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**1] Introduction**

The **Internal Combustion Engine** is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine, the expansion of the high-temperature and -pressure gases produced by combustion applies direct force to some component of the engine, such as pistons, turbine blades, or a nozzle. This force moves the component over a distance, generating useful mechanical energy.

Internal Combustion Engines have been the mainstay of economy since past two hundred years. The economy has grown influenced by developments in the field of IC Engines.

Statistics show that over half the total production of petroleum is used by automobiles. As these fuels are being burnt, very high amounts of Carbon di-oxide [CO2], Carbon Monoxide [CO], Un-burnt Hydrocarbons [HC], and Nitrogen Oxides [NO] are being let out into atmosphere. These poisonous gases are creating ozone layer depreciation, **Green House Effect**. Global Warming as a result will be very disastrous with scientists predicting that Earth’s polar ice cap will melt and ocean water levels will rise by 3 meters. This has led the observers to pinpoint IC Engines as main culprits.

Hence growing environmental awareness, Rising fuel costs, lack of equally easily usable resource, realization of fact that fossil fuels which supply almost over 75% of human energy needs are to run out in a hundred years from now has influenced, scientists, researchers and engineers to work on and develop better energy utilizing, highly efficient, cost-effective IC Engines also named as **Green** **Engines**.

With many institutions in educational and corporate sectors investing their talent, money and time in development of new types of IC Engines also called ‘**Green Engines**’ the scary and grim situation has begun to look less scary and less grim and future for such types of engines looks very promising.

**2]** **Types of Green Engines:**

1. **Turbocombustion Green Engine** by Perfect Motor Corp., LA, USA.
2. **Radial Internal Combustion Wave Rotor** by Michigan State University, USA and Warsaw Institute of Technology, Poland.
3. **Green Engine** by Paradigm Energy Conversion Systems, USA.
4. **Internally Radiating Impulse Structure Engines** by IRIS Engine Inc.

**3] Construction & Working**

3.1] Turbocombustion Green Engine:

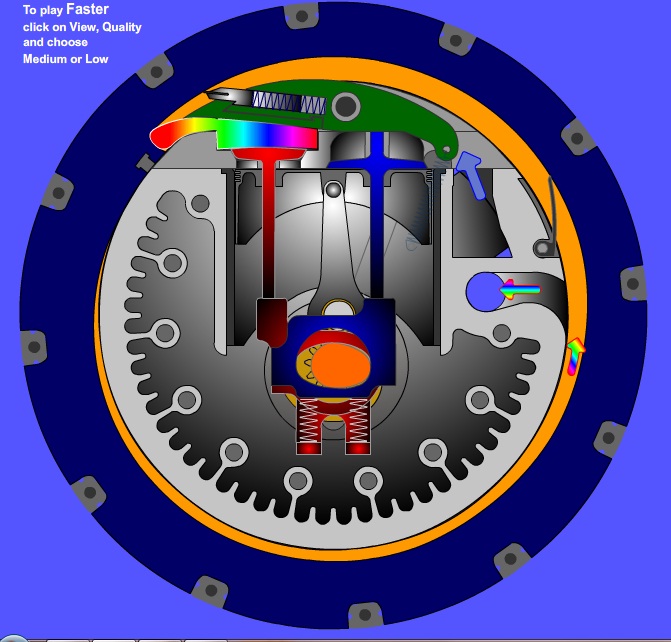


Fig1: Turbocombustion Green Engine cut view

This Engine is a developmental research project by Perfect Motor Corp., LA, USA. A single cylinder engine consists of a piston mounted at 90 degrees to the rotor such that the combustion force is applied tangential to the rotor and at maximum pressure angle possible.

The Engine has a piston, a fuel intake valve, a spark plug, an exhaust valve, a cam-operated crankshaft and a rotor also acting as a casing which allows for expansion of hot gases and also allows the hot gases to directly transfer their energy to the rotor.

The Working of this engine takes place as such, the air-fuel mixture is sent in axially to the engine. In the intake cycle, the mixture is sent in through inlet valve. The piston compresses the mixture in its compression cycle and by the action of spark plug the fuel is ignited. Combustion of fuel takes place. Immediately the exhaust valve opens into the rotor where the combusting mixture expands and transfers its energy to the rotor. As the rotor rotates the energy is transferred to the main shaft or the wheel.

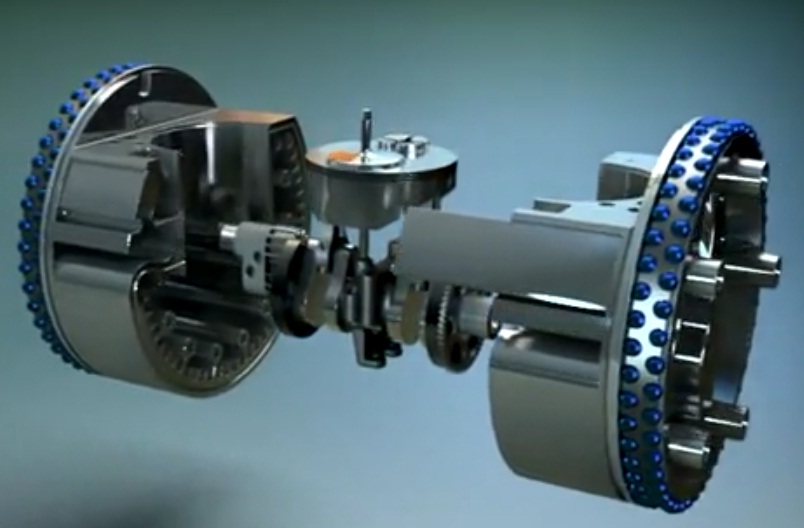


Fig2: Turbocombustion Green Engine parts

3.2] Radial Internal Combustion Wave Rotor:

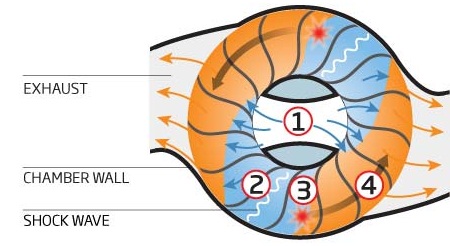


Fig.3: Radial Internal Combustion Wave Rotor symbolic diagram

This Engine has been a research project by Michigan State University, USA and Warsaw Institute of Technology, Poland. It has been recently funded by US’s Dept. of Energy’s ARPA-E program to the amount of $2.5million.

The design does away with many of the components of a conventional engine, including pistons, camshaft and valves.

It is a piston-less rotary engine. The engine has a spinning disk with curved blades. As the rotor spins, the air-fuel mixture fills up the chambers. Pressure builds up when the inlet and outlets are blocked and the air-fuel mixture gets compressed. This mixture then ignites. This sends shockwaves within the chamber. As the gas escapes at high speed, it pushes against the blade-like ridges inside the rotor, keeping it spinning and generating power.

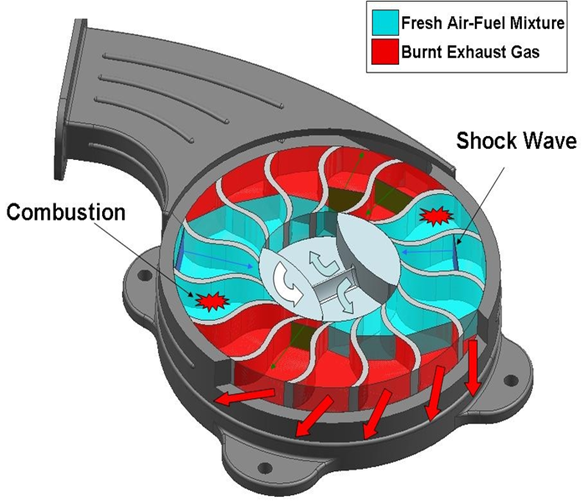


Fig.4: Another view of Radial Internal Combustion Wave Rotor

3.3] Green Engine (Paradigm Engine):



Fig.5: Prototype of Green Engine [2009]

This engine has been developed by Paradigm Energy Conversions Systems Inc., USA. The Green engine is a six phase, internal combustion engine with much higher expansion ratio. The term “phase” is used instead of “stroke” because stroke is actually associated to the movement of the piston.

The engine comprises a set of vanes, a pair of rotors which houses a number of small pot-like containers. It is here, in these small containers that compression, mixing, combustion are carried out. The engine also contains two air intake ports, and a pair of fuel injectors and spark plugs.

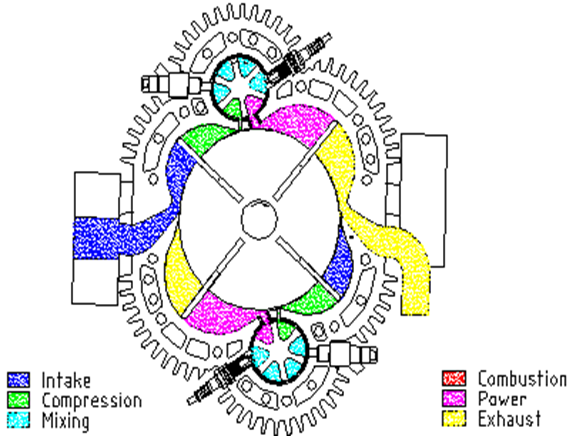


Fig.6: Symbolic Diagram of Cut-Section of Green Engine.

**Intake-**The air arrives to the engine through the direct air intake port in the absence of an air inlet pipe, throttle and inlet valves on the air intake system. A duct is provided on the sides of the vane and rotor. The duct is so shaped that when the air moves through, strong swirls generate when it gets compressed in the chamber.

**Compression-**The rushing air from the duct is pushed by the blades into the small chambers in the rotor. The volume of these chambers is comparatively very small.

**Mixing-**As soon as the chamber comes in front of the fuel injector, the injector sprays fuel into the compressed air. Because of the shape of the chamber, the fuel mixes well with the compressed air. Because of the strong swirling, a centrifugal effect is exerted in the air-fuel mixture. Moreover, the rotation of the burner, makes this centrifugal effect all the more effective.

**Combustion-**As the chamber rotates towards the “end” of its path, it is positioned before the spark plug. A spark flies from the plug into the air-fuel mixture. Because of the mixing phase, the air-fuel mixture is denser near the spark plug, thereby, enabling lean-burning of the charge and also a uniform flame front. As soon as the whole charge is ignited, the burner rotates to position itself in front of the narrow exit.

**Power-**The expanded gas rushes out of the chamber through the narrow opening, thereby pushing the name in the process. The sudden increase in volume ensures that more power is released. Or in other words, the thermal energy is fully utilized.

**Exhaust-**As the thermal energy is fully utilized, the exhaust gases bring along comparatively less heat energy. This mainly helps in the thermal efficiency of the engine.

3.4] Internally Radiating Impulse Structure Engine:

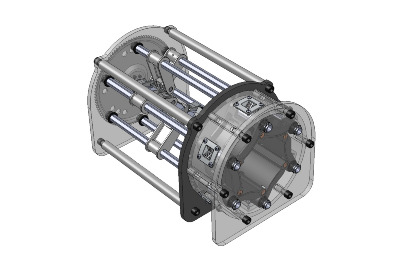


Fig.7: IRIS Engine representation

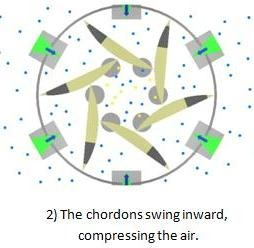
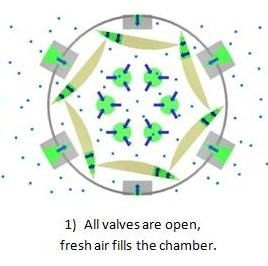
The Internally Radiating Impulse Structure (IRIS) is an advanced internal combustion engine design with thermal, volumetric and cycling efficiencies superior to those currently available or under development in ICEs.

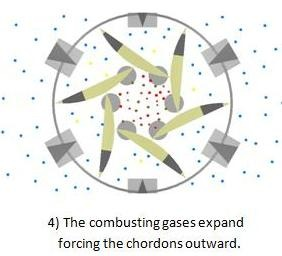
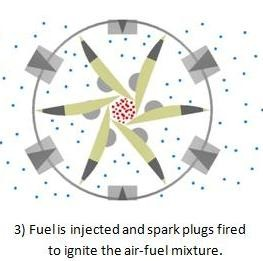
The IRIS is a transformational geometry for the ICE combustion chamber that increases the area of the chamber reacting productively to expanding gases.

In an IRIS combustion chamber, a number of inverted segments of a circle, or "chordons," interact to create a continuously sealed chamber of variable volume. Instead of elongating during combustion, as a traditional engine does, the IRIS engine's chamber expands in diameter. The inventors’ claim that this innovation will reduce waste heat and will increase the amount of surface area the engine has available to produce torque.

The IRIS offers the simplicity of a two-stroke combustion cycle with the efficiency of a four-stroke engine.

The working can be explained in a series of images as follows:





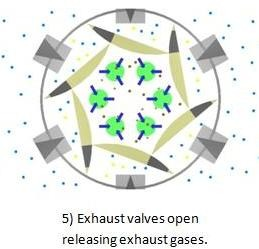


Fig.8: IRIS Engine working schematic diagrams.

IRIS technology addresses a primary cause of inefficiency in ICEs by expanding in diameter rather than length, increasing the ratio of “productive surface area” (area that does work) to “passive surface area” (area that generates waste heat).

The IRIS changes the combustion chamber's design from one piston in a cylinder to six "chordons" which act as expanding walls.

The IRIS chamber expands in diameter. This design innovation means the vast majority of the IRIS's surface area reacts productively to the forces of combustion, generating torque throughout each combustion cycle.

**4] Advantages:**

Turbocombustion Green Engine:

* Complete cycles occur in every rotation, suction and expansion cycles occur simultaneously in half a rotation; compression and exhaust on the other half, allowing power stroke on every rotating cycle.
* Expansion capacity in a Turbocombustion Engine is much larger than the cylinder capacity.
* Constant suction and compression by the piston eliminates the throw and, consequently, the vertical vibration. Since the expansion occurs outside of the cylinder, the piston’s weight is reduced to a minimum and is perfectly balanced with the crankshaft to minimize or eliminate the horizontal vibration.
* The power stroke outside of the cylinder significantly diminishes oil deterioration, prolongs the moving parts life, and uniforms overall engine

temperature.

Radial Internal Combustion Wave Rotor:

* Works without a cooling system, saving weight.
* The rotational speed of the wave disk engine is lower, which creates lower stress on material.
* Prototype testing results indicate it to be 3.5x more efficient than conventional IC Engines.
* 20% lighter.
* 30% cheaper to manufacture.
* Reduce emissions by 90 percent.

Green Engine (Paradigm Engine):

* Direct Air Intake.
* Superior Quality of Air-Fuel Mixing.
* High Expansion Ratio.
* Modular Design.
* Limited Parts, Small Size and Light Weight.
* Multi-fuels.
* Near-zero Emissions.

Internally Radiating Impulse Structure Engine:

* Gases can expand further than in an ordinary engine before opening the exhaust valves.
* 70% of the chamber's surface area is productive.
* The design utilizes an innovative valve/vent system that also enables the engine to breathe far more effectively.
* Power density achieved is superior to 2-stroke engines and efficiency better than that achieved in 4-stroke engines.

**5] Future:**

The Green Engines described here are one of the most recent developments in the field of IC Engines. Only their prototypes are in existence and are currently undergoing extensive testing. These engines can be used in all commercial applications of current IC Engines and also can be used as alternative power resource in Hybrid Vehicles and Electric Vehicles.

**6] Conclusion:**

The Green engine’s prototypes have been recently developed, and also because of the unique design, limitations have not been determined to any extent.

But even in the face of limitations if any, the Green engines promise to serve the purpose to a large extent.

Their higher than industrial standard efficiencies are very promising and will help in reducing pollution caused by their previous generations.

Their promise of multi-fuel capability will hopefully reduce human dependence on fossil fuels to some extent.

**Thank You**

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* Green Engine from [www.greenenginetech.com](http://www.greenenginetech.com).
* Turbocombustion Engine from [www.tcengine.com](http://www.tcengine.com).