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ROTARY ENGINE TECHNOLOGY- AN OVERVIEW

Abin Mathew

Assistant Professor, Department of Automobile Engineering
Amal Jyothi College of Engineering, Kanjirapally,Kottayam,
Kerala, India

ABSTRACT

Internal combustion engines have been relied upon as principal source of power in a variety of applications throughout the world. Of those engines, the most widely used are the reciprocating piston engines which are found in automobiles and other forms of transportation, as well as in a variety of industrial and consumer applications. It is not appropriate to conclude, however, that the mechanism of the internal combustion engine must be of the reciprocating type solely because the early history and all developments till date of the internal combustion engine is primarily that of the reciprocating one. This work investigates the proposed rotary engine technologies of the world that can revolutionary substitute the underperforming reciprocating engines with much competitive models. No matter how innovative an invention may be, there is no invention that is absolutely perfect from the beginning. Satisfying all the requirements for a practical internal combustion engine is not as simple as to be achieved by a mere casual idea and automotive applications demand still more rigorous requirements. This explains the reason why many efforts for perfecting a practical rotary engine did not succeed. Also the number of years and the scale of research work devoted toward the rotary engine compared with that of the reciprocating engine, however, are still small. This is an effort to discuss breakthrough engine technology of rotary type which has the potential to pursue the part of improvement to achieve the status of a practical engine technology for all sorts of power applications.

Keywords: internal combustion engine; rotary engine; reciprocating engine

1. INTRODUCTION

Rotary engine is defined as an internal combustion engine that performs four strokes of intake, compression, power and exhaust while the working chamber changes its volume and moving parts always rotates in same direction (Yamamota, 1981). Many rotary engines were developed since the first of the type was invented by James Watt in 1759 for his steam engine. To classify rotary engine to sub groups is a tedious task as there are many novel ideas proposed to substitute reciprocating engine and still all remains in the paper as design proposals expect Wankel engine. Examples of other models proposed are planetary rotary engine, Noval rotary engine, variable geometric toroidal engine, radial engines, monosoupage engine, Gnome engine, nutating internal combustion engine, and quasi-turbine and so on. This work intent to study basics and the problems associated with very familiar and the only commercialized rotary engine- Wankel engine and two less popular but highly potential rotary engine models namely Mighty Yet Tiny Engine belonging to planetary rotary engine group.

The rotary engine has lot of advantages that make it a formidable contender for some of the tasks currently performed by reciprocating engines. The piston in a four stroke- cycle reciprocating engine must momentarily come to rest four times per cycle as its direction of motion changes. In contrast, the moving parts in a rotary engine are in continuous unidirectional motion. Higher operating speeds, ease of balancing, and absence of vibration are a few of the benefits. The high operating speeds allow the engine to produce twice as much power as a reciprocating engine of the same weight. It has significantly fewer parts and occupies less volume than a reciprocating engine of comparable power. With all these advantages, why are there so few Wankel engines in service? Part of the answer lies in the reciprocating engines remarkable success in so many applications and its continuing improvement with research. Why change a good thing? Manufacturing techniques for reciprocating engines are well known and established, whereas production of rotary engines requires significantly different tooling. While the rotary engine may not enjoy the great success of reciprocating engines, it is worthy of study as an unusual and analytically interesting implementation of the familiar Otto cycle. Even the present success of this latter-day Otto engine should serve as an inspiration to those who search for novel ways of doing things.

2. WANKEL ROTARY ENGINE

Dr. Felix Wankel was the founder of the first successful rotary engine. He was invented in 1957. The engine consists of 3 sided rotor (triangular shaped) which rotates inside a case of some specific shape (two lobed epitrochoid).This combination of housing and rotor shapes ensures that they remain in contact with each other throughout the rotation. Inlet and outlet port is provided on casing for breathing and exhaust. There are 3 separate volumes trapped between rotor and case will perform induction, compression, combustion, expansion and exhaust process in sequences. There are 3 power impulses for each revolution of the rotor. The output shaft rotates three times per one rotation of rotor. So there is only one power per rotation of output shaft. It takes 3 suction ,3 compression ,3 power and 3 exhaust in one rotation of rotor. One Wankel engine is equivalent for 3 cylinder four stroke engines. The engine has a three lobe rotor which is driven eccentrically in a casing in such a way that there are thrice separate volumes trapped between the rotor and the casing. These three volumes perform induction, compression, combustion, expansion and exhaust process in sequence.

2.1 Problems assoiated with Wankel Engine

There are two major design problems assoiated with Wankel engines; fuel efficiency and complicated design of the seal.

2.1.1 Fuel Efficiency: A major problem of the Wankel automobile engine is that it does not quite measure up to the fuel economy of some automotive reciprocating SI engines. It is the judgment of some authorities that it does not offer as great a potential for improvement in fuel economy and emissions reduction as reciprocating and gas turbine engines. Continued engineering research on the rotary engine has resulted in performance improvements through lean-burn combustion, fuel injection, integral electronic control, improved intake design, weight reduction, and turbocharging. Despite vehicle weight increases, the Mazda RX-7 with a two-rotor 1380 cm^3 –displacement engine improved 9.4% in fuel consumption and 8% in power output between 1984 and 1987 (Fujimoto, 1987). During this time period, the addition to the engine of a turbocharger with intercooling increased its power output by 35%. Rotary engine has inherent resistance to knock(Yamamota,et al., 1980) also allow a scope for various blends of various biofuels.

2.1.2 Apex Seal: The problem of properly sealing a Wankel engine's moving parts is a tough one. While piston engines use multiple springy steel rings for sealing their round pistons against the round cylinders, and get reasonably good results from this simple and age-old technology, the problem is much harder in the Wankel engine. 30 % more blow by gas compared to that of reciprocating engines passes through the apex seal when wankel engine is running at slow speeds(Jost,200). There are long, flat edges to be sealed. The corners formed by the apex seals and the rotor-to-wall seals are particularly hard to get airtight. And bad sealing not only makes an engine loose power, and burn more fuel, but it also causes lots of additional pollution - something that is unacceptable in today's world. Fortunately the technology has brought great advances in this field.. So today it all boils down to Wankel seals being more costly than piston rings, but they are approaching the same level of reliability and effectiveness. However, there is still large scope for improvement in the design of the seal which could completely change the popularity and usefulness of this engine. Springloaded, self-lubricating apex seals which allow for sliding with low friction over the treated-chrome-alloy-plated housing inner surface used in Madza RX-7 rotary engine.

3. MIGHTY YET TINY (MYT) ENGINE

Raphial Morgado in association with Angel Labs, LLC in Lodi, California, developed the concept of Mighty Yet Tiny Engine (US Patent 6,739,307,2004). MYT Engine is a piston less toroidal cylinder rotary engines in which pistons on different rotors move relative to each other to form chambers of variable volume. The engine uses solid rotor rotating inside the combustion chamber.MYT Engine's toroidal chamber features 4 sets of piston pairs in each of the two disks that are connected to crankshaft. They not only rotate around the central shaft but can also move in relation to each other which lead to brand new concept of Virtual displacement. The Mighty Yet Tiny engine can be consider as an assembly of two parts, namely, 1)the toroidal chamber and the rotor assembly and 2) the output shaft and the related embodiment. The Otto or Diesel cycle process is carried out in the toroidal chamber and the conversion of the step-wise rotary motion obtained in each of the individual rotor is converted continuous circular rotary motion by the output shaft and its related embodiment.

3.1 Working

The working of mighty yet tiny engine can be split into two parts; first one power production and second one power transmission

3.1.1 Power Production in Mighty Yet Tiny Engine: The pistons move in stepwise fashion(cat-and-mouse type or scissor action), with the pistons on one rotor travelling a predetermined distance while the pistons on the other rotor remain substantially stationary. Fuel is drawn into a chamber as one of the pistons defining the chamber moves away from the other, and then compressed as the second piston moves toward the first. Combustion of the fuel drives the first piston away from the second, and the spent gases are then expelled from the chamber by the second piston moving again toward the first. The reason why the MYT Engine is so huge in displacement is because of frequent firing. It fires 16 times in one rotation, making it equivalent to 32cylinder, four stroke engine. With four pistons on each rotor and a 4:1 ratio between the sun and crankshaft gears, eight chambers are formed between the pistons, and there are two power strokes in each of those chambers for each revolution of the output shaft. In two shaft revolutions, there are 32 power strokes, which is equivalent to having 32 cylinders in a conventional 4-stroke engine. The crosssectional view of myt engine is shown in Figure 1.

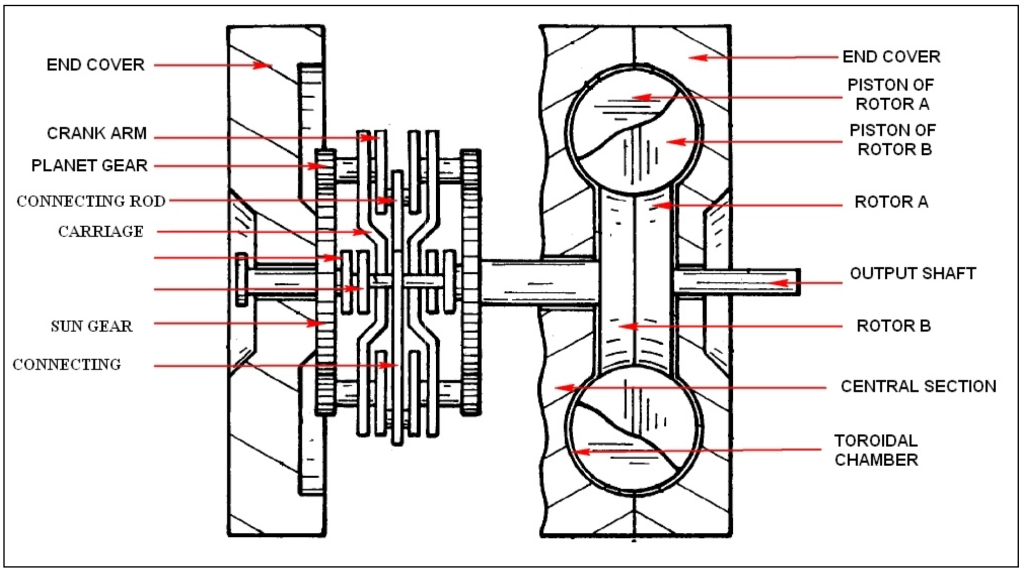
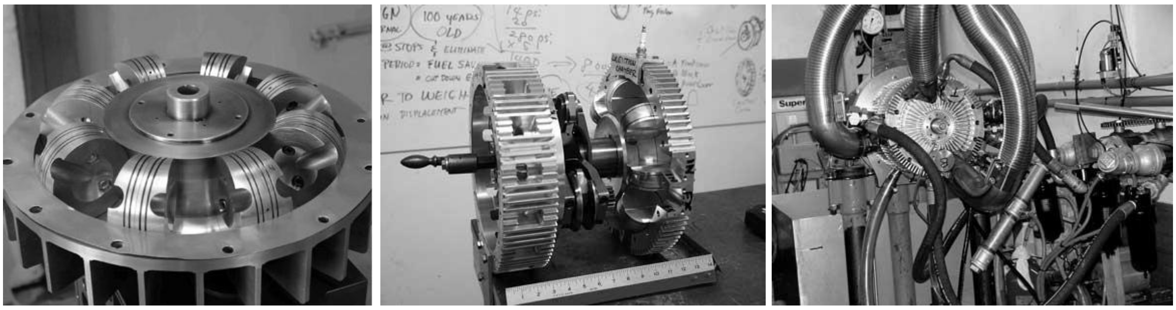


Figure.1. Cross Sectional View of MYT Engine(US Patent 6,739,307,2004)

3.1.2 *Power Transmission:* The stepwise rotation of the rotors is converted to continuous rotation of the crankshafts by cranks connected to the rotors and connecting rods connected between the cranks and the crankshafts, with the cranks having longer throws than the crankshafts. This is further imparted to the carrier and the output shaft by engaging planet gears connected to the crankshafts with a sun gear disposed coaxially of the output shaft. connecting rods interconnecting the crank arms and the crankshafts such that the crankshafts rotate continuously as the crank arms turn alternately in stepwise fashion, with the pistons on one rotor remaining substantially stationary and forming seals between the intake and exhaust ports while the pistons on the other rotor advance, drawing fuel into chambers in communication with the intake ports and expelling exhaust gas from chambers in communication with the exhaust ports and gears on the crankshafts in meshing engagement with the sun gear for rotating the carrier and the output shaft continuously about the axis of the output shaft as the pistons move in stepwise fashion and the crankshafts rotate about their axes. The prototype of engine developed and exhibited by Raphial Morgado and angels lab is given in Figure 2.

3.2 Benifits of MYT Engine over convential engine

Biggest benifit of toroidal chamber is that it reduces the sealing problems compared to wankel engine. The pistons can use pistion rings as in case of reciprocating internal combustion engine. The theoretical efficiency of the Otto cycle engine is given by: $ή = 1-1/(r)^{γ-1}$,where r is the compression ratio and γ is the ratio of specific heat at constant pressure to specific heat at the constant volume. Assuming γ = 1.4 and V1/V2 = 8 the theoretical efficiency would be approximately 56.5%.But if VI'/V2 = 20,then the theoretical efficiency would be approximately 67%,an increase of about 18.6%. Also At TDC piston of standard internal combustion engine has zero degrees of duration – in other words, the piston is always either approaching TDC or leaving it, but it doesn't ever remain there. In comparison, the MYT Engine has a carry-over of 12 degrees at TDC due to the 2 crankshafts' duration at the timing events. It leads to very clean combustion of the fuel-air mixture that lasts the duration of the power stroke, giving us better performance and a cleaner burn than in a conventional engine by reducing Carbon Monoxide, Hydrocarbon and NOX and other gases. Another great advantage of the engine is the less number of parts used in the engine. Compared to 1000 of the parts of the standard reciprocating counterpart it has a total part count of just 31 of which only 15 takes part in any type of motion.



(a) (b) (b)

Figure 2. Mighty Yet Tiny Engine; (a) Toroidal Chamber with 4 pistons on each planetary disc (b) Prototype of MYT Engine exihibited in Nasa Techbrief 2005 (c) Air motoring of the MYT Engine through 4 ports Result:1100 Nm torque from 10 bar air input (courtesy:Angel Labs, http://www.angellabsllc.com)

3.3 Disadvantages:

The consideration of material science is much more in the case of this engine as high power is transmitted through small shafts considering its size. A new fuel injection and spark distribution method must be employed as the engine has no cam shaft or timing mechanisms. The initial cost is high as new production and assembly line is to be established for the mass production of machinery. The step wise rotary motion and the stop and start of alternate rotors is achieved by a complex mechanism which needs much consideration and care in design.

4. CONCLUSION

MYT Engine is thus a promising rotary engine technology for who belives in the multiple benifits of rotary engine technology. Advanced manufacturing tools and systems may be required for producing this engine on commercial basis. It provides a very compact and highly efficient engine which can be used in a variety of applications, both large and small, also it can burn a variety of fuels including bio fuels. Yo -mobile, a hibrid car concept form Yo –auto, Russia is lickly to produce first car power by a concept similar to this engine. Advanced research and studies are recommented in detail to unleash real potential of this Engine.

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