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Duke Engine: An Overview of Present State of Art and Future Potential

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Abstract: ***During the past three centuries, there has always been an emphasis on development of a kind of engine that has superior efficiency, less polluting and good power generation. Among them, a recent innovation is duke engine. It is an advanced stage of simple 4 stroke IC Engine which is capable of producing high speed with low vibrations, has an axially arranged arrangement with five cylinder and three injector systems. This engine has a negligible first order vibration and is also expected to have low vibrations in higher order running. Being compact in size, there is more reduction in weight and on the other hand, it is capable of generating heavy torque. This 3rd generation engine has the ability to run on different combustible fuels and petroleum products at different octane level. Thus it has potential in replacement for petroleum based fuels such as biofuels, compressed natural gas, liquefied petroleum gas, suitable mixtures with Methanol/ Ethanol, Hydrogen etc. Due to utilisation of less components, there is reduction in manufacturing and production cost that could lead to great economic value. This engine delivers a superior torque at high power density and a counter rotating cylinder leading to cancellation of gyroscopic forces. In this review, an effort has been done to highlight various aspects of Duke Engine.***

Keywords: duke, mechanical, internal combustion, power, engine

1. Introduction

The internal combustion engine is a heat engine that converts one form of energy (chemical energy) into mechanical energy. Inside the cylinder of the engine, due to combustion or oxidation with air the fuel's chemical energy is converted into thermal energy. The temperature and pressure of gases is raised by this thermal energy within the combustion chamber and high-pressure expands against the mechanical mechanisms of the engine [1].Classification of Internal-combustion is shown in figure a.

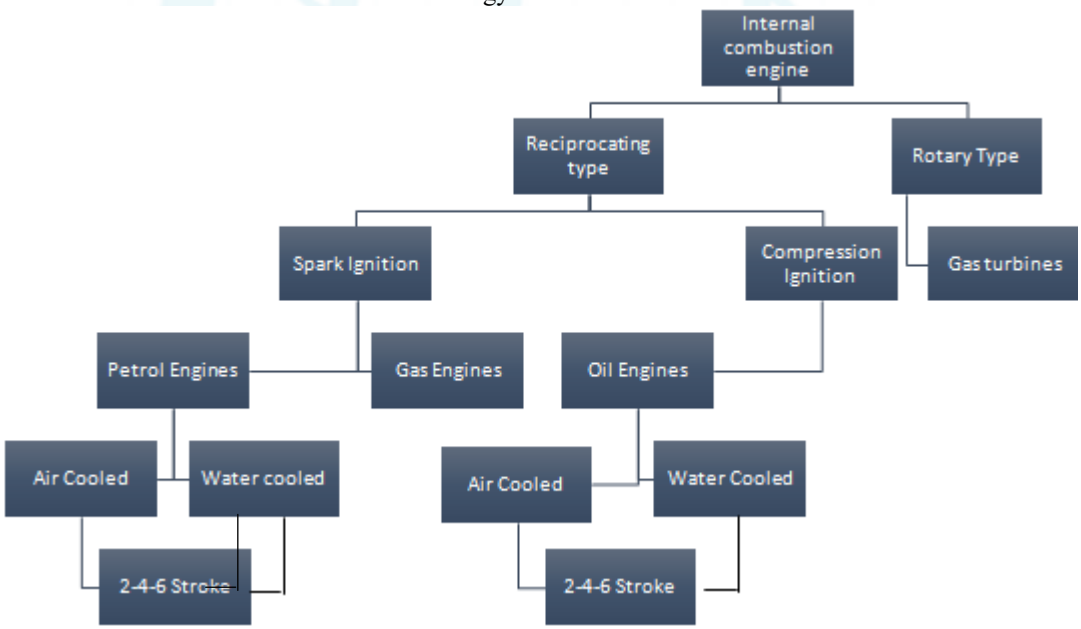

Figure 1: Classification of Internal Combustion Engines
Source- Rajput 2008[1]

2. Historical Aspects

The rapid depletion of fossil fuels and rising of oil prices has led to increase the efficiency of IC engines output. During the 19thbeginning of century, there were a lot of developments in IC engines and in 1860, J.J.E Lenior practically introduced first engine with the power generation of 4.5 kW and mechanical efficiency of 5% [2]. In,1867, Otto- Langen further improved the efficiency to 11% by designing a type of atmospheric engine with the power stroke propelled by atmospheric pressure acting against the vacuum [2]. In 1870's,there was a great focus on development and modification of encouraged four stroke IC engine which Nikolaus August Otto and Langen to develop first internal combustion engine that compressed the fuel mixture prior to combustion for far higher efficiency than any other engine developed that time [3]. Although, in 21st century many modifications were made in axial engines and a new compact engine was made There are many axial engines and several modifications were made in these engines and that are summarized in Fig 2.

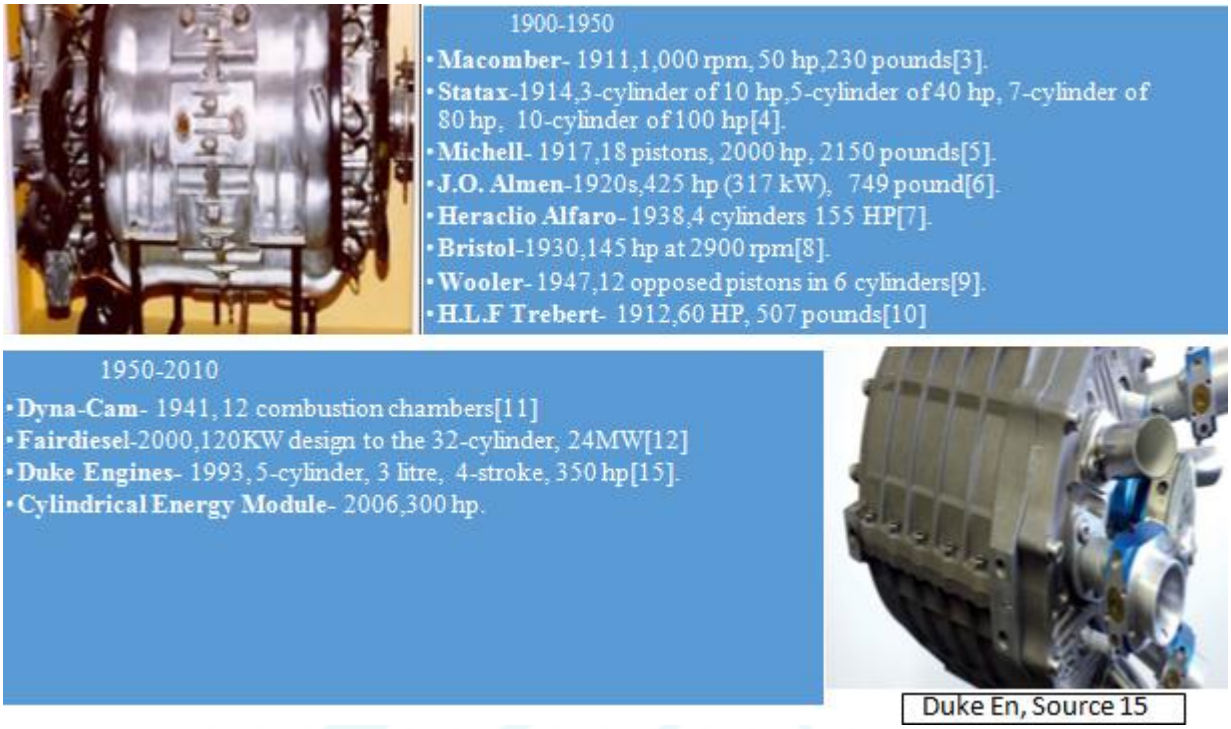

Figure 2: Various axial engines

A third generation engine namely duke engine came up with numerous advantages in terms of size, power, pollution and overall efficiency.

Axial engines

These are the engines which are alternatively known as barrel or Z-crankengines in which pistons are arranged in such a way that the reciprocating motion is achieved and supplied to the output with their axes parallel to the shaft. The name Barrel refers to the axial engines which are having cylindrical shape [1].

Duke engine

Many modifications were made to improve the efficiency of four stroke engines, one example is modifications of Forced Induction that creates more power without an increment in the size of engine [4], Here, Carburettors are replaced by Fuel Injection due to which there is better throttle response, easier starting and increased fuel efficiency.

Billions of combustion engines are running worldwide at this time and this era is not going to end right now. A recent modification is Duke Engine. In 1993, the idea of this engine came into the mind of NOEL DUKE, who further tested it in University of Auckland dyno(1998) and named V1 (996cc) engine. In the year 1999, Daihatsu Charade installed this V1 engine. The Daihatsu Charade is a super-mini car produced by the Japanese manufacturer Daihatsu from 1977 to 2000 which considered by Daihatsu as a "large compact" car [5]. Perhaps many developments were made in 2000's i.e., V2.1 (933cc), V2.1(4500rpm), V2.2 (6500rpm) and V3 (3-litre) [6-7]. These improvements were generally in terms of design aspects and fuel injections perspectives. In the year 2011 at UoA dyno,V3i engine was successfully tested on both petrol and JetA1.

Configuration and Working

Noel Duke and his team have described the engine as a four-stroke internal combustion engine which has five cylinders and has a capacity of three litres. The duke engine reforms the linear arrangement into circular orientation creating an axially arranged configuration. It works on basic principle of Wobble-plate as shown in fig 3. A wobble-plate working is similar to a swash plate which is a device used in aircrafts, example is helicopters that translates input via the helicopter flight and controls the motion of the main rotor blades [8]. The motion which is acquired can be simulated by placing a Compact Disc on a ball bearing at wobble-platecentre and pressing down at impact places around its circumference. Although the wobble-plate and swash plate are not basically same devices, a wobble plate does not go round; it is mounted on the Z-shaped crankshaft by a bearing which is articulated to the connecting rods by ball-joints. This wobble-plate nutates like a nutating disc engine which is an internal combustion engine comprising fundamentally of one moving part and a direct drive into the crankshaft [9]. Hence, the wobble plate translates with the motion of a piston into rotary which is further supplied to the output of the engine. The standard pistons are mounted on a single casted machine mono-block which rotates slowly around and in-line with the shaft. These pistons drive a star shaped element called reciprocator(shown in fig 3) which is attached to it and allows all parts to move in sinusoidal motion [4]. The wobble plate is attached with the coaxially attached pistons.

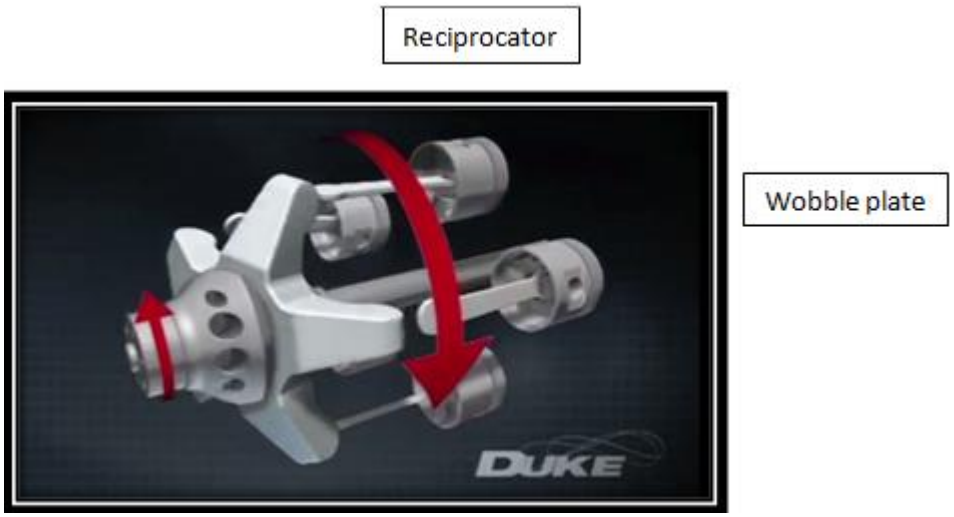

Figure 3: A reciprocator attached with wobble plate source dukeengines.com

A stationary cylinder head ring which is mounted by spark plugs and slide passes forth that leads to a complicated valve system which is utilized and the fuel induction and air charge is supplied by this slide pass mechanism. As the system comprise of 3 sets of inlet port, spark plugs, exhaust ports and relative manifolds [4], the system first gets charge induction through these inlet ports giving induction or suction stroke and then compressed before the cylinder further exposed to spark plug for ignition of power stroke. This power stroke give the momentum to the piston causing the piston to move downward(fig 4). The system is attached to the wobble plate which rotates in accordance with the cylinder head movements causing the piston to reach the exhaust port, hence, the piston rises thereby ejecting the burnt gases and completing the working stroke of the engine.

Usefulness of Duke Engine

Modifications of the engines lead to a discovery of enormous advantages and Duke engine stands in good rank considering in the forms of features of this engine. The engine weighs nearly 101 lbs. or 48.4 kg [4] which is comparatively very small as compared to other internal--combustion engines like 4-stroke with similar number of cylinders (five) and weighs nearly 100-150 kg [4]. Sometimes due to heavy irregular torsion movements there is a lot of vibrations so as to reduce it a heavy flywheel is used but in duke engine there is very regular generation of torque during power stroke because of

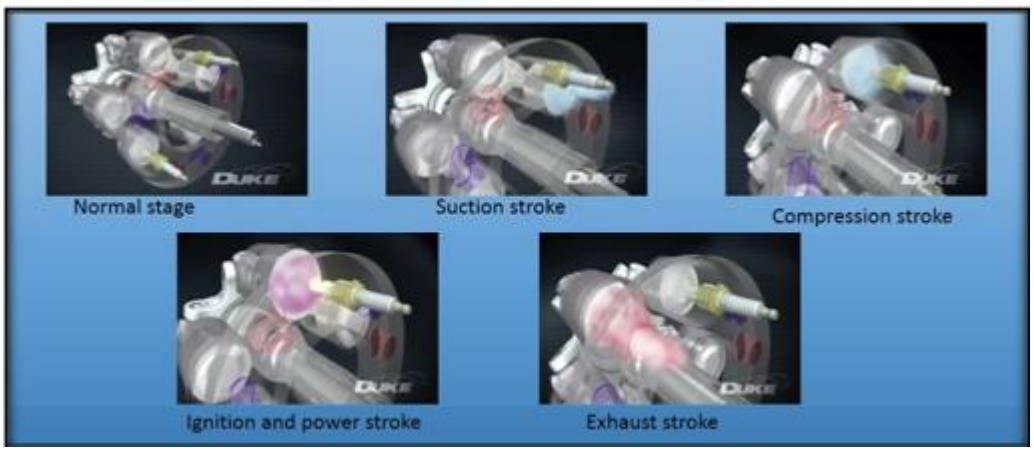

Figure 4: Working of duke engine
Source dukeengines.com

reciprocator attached with the wobble plate. Also, there is partial cancellation of gyroscopic effect which is used in balancing and is achieved from slow speed counter rotation. There are no additional shafts used in this engine for the mechanical balancing of the engine. This engine is very well considered for the applications with power output of nearly 40kW or much more [15]. It will be very useful for marine, aerospace and military agencies as compact vehicles can be used in various applications. The exhaust temperature is really very high as compared to other IC engines which proves it to be an advantage for catalyst light-off application i.e., diesel oxidation catalyst (DOC). Compact Aircrafts boosted with this engine will serve a greater efficiency and economy.

Many search projects in military assembled with a combination of battery operated motor can be replaced by designing a smaller engine of this type so that a heavy power can be generated and even more compactness is achieved.

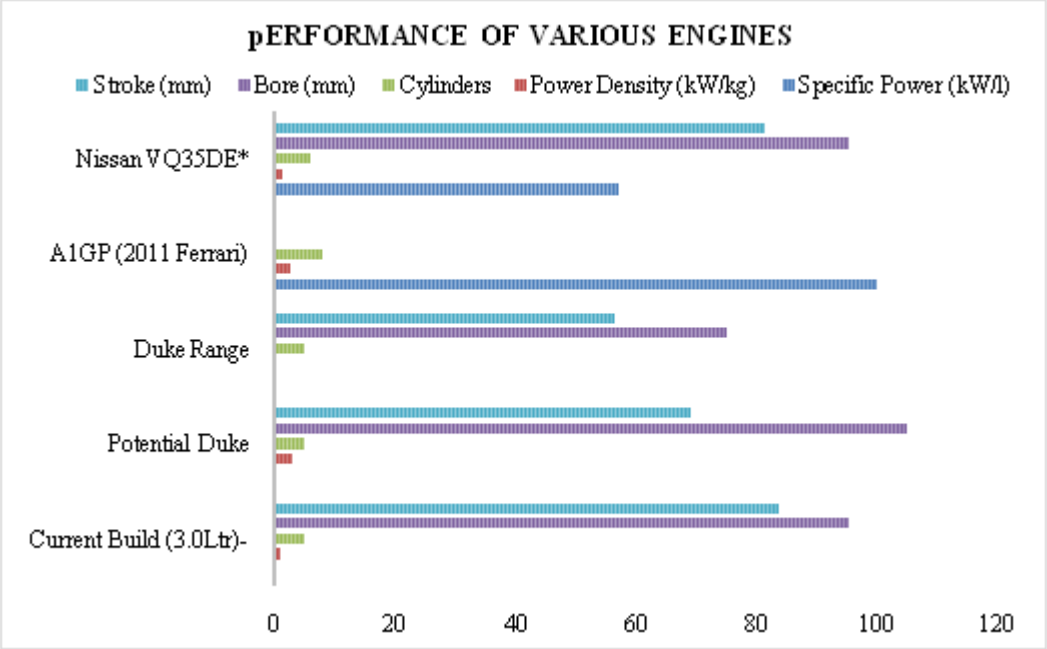

Figure 5: Performance characteristics of various engines (modified from data sheet of http://www.dukeengines.com/advantages/power-density)

This chart summarizes the performance parameters of different engines (fig 5), and compares these engines in terms of various parameters like, bore, lengths of stroke, number of cylinders, power density and the specific power. From the chart it is clear that the duke engine has good or equivalent performance characteristics like other engines with various advantages.

3. Limitations and Future modifications

There are some problems with the design aspects of this engine, the first is the port timing. It is interrelated and not independent from each other as nail port and therefore the control of timing will be very difficult with the variation of load. Also, the charge during the intervals between the strokes is lost hence, reducing the working efficiency of engine.

Due to simpler port mechanism, it is expected to have some charge leakage that can be avoided by Mushroom ports can be used here in the duke engine as it can reduce the charge leakage. Mushrooms ports will have taper ending so that it can reduce the meshing area of contact and hence will not not flow out of the ending, also it will increase the velocity of the charge particles that help in proper combustion in the cylinder.

Pollution can be reduced by addition of diesel oxidation catalyst (DOC) in the exhaust of the engine. Supercharging of this engine will give a very high efficient engine. [10] An engine of compact design i.e., a smaller wobble-plate can be designed for even smaller work applications.

4. Conclusion

Overall economy of Duke Engine is less as compared with modern conventional engines when we concern in terms part or full load fuel performance, design aspects and manufacturing aspects. Frictional losses that faced in internal combustion engines are reduced due to reduction in parts. Diesel oxidation catalyst will be very effective in this engine because of generation of high exhaust temperature.

Addition of practical use of this engine in large scale will change the different parameters like fuel efficiency, pollution, heavy and costly designs etc. hence the operation of this engine leads to a better living standard instead of a simple polluting internal combustion that are in use nowdays.

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