CARITAS UNIVERSITY AMORJI-NIKE, EMENE, ENUGU STATE

Caritas Journal of Engineering Technology

CJET, Volume 4, Issue 1 (2025)

Article History: ***Received: 12th December, 2024 Revised: 23rd January, 2025 Accepted: 10th February, 2025***

REHABILITATION AND UPGRADE FOR THE CONFIGURATION TECHNIQUES OF A SPARK IGNITION ENGINE TEST BED. A CASE STUDY OF CARITAS UNIVERSITY AMORJI NIKE EMENE ENUGU.

Agu Hillary
Department of Mechanical Engineering
Caritas University Amorji-Nike, Enugu

Abstract

This paper presents the configuration of a spark ignition engine test bed, a device which allow measurement on engines by making them run in a static way, where there is no need to use the vehicle to which the motor was made, used specifically for research and development department of motor manufacture, in order to ensure the design and the operation of prototypes, and to evaluate the performance of spark ignition engines. The testing bed incorporates a dynamometer, fuel measurement system, emissions measurement system, and data acquisition system to measure engine performance parameters, including power output, torque, fuel consumption, and emissions. The configuration of the testing bed is discussed in detail, including the selection of components which thousands of different component where manufactured in different factories with high degree of accuracy and interchangeability, integrated to the systems. A case study is also presented at the Caritas University, a configured internal combustion engine testing bed to demonstrate the effectiveness of the testing bed in evaluating the performance of a spark ignition engine. The results show that the testing bed is capable of accurately measuring engine performance parameters, making it a valuable tool for engine development, testing and research.

Keywords: engne development, engine performance, internal combustion, spark ignition,

INTRODUCTION

A spark ignition engine is an internal combustion engine that generates power by a combination of air, fuel and spark which produces a small explosion that drives a piston down and ultimately turns the crankshaft, producing rotary motion. It is widely used in various applications, including transportation, power generation, and industrial processes. The performance of spark ignition engine is critical in ensuring their efficiency, reliability, and environmental sustainability. It is influenced by various factors, including engine design, fuel type, and operating conditions.

In the four stroke engine each piston of the engine is equipped with at least two valves, one to admit air–fuel mixture and a second to exhaust spent gases after ignition. The opening and closing of these valves is mechanically synchronized with the movement of the piston backward and forwards. Starting the operation with the piston at the top of its chamber, and the chamber empty, the first stroke in which fuel and air mixture is drawn into the piston chamber by movement of the piston to expand the volume of the enclosed space with the air-fuel mixture while the valve open. This valve close at the end of the first stroke and the second stroke, a spark ignites the fuel-air mixture at the top of this stroke, creating an explosive expansion of the compressed mixture which forces the piston down again, which is the power cycle, the third stroke. The fourth stroke is the exhaust stroke during which the exhaust gases are forced out of the piston chamber though the second valve, now open. This close at the end of the fourth stroke, the cycle begins again. A large flywheel attached to the crankshaft store angular momentum generated by the power stroke and this provides sufficient momentum to carry the crankshaft and the piston through the three other strokes required for each cycle. However, in the cylinders of four stroke engine the pistons are attached to the crankshaft, with one of each set of four timed to produce a power stroke while the other three move through different stages of their cycles.

To evaluate the performance of a four-stroke cycle engines, a special test bed is required. A spark ignition engine test is a facility designed to evaluate the performance of spark ignition engines under various operating conditions. The configuration of a spark ignition engine test bed is critical in ensuring accurate and reliable test results, and components that includes a cylinders as chambers where the fuel is burned through the pistons that moves up and down in the cylinders, driven by the explosive force of the fuel, connected to a crankshaft that converts the up-and-down motion of the pistons into rotary motion, and a camshaft that operates the valves that allow air and fuel into the cylinders and exhaust gases out of the cylinders, integrated to a valves that control the flow of air and fuel into the cylinders and exhaust gases out of the cylinders.

In the mechanical performance the maximum Power output of the engine, usually measured in horsepower (hp) or kilowatts (kw). Torque is the rotational force produced by the engine, usually measured in pound-feet (ib-ft) or newton-meters (Nm). The Speed at which the engine operates, usually measured in revolution per minute (rpm). Efficiency, normally the percentage of energy converted from fuel work, usually measured as thermal efficiency, brake thermal efficiency, or indicated thermal efficiency. Specific fuel consumption is the amount of fuel consumed per unit of power output, measured in grams per horsepower (g/kwh) or pounds per horsepower-hour (lb/hp-h). Heat transfer is the rate at which heat is transferred from the engine to the surroundings, usually measured in watts (w) or British thermal unit per hour (Btu/h). Emission is the amount of pollutions released into the atmosphere, and is measured in grams per kilowatt-hour (g/kwh) or pounds per horsepower-hour (ib/hp-h).

MATERIALS AND METHODS

A spark ignition engine test bed includes the hardware components, such as the engine block in which the cylinders are grouped, the crankcase which supports and locates the crankshaft. To this components, are attached the cylinder head in which the combustion chambers are formed and which seals off the upper ends of the cylinder. The inlet and exhaust manifolds, and the sump which seals off the lower face of the crankcase and which in most vehicle engines, acts as an oil tank. A dynamometer, fuel measurement system, emission measurement system, sensors and instrument. A specialized software that include data acquisition software, engine control software, and emissions analysis software.

DESCRIPTION OF THE COMPONENTS PARTS

a) ENGINE BLOCK: Integrated constructed engine is the simplest and cheapest form used for engine of most car and light commercial vehicle, all overhead valve engines. The cylinder bores, water jackets, and crankcase are produced as a single iron casting which is very rigid and produces no problems in positioning the cylinders on the crankcase. The crankcase portion has very heavy webs which support the crankshaft and camshaft and hold them in position, the crankcase well and the webs being ducted to direct lubricating oil to the shaft bearings. The end and lower faces of the crankcase are machined to provide mounting for the clutch and gearbox housing, the sump, and units such as oil and fuel pumps, filters, and timing-gear covers. Side-by-side valve arrangement were formed in the cylinder head. The cylinder block is a box like casting of iron or aluminum alloy and a liner is held in position at its upper end, by a shoulder fitting into a recess in the block top. Rubber sealing rings, or a shoulder and a paper gasket, are used to seal the lower end. The top of the liner protects about 0.13mm above the face of the block at all points around its circumference to obtain a good gas-tight seal.

b) CYLINDER HEAD: The cylinder head is secured to the block by studs which pass through the head, nuts being used to tighten the head down upon a gasket which makes a gas-tight seal. The cylinder head is complicated by the positioning of the valve points and sears, the valve guides, the screwed holes for spark plugs, and the combustion chambers and water jackets. The head is usually of cast iron but may also be of cast aluminum alloy.

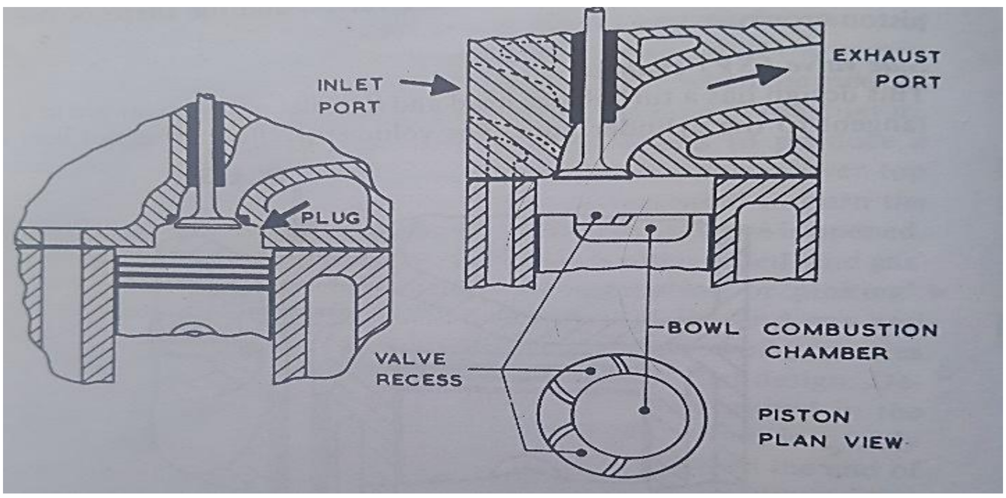
c) HEAD GASKET: These are usually formed from two stamping of thin sheet copper separated by a layer of clay and asbestos. The inner edges of the various holes through the gasket are rolled over or lined to make gasand water- tight seals.

d) COMBUSTION CHAMBERS: The combustion chamber is the space within an internal combustion engine where the fuel-air mixture is forced towards the end of the compression stroke, and in which it is ignited, producing power. It is typically located within the engine's cylinders, which are arranged in a line or in a V-shape. The shape of the chamber has a very great influence upon the power output and performance of the engine, and was designed that the speed of the spread of the flame is strictly controlled.

e) OVERHEAD VALVE CHAMBER: This is a compartment located above the cylinders in an internal combustion engine. The design has a valve arranged in line above the cylinder to contains the intake and exhaust valves, which are responsible for controlling airflow into and out of the cylinders. The valve springs provide the necessary force to close the valves. Valve retainers hold the valve springs in place. A valve stem seals prevent the oil from leaking into the combustion chamber. The rocker arms are located in the overhead valve chamber and transmit the motion of the camshaft to the valves. Camshaft is located in the overhead chamber and operate the valves by rotating the rocker arms. A push rod and a rocker arm

are fitted between the tappet and the valve in such a way that the lifting of the tappet causes the valve to be forced down away from its seat. It is a simple design which is easy to service, and large inlet valves and ports are used. The volumetric efficiency is high, which provides mixture swirl, and extra turbulence is provided by placing the combustion chamber off center in relation to the bore, the mixture is being directed from the cylinder into the combustion chamber at end of the compression stroke. The second form of turbulence is called 'squish'. The flame travel is short and detonation is less likely to occur.

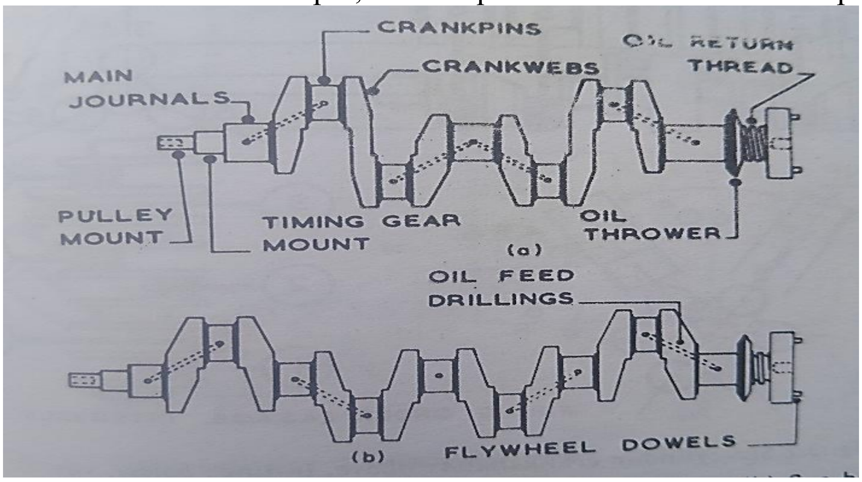
f) THE PISTON: A piston is a moving component that reciprocates up and down within a cylinder, driven by the explosive force of the fuel-air mixture. It acts as a movable gas-tight plunger in the cylinder during the induction, compression and exhaust strokes. It converts the expansion pressure of the burning mixture into a force which is transmitted to the crankshaft by the connecting rod during the power stroke. And to form a guide and a bearing for the small end of the connecting rod, and to take the side thrust caused by the angularity of the crankpin and connecting-rod assembly. The piston shape is that of a cylinder, sealed at one end. The piston and connecting rod are fastened together by the gudgeon pin. The top part of the piston is termed the crown and this may be flat, convex or concave, according to the shape desired for the combustion chamber, and for compression ratio needed. The piston has rings which maintains a gasseal between the piston and the cylinder wall under all normal temperatures, pressures and piston speeds. It prevents the passage of lubricating oil up to the combustion chamber, and to transfer heat from the piston crown to the cooled cylinder walls.



Piston head fig. 1

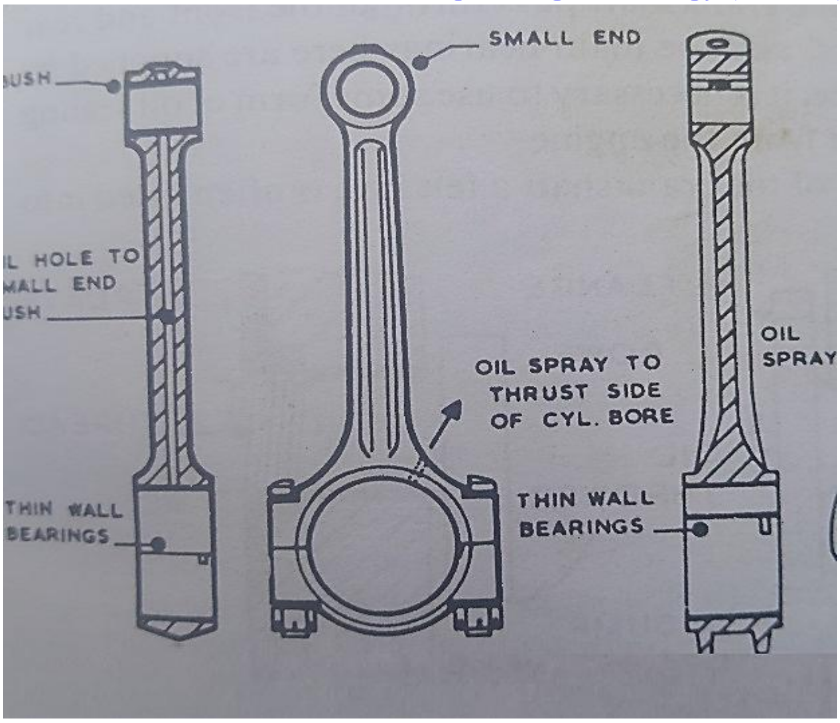
g) THE GUDGEONPIN: Gudgeon pin is typically located in the piston, cylindrical piece with it outer surface accurately ground to size and give a very fine finish, passing through the piston pin bosses and connected to the connecting rod. It connects the piston to the small end of the connecting rod, allowing it to pivot in relation to the piston to move up and down in the cylinder while transferring the force generated by the explosive combustion process to the crankshaft.

h) THE CRANKSHAFT: The crankshaft is probably the most highly stressed part of the vehicle and is made very stiff and tough to resist the very large bending and twisting forces imposed upon it. The shape of the crankshaft is related to the number and the arrangement of the cylinders, but usually consists of a number of main journals which all rotate about the same axis or center line. Crankpins are arranged between these main journals, at the same distances from the center line, and are connected to the journals by webs. The crankpins are, as far as possible, arranged so as to counterbalance each other across the axis of the shaft, and weights may be fitted to the webs to counterbalance the weights of the crank-pin and the big-ends of the connecting rods. The crank-webs are drilled to direct high-pressure lubricating oil from the main journals to the crankpins, thus cooling the bearings as well as reducing friction and wear. The crankshaft is supported in the crankcase by main bearings in which the main journals rotate. The bearings may be thick walled or thin walled and are split, plain types. A rotating shaft has a tendency at high speeds for its center to be deflected by centrifugal force, this deflection is called 'whip' and it is reduced by using more supporting main bearings. Throw of the shaft, is the distance between the center of the crankshaft and the center of the crankpin, and is equal to half the stroke of the piston.



Crankshaft fig 2

i) CONNECTING ROD: The connecting rod is used to transfer thrust in either direction between the piston and the crankpin. The small end of the connecting rod is connected to the piston pin, the bib end is connected to the crankshaft, the beam is the main body of the connecting rod, while the bearing is located at the big end and allows the connecting rod to rotate smoothly. It is transferring the up-down motion of the piston to the crankshaft, which converts it into rotary motion. It is usually about twice as long as the stroke of the engine and is subjected to forces which try to bend, stretch, and compress it. The big end bearing is lubricated by feeding high-pressure oil, through a duct or drilling in the crankshaft, from a main journal to the crankpin. Some connecting rods have a small hole drilled through the upper shell and rod so that it lines up with the main feed hole of the crankpin once each revolution, and results in a small jet of oil being sprayed out to lubricate the cylinder wall.



Connecting Rod fig. 3

j) FIRING ORDERS: The mixture of petrol and air is distributed between the cylinders that the same mass of mixture is induced into every cylinder. In practice this even distribution is not obtained because the changes in direction and velocity of the mixture, as it flows through the manifold, make less mass of mixture available to some cylinders. The induction strokes of a multi-cylinder engine do not take place in numerical order but in special sequence which is used to reduce the number of direction and velocity changes in the flow of the mixture. In this way the cylinders are able to induce approximately the same masses of mixture, and the distribution of the mixture is made more even. The particular sequence used depends upon the number and arrangement of the cylinders, and upon the shape of the crankshaft. These sequence are called the firing orders. The most common used type of crankshaft is that with four cylinders in line. Three or five main bearing are employed and the crank throws are all in the same plane. Piston one and four will be at top dead center together, although on different strokes, while pistons two and three will be at bottom dead center. The firing interval are equal at 180*, but the toque fluctuates because one power stroke is dying away as the next is building up. The distributor cam will have four lobes. The firing order will be 1,3,4,2 or 1,2,4,3.

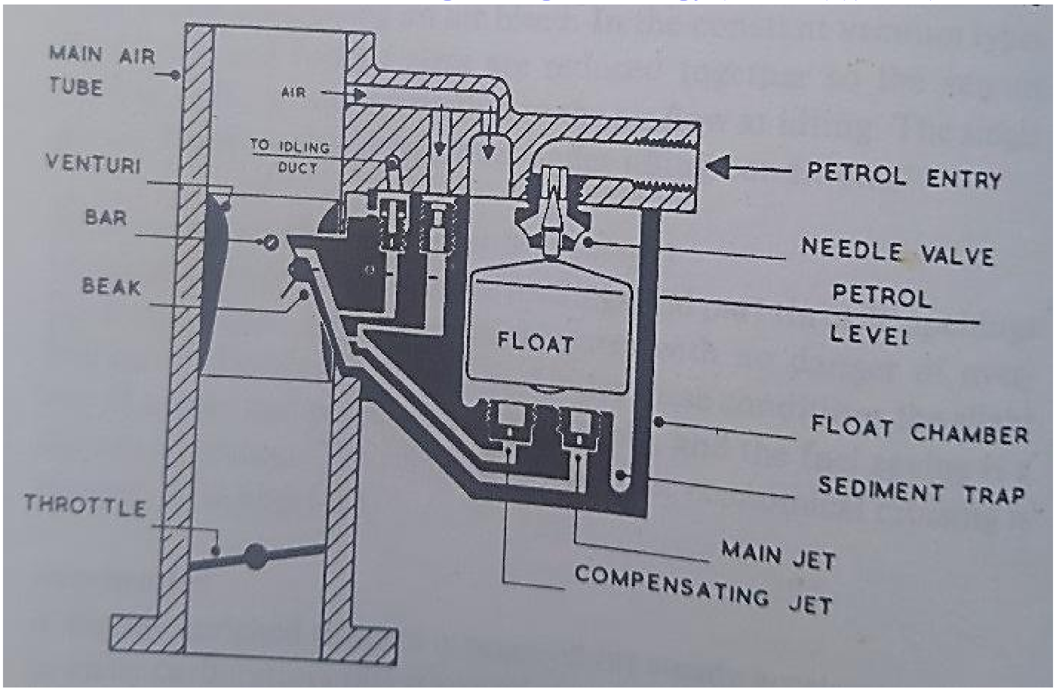
k) THE FLYWHEEL: The main function of the flywheel is to retain some of the energy given to the crankshaft during the power stroke and then to release this energy to keep the crankshaft turning the idle strokes, it helps to keep the crankshaft rotating smoothly. It also forms one driving face of the clutch assembly and acts as a gear for the engagement of the starter motor. The flywheel consists of steel-disc with a very heavy rim. This mass, at the largest possible radius, gives the flywheel a large moment of inertia, resistance to changes in velocity, which enable it to store and release energy as required. The greater the number of power strokes during each crankshaft revolution the lighter the flywheel can be, and the quicker the response on the engine to the demanded changes in speed. The rear face of the flywheel is used to mount the clutch assembly, and this face is usually hardened to resist wear. The outer circumference of the flywheel carries a set or ring of gear teeth which may be integral with the flywheel or may be shrink fit. The gear on the end of the shaft of the starter motor engages with this ring gear when the motor is energized.

l) THE CAMSHAFT: The camshaft is use to locate, support, and rotate the cams in such a way that each valve is opened at the correct time, is held open for the correct time in relation to the movement of the pistons. The inlet and exhaust valve cams for each cylinder are paired and their relative positions on the shaft are such that they form an angle when viewed from the end of the shaft. This angle determines the opening and closing times of the valves, while the shape of the cam determines how long each valve is held open. Each pair of cams therefore determine the valve timing of cylinder. The correct induction or arranging the pairs at the correct angles to each other. The camshaft is generally arranged above, to one side of, and parallel with the crankshaft, and rotates in bearings in the cylinder block. Under four stroke the four-stroke cycle, the camshaft is driven at half the speed of the crankshaft because each valve is required to operate only once in two revolution of the crankshaft. This speed reduction is obtained by having twice the number of teeth on the driving gear of the camshaft than there are on the crankshaft gear. Both gears are keyed to their respective shafts, driven by a system of chains.

m) OIL SUMP: An oil sump, is a critical component of internal combustion engine that stores the engine oil, which lubricates the engine's moving parts. It also helps in cooling the engine oil which can became hot during the engine operation. Also protects the engine from damage by containing the oil and preventing it from leaking out. It has an indicator that show the quality of oil in the sump at any time. A drain plug is fitted to the sump to enable the oil to be changed.

n) OIL PUMP: The oil pumps are usually mounted on the underside of the crankcase and are driven from the camshaft by skew gears. The body of the pump is immersed in the oil and drilled hole connects the pumping chamber with the main oil gallery. It enclosed a small volume of oil and forcing it into a system already full of oil. Each separate volume of oil is forced into the system at a faster rate than oil can escape from the system, and so the pressure built up is really a back pressure. Submerging the pump chamber in the oil makes the sealing more effective by reducing the chance of air leaking into the pump, and also make the pump self-prime. The pump filters pressure differences, which cause the oil to enter the pump chamber are quite small, so the filter, which protects the pump from the larger particles of dirt and metal, must offer only a very slight resistance to the flow of oil. Such filters are made from a fairly coarse wire gauze and are arranged across the intake of the pump chamber.

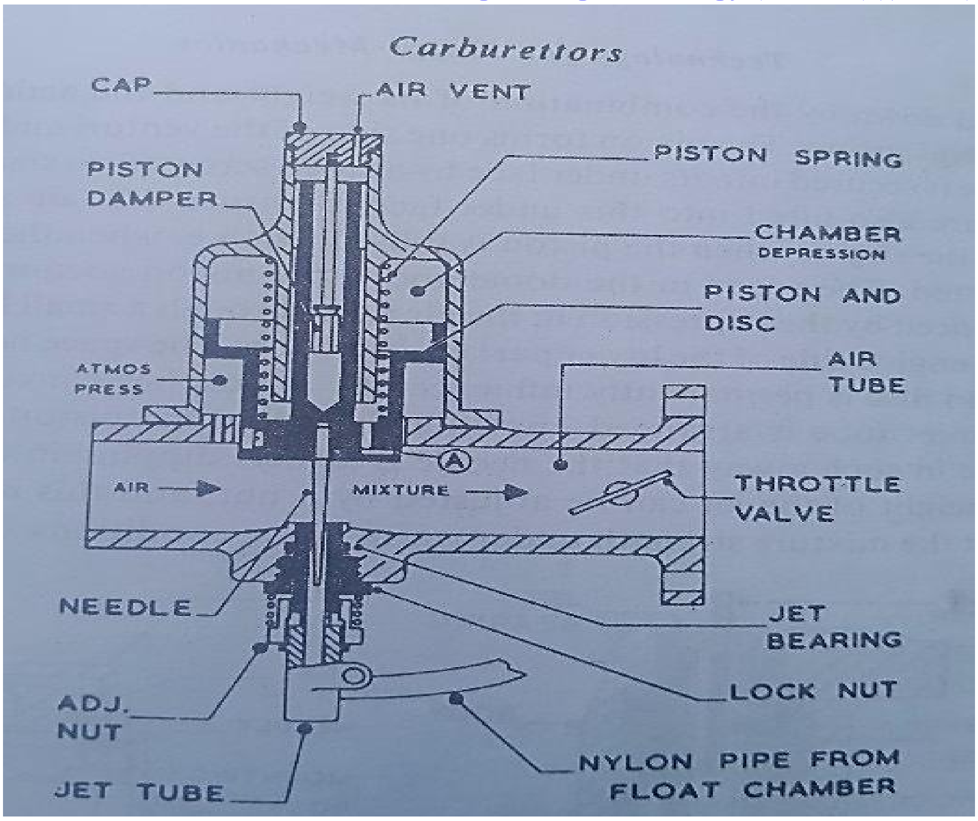
o) MECHANICAL PETROL PUMP: This transfer fuel from a low-level tank to a carburetor float chamber at higher level, at a rate greater than the maximum rate of engine fuel consumption. The pump is bolted to the engine and is operated by an eccentric on the engine camshaft. Metal pipes are used to connect the pump to the tank and to the float chamber. The pump is an assembly of die-castings which form a sediment chamber and a pumping chamber, the incoming petrol first passing through a fine wiregauze filter. The pumping chamber has a flexible wall in the form of a rubberized fabric diaphragm which is moved inward by the action of a spring, and outward by the action of a link arm. This link arm is mounted upon the same pivot as the rocker arm and the two normally act as a solid lever, a contact face being formed on each. The rocker arm is spring-loaded in such a way that it always maintains contact with the camshaft eccentric.



Fuel pump fig. 4

p) THE CARBURETOR: It is a device that blends air and fuel for an internal combustion engine. The carburetor mixes air and fuel in correct proportions for efficient combustion. It regulates the amount of fuel deliver to the engine based on factors like engine speed, load, temperature, and controls the air-fuel mixture. The unit consist of a main air tube with a disctype throttle valve, a float chamber, a tubular petrol jet.

A tapered needle attached to a piston, and a dome or chamber which encloses the piston. The throttle valve is arranged at the engine end of the main air tube, with its axis or spindle parallel with the axis of the intake manifold. An adjustable, low-speed, throttle stop is provided. The float chamber is arranged forward of the air tube and is secured to it by a bolt. The piston and its enclosing dome are arranged at right angle to the air tube, and the dome is secured by screws. The piston has an integral suction disc, and is forced down by the combination of its weight and the action of a light coil spring. The piston form one side of the venture and the jet needle is secured into its under face by a small screw. Two small pins are also fitted into this under face to ensure that air can still enter the engine when the piston is fully down. The space below the suction disc is permanently influenced by atmospheric pressure. The jet tube is arranged immediately below the piston and the needle in such a way that the needle is always dipping into the jet. The height of the jet can be adjusted by a nut, and this is used to adjust the mixture strength under warm idling conditions. The floor of the air tube is raised slightly under the piston to form the jet bridge. This helps the rush of air to atomize the liquid fuel adequately under all operating conditions.



Carburetor fig. 5

q) THE IGNITION AND STARTER SYSTEMS: The function of coil ignition is to provide, at correct time and in the correct sequence, a series of sparks of sufficient intensity to ignite the highly compressed mixture of air and petrol in the cylinder of the engine. The complete system consists of:

~ A battery which supplies voltage (12 volts) to force a small current through the primary winding of ignition coil.

~ A contact breaker, or engine-operated switch, which interrupts the flow of battery current through the primary winding of the coil at regular and predetermined intervals.

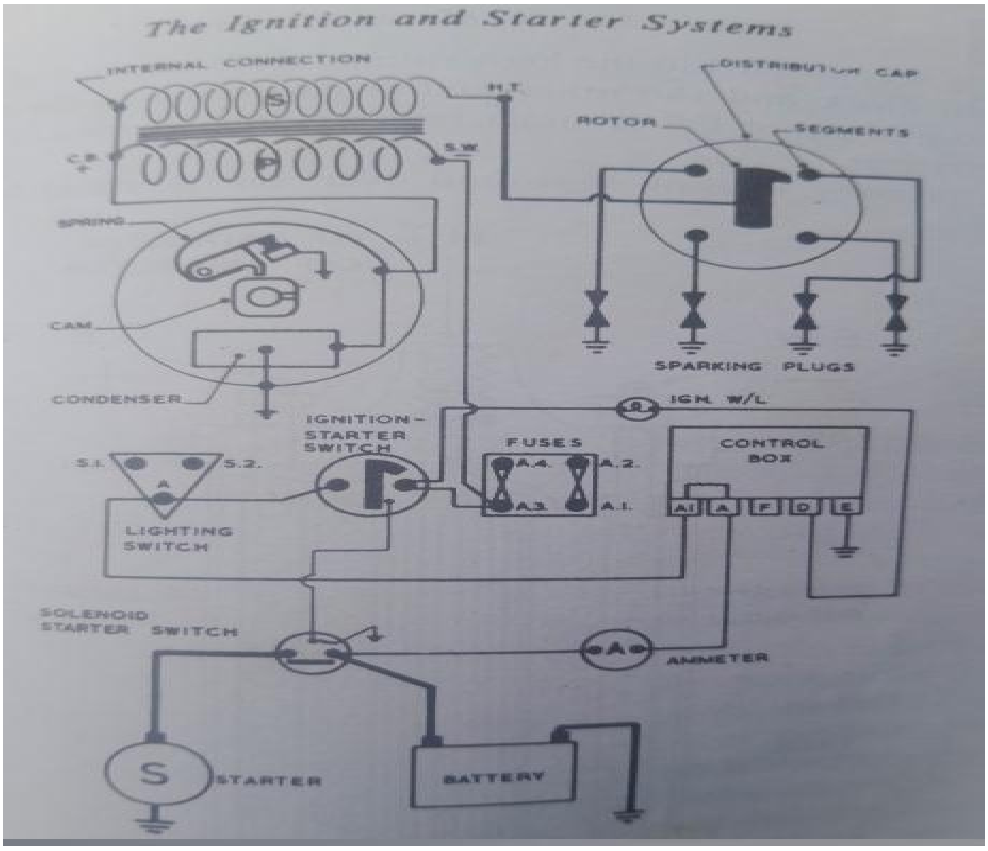
~An ignition coil or transformer which converts the battery voltage into a voltage high enough to cause a spark to jump the gap between the points of a spark plug in a highly compressed mixture of air and fuel.

~ A condenser which helps to provide a stronger spark and also reduces the arcing or burning of the points of the contact breaker.

~ A distributor which directs the high voltage current to the spark plug of whichever cylinder is nearing top dead center on its compression stroke.

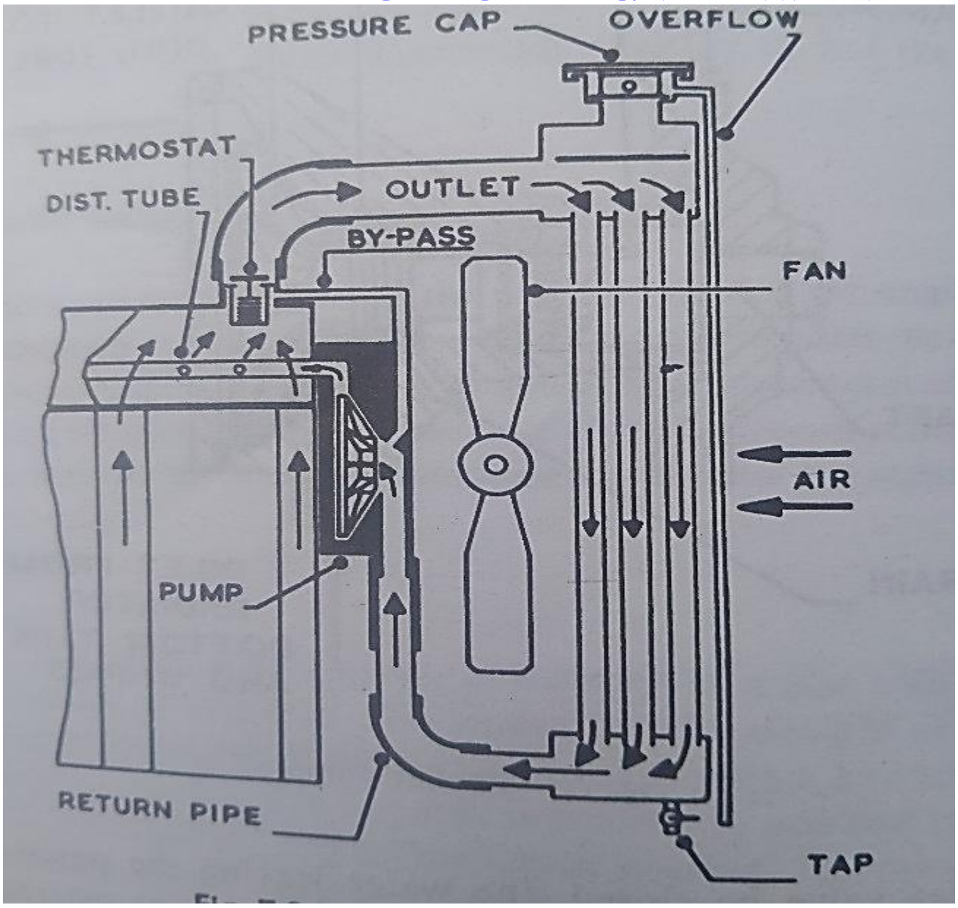
~ A spark plug for each engine cylinder. This introduces the spark into the compressed mixture or air and fuel in the cylinder.

An ignition switch is used to control the flow of battery current through the contact breaker and the primary winding of the ignition coil.



Ignition system fig. 6

r) THE COOLING SYSTEM: In all type of vehicle engine the power is derived from the expansion of air. The necessary heat is obtained by the burning of the fuel in the air, and this produces temperatures which are higher than the melting point of the materials. The radiator is designed to expose to the air stream as large a cooling area as possible in as small a frontal area as possible. In this system, the impeller pump draws cooled water from the bottom tank of the radiator and passes it into the distributor tube. The fan is used to draw air through the radiator core. The tube directs cooled water through its perforations on to the hottest areas of metal surrounding the combustion chambers and the exhaust ports. The cooled water absorbs most of the heat and passes up around the open valve of the thermostat and out of the cylinder head to the top tank of the radiator. As the heated water passes down the radiator core, the absorbed heat is removed by into the impeller pump to be recirculated.



Cooling system fig. 7

s) THE FUEL TANK: The fuel tank stores fuel for the engine, providing a reservoir for the fuel system. It supplies fuel to the engine through the fuel pump and fuel lines, also helps regulate fuel pressure in the fuel system. A fuel filter is a critical component of a vehicle fuel system that is responsible for removing contaminants and impurities from the fuel, by removing dirt, dust, and other contaminants from the fuel, ensuring it's clean and free of impurities.

- DYNAMOMETER: A dynamometer is a device used to measure the

engine's power output and torque.

- FUEL MEASUREMENT SYSTEM: This is a system used to measure the engine's fuel consumption, including fuel flow meters and fuel pressure sensors.
- EMISSIONS MEASUREMENT SYSTEM: A system used to measure the engine's emission, including emissions analyzers and sampling systems.
- DATA ACQUISITION SYSTEM: A system used to collect and analyze data from the various sensors and instruments, including data acquisition cards, software, and computers.

ENGINE ASSEMBLING

The engine block and the cylinder is bolted together, and the crankshaft is installed in the engine block. The pistons are attached to the connecting rods, which are then attached to the crankshaft. Camshaft is installed in the cylinder head, and the valve train is attached to the camshaft. The valves are installed in the cylinder head. The spark plugs are installed in the cylinder head. The fuel system is connected to the engine. The ignition system is connected to the engine. Accessory components such as the alternator, water pump, and the battery are installed and connected to the engine. The dynamometer is connected to the engine output shaft. Fuel measurement system is connected to the fuel supply line. Emission measuring system is connected to the exhaust system.

RESULTS AND ANALYSIS

The rehabilitation and upgrading techniques of a configured spark ignition engine test bed involve various methods to optimize engine performance, result in improved engine efficiency, leading to better fuel economy and reduced emissions. It increases power output, torque, and overall engine performance, reduces emissions such as CO, HC, and NOx, by optimizing engine operating conditions.

A proper engine configuration can improve engine reliability, reducing the risk of engine failure and downtime. The configuration of a spark ignition engine test bed is critical in ensuring accurate and reliable test results, and components that includes a cylinders as chambers where the fuel is burned through the pistons that moves up and down in the cylinders, driven by the explosive force of the fuel, connected to a crankshaft that converts the up-and-down motion of the pistons into rotary motion, and a camshaft that operates the valves that allow air and fuel into the cylinders and exhaust gases out of the cylinders, integrated to a valves that control the flow of air and fuel into the cylinders and exhaust gases out of the cylinders. It is essential that, when the mixture is first ignited by the spark plug, a very rapid burning of the mixture occurs. The rate of burning must then be slowed to produce a smooth and powerful power stoke as the piston passes over top dead center (T.D.C.). The rate must then be increased to burn the remaining portion of the mixture before the exhaust valve is opened. The principle involves air and fuel drawn into the cylinders through the intake valves, the air and fuel mixture is compressed by the piston, the spark plug ignites the compressed air and fuel mixture, producing a small explosion, the explosion drives the piston down, which turns the crankshaft, while the exhaust valves open and the exhaust gases are released out of the cylinders. The final portion of mixture to be burned is often called (end gas) and it must be kept relatively cool to avoid (detonation) or (pinking). Detonation is the instantaneous combustion of the end gas and results from the gas being subjected to temperatures and pressures above those normal for a combustion chamber of that design. Detonation always occurs after the mixture has been ignited in the usual way by the spark plug.

Normally the flame spreads in a fairly steady sequence but the rate of travel increases towards the end of combustion. The end gas is therefore subjected to pressure and to radiated heat and, if for some reason the temperature of the end gas becomes too high, it will burn instantaneously and not progressively. The instantaneous combustion results in an uncontrolled and very rapid rise in pressure which is made evident by a knocking sound in the chamber. The sound is produced by the pressure shock wave striking the piston crown, and this can cause damage to the piston and the bearings if allowed to continue over a long period. Detonation wastes petrol and reduces the power output.

The test bed is equipped with specialized equipment, including a ``dynamometer that is connected to the engine crankshaft and measured the rotational speed and torque of the engine. A fuel measurement system that measured the engine fuel consumption which include a fuel flow meter and a fuel pressure meter. An emission measurement system is used to measure the engine emissions, including carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx), also include an emission analyzer with a sampling system. A data acquisition system used to collect and analyze data from the various sensors used as an instruments that includes a data acquisition card, software, and a computer. The integration of these systems required careful consideration to ensure seamless communication and accurate data collection.

CONCLUSION

Internal combustion engine is still an essential part of our transportation system, and continue to be vital for global transportation, and advancing efficiency and sustainability even as the automotive sector navigates profound changes. In order to ensure that the pulse of mobility resonates with both the legacy of combustion engines and the demands of a fast changing automotive market. Internal combustion engines are advancing the transition to a more efficient and sustainable future, whether through hybridization, the use of cleaner fuels or the integration of artificial intelligence. The study presents a comprehensive rehabilitation and upgrading strategy for the configuration techniques of a spark ignition engine test bed. The proposed approach enhances the test bed's capabilities, improves engine performance, and reduce emissions. The findings of this study can be applied to various engine test beds, enabling the optimization of engine configuration techniques and contributing to the development of more efficient and environmentally friendly engines

References

[1] Edward Arnold: Technology for Motor Mechanics part 3

[2] Shantanu Ingale: Fueling Advancement in Development of Internal Combustion Engine Designs-(2023) Volume 12, Issue 6.

[3] Amarki, Jamial Da Silva, Joao Nuno Pomet, Adrian Pantelimon, Bogdan: Design and Construction of a new , adaptable, test bed mounting system for an internal, combustion engine-2016