of the mixture at higher speeds of the engine. As the fuel-air mixture passes through the device, the fuel particles start to break into smaller pieces as it collide with the loops of the spiral on its way along the intake manifolds entrance. This process will lead to uniform dispersion of the particles produce a homogeneous mixture inside (see Figure (1)) that is easy to evaporate and burn the combustion chamber. This homogeneous mixture can reduce the specific fuel consumption and also reduce the environmental pollution resulting from incomplete combustion at all running speeds.

![Fig. 1: A schematic drawing of the designed device shows the main dimensions](image)

The loop has been designed in long procedure. This procedure includes material selection, manufacturing processes and the best dimensions that make the loop cheap, working properly and simple. Extensive experiments showed that the diameters of the loop must has a ratio of \((d/D) = 1/13\) and \(D\) is 90% of the diameter of the intake manifold entrance. The number of the spiral loops (N) is 1 loop per 2 cm length of the intake manifolds entrance.

As a preliminarily test of the loop, it has been installed on an actual car engine (Mercedes Benz Gasoline 1997 cc engine). Whereas, before installing the loop, the average fuel consumption for long run trip, was recorded at 180 kilometers per 20 liters of gasoline. And after successfully installing the foresaid loop, the average fuel consumption was recorded for a typical trip at 200 kilometers traveled per 20 liters. The initial conclusion is that this newly designed device, achieved a fuel savings of 10%. This encouraged results lead to a more comprehensive test on a small size gasoline engine that will be discussed in the next section.
RESULTS AND DISCUSSION

The effect of the above loop has been tested again after integrated it in a small engine. The performance of this engine has been extracted before and after fixing the device in order study its effect. The test is performed on Honda G200 that Classified as a carburetor gasoline engine (Table 1 shows the full specifications of it and more details can be found in its user manual (Honda Company, 2007). The engine is set-up with the required measurement rig (see figure (2)). These include, and not limited to, the accurate measuring fuel vessel that made especially for this work, the required piping and fittings, the gas analyzer (Motor-scan gas analyzer 8070), thermocouples, tachometer, thermometer and etc. The experiment is divided into two parts; the first part is conducted without the device and the other is performed with it. All tests were conducted at steady state conditions after the engine had reached its operating temperature. The engine has been set at the different speeds which are cover the required range to extract performance of the it. The results then recorded, averaged for many runs, analysis performed and the saving rate calculated. Figure (3) shows the relationship between the speed (rpm) and the gas temperature (°C). Figure (4) shows the relationship between the speed (rpm) and the fuel consumption. The saving rate then calculated and presented in figure (5) that shows an average saving rate of about 14.78 %. The pollutions of the engine with and without the loop are shown in figures (6-9). These figures show a great improvements as a result of using of the loop.

Table 1: Honda G200 specifications (Mangion, C., 1972.)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore x Stroke</td>
<td>67 x 56 mm</td>
</tr>
<tr>
<td>Displacement</td>
<td>197 cm</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>6.5:1</td>
</tr>
<tr>
<td>*Maximum Power Output</td>
<td>5.0 HPS / 3,600 rpm</td>
</tr>
<tr>
<td>Maximum Torque</td>
<td>1.06 kg-m / 2,500 rpm</td>
</tr>
<tr>
<td>Fuel Tank Capacity</td>
<td>3.5 liters</td>
</tr>
<tr>
<td>Oil Capacity</td>
<td>0.7 liters</td>
</tr>
<tr>
<td>Dimensions ( L x W x H )</td>
<td>337 x 375 x 425 mm</td>
</tr>
<tr>
<td>Dry Weight</td>
<td>15 kg</td>
</tr>
</tbody>
</table>

Fig. 2: A schematic drawing for the manufactured device installed in the engine test bed.

Fig. 3: Relationship between the speed (rpm) and the gas temperature °C.
Fig. 4: The relationship between the speed (rpm) and the Fuel consumption (kg/hr).

Fig. 5: The relationship between the speed (rpm) and the saving rate %.

Fig. 6: The relationship between the speed (rpm) and Lambda.
Fig. 7: The relationship between the speed (rpm) and carbon Dioxide.

Fig. 8: The relationship between the speed (rpm) and carbon monoxide.

Fig. 9: The relationship between the speed (rpm) and Hydrocarbons.
Conclusion:

This loop is simple in shape, easy to manufacture, easy in installation, and there is no need for any adjustments of the engine for this device to work. Through scientific experiments it was found that the device does not cause any aerodynamic resistance in the intake manifold, therefore does not affect the running of the engine.

The tests showed that the loop provide a relatively efficient mixing of air and fuel inside the Intake Manifold, Improved fuel economy and increased stability of the engine. Using this loop reduces the fuel consumption by (14.78 %), also reduces the emission temperature, and this in return reduces the pollution caused by incomplete combustion problems caused by bad mixing in the carburetor and intake manifold.

More chemical tests and analysis must be conducted before reach a clear conclusions in the effects of the device on the emission components.

Computer modeling for the flow inside the inlet manifold with the loop using CFD software packages will be useful to improve the validity of the loop.

NOMENCLATURE AND ABBREVIATIONS

| D  | SI         | h    | f   |
|----|------------|------|-----|-----|
| D  | Coil Diameter |     |     |     |
| D  | Manifold Diameter |     |     |     |
| E  | Intake manifolds forces |     |     |     |
| F  | The walls forces |     |     |     |
| G  | Gas conditions |     |     |     |
| T  | Temperature |     |     |     |

Subscripts

Gas, Gas conditions: Atm. Atmospheric conditions: c Centrifugal

REFERENCES


