Recent Trends in Internal Combustion Engine

Rahul T L

Student of Department of Mechanical Engineering, Siddaganga Institute of Technology Tumakuru, Karnataka, India

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Abstract - *The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar four-stroke and two-stroke piston engines, along with variants, such as the six-stroke piston engine and the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described. The internal combustion engine (or ICE) is quite different from external combustion engines, such as steam or Stirling engines, in which the energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized water or even liquid sodium, heated in some kind of boiler.*

A large number of different designs for ICEs have been developed and built, with a variety of different strengths and weaknesses. Powered by an energy-dense fuel (which is very frequently gasoline, a liquid derived from fossil fuels). While there have been and still are many stationary applications, the real strength of internal combustion engines is in mobile applications and they dominate as a power supply for cars, aircraft, and boats, from the smallest to the largest.

Key Words: Internal combustion engine, four stroke engine, two stroke engine, Fossil fuels, mobile application, power supply.

1. INTRODUCTION

The vehicle propulsion is usually obtained by means of engines, also known as prime movers, i.e. mechanical devices capable to convert the chemical energy of a fuel into mechanical energy. By the way, the English term "engine", is likely to have a French origin in the Old French word "engine" which in turns is thought to come from the Latin "ingenium" (sharing the same root of "ingénieur" or "engineer").

The chemical energy of the fuel is firstly converted into heat through combustion, and then the heat is converted into mechanical work by means of a working medium. This working medium can be a liquid or a gas. Indeed, the heat produced by combustion increases its pressure or its specific volume, and thanks to its expansion, mechanical work is obtained.

In internal combustion engines (ICE), the combustion products (e.g. air and fuel) themselves are used as the working medium, while in external combustion engines, the combustion products transfer heat to a different working medium by means of heat exchanger. Moreover, while in ICE the combustion takes place inside the cylinder, in external combustion engines, the combustion is obtained in a separate chamber, usually called burner.

2. The Trend

The trend of electric-powered cars has grown far beyond hybrids like the ubiquitous Toyota Prius. Early this year, Ford Motor announced that it would develop hybrid versions of both its brawny F-150 pickup, the country's best-selling vehicle, and the performance-focused Mustang. Last month, Volvo said that starting in 2019, all of its newly released models would be hybrid or all-electric. This was quickly followed by the news that France and Britain plan to ban the sale of new petroleum-burning vehicles by 2040.

Definitely. John Heywood, a professor of mechanical engineering at the Massachusetts Institute of Technology, predicts that in 2050, 60 percent of light-duty vehicles will still have combustion engines, often working with electric motors in hybrid systems and largely equipped with a turbocharger. Vehicles powered purely by batteries, he estimates, will make up 15 percent of sales.

The power-boosting advantage of turbochargers is widely deployed today, but in coming years it could be tilted toward the design of smaller engines that still meet customers' needs. "The real benefit comes from downsizing," Dr. Heywood said. "That reduces friction, which chews up a significant part of the energy input."

Dr. Heywood, who has pondered whether he would best serve his students by teaching combustion or electrochemistry, addresses the challenge of gasoline's future from a somewhat different direction: the practical limitations of battery electric cars. "Holding a gas nozzle, you can transfer 10 megawatts of energy in five minutes," he said, explaining today's refueling reality. To recharge a Tesla electric at that rate today, he said, would require "a cable you couldn't hold."

The question is how much better gas engines can get. Conventional piston engines have come a long way, and technical refinements like direct fuel injection, variable valve timing and cylinder shutdown systems are now widespread. Along with innovations in lightweight body materials and dual-clutch transmissions, mileage has steadily improved, so naturally, further gains are now harder to come by — usually in single-digit percentages.

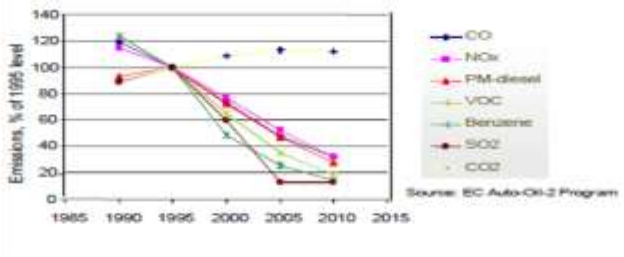

Fig-1: Road Transport emission trend

3. Current Solutions

Engine technology has come a very long way over the decades, from two-valve systems with gravity-fed combustion mixtures to the modern-day fuel injection systems. There's also been an influx in electric vehicle technology, completely eliminating the need for a combustion engine.

Firstly, Diesel Direct Injection (DI) is a basic type of fuel injection system which many earlier generation diesel engines used. The simple DI diesel engines inject the fuel into the combustion chamber above the piston directly. The compression of air inside the combustion chamber raises its temperature above 400oC. Then, it ignites the diesel-fuel injected into the combustion chamber. Hence, the diesel engines are also known as 'Compression Ignition' engines.

This technology i.e. simple DI engine differs in the method by which it supplies the diesel to the injectors and operates them to its successor Common-Rail Direct injection (CRDi). Moreover, it was in vogue until the development of the latter. At present, some heavy diesel vehicles such as utility vehicles, trucks, buses & generators still use DI technology.

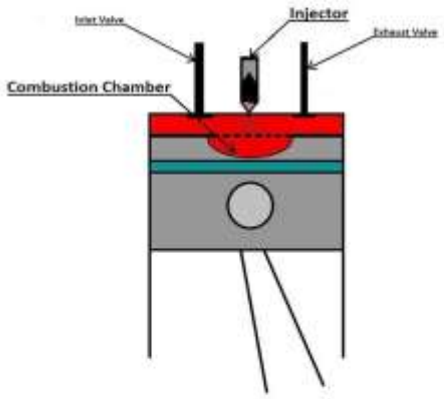

Fig 2: Direct Injection-Working Principle

3.1 Advantages of Direct Injection

1. Power Output

With the exception of some high end modified vehicles, fuel injection usually offers a much better power output and performance than a standard carburetor-based vehicle.

2. Fuel Efficiency

Because fuel injection is usually controlled by a vehicle's electronic control unit or car computer, fuel consumption is usually managed much better than with a carburetor. It almost always results in better fuel efficiency.

3. Emissions Performance

With better fuel efficiency comes better emissions performance. Fuel injected vehicles produce far fewer carbon-based emissions than vehicles with carburetors.

4. Ability to Accommodate Alternative Fuels

Vehicles that use direct fuel injection are better equipped to handle alternative fuels, and fuels with additives that are designed to help keep your car engine clean.

5. Drivability and Smooth Operation

Vehicles that use fuel injection rather than a carburetor usually drive much smoother, because fuel flow is better managed and more consistent.

6. Diagnostic Capability

Because direct injection is regulated by your car's computer, problems with fuel injection can easily be diagnosed with a simple computer diagnostic test.

3.2 Multi Point Fuel Injection

The MPFI is a system or method of injecting fuel into internal combustion engine through multi ports situated on intake valve of each cylinder. It delivers an exact quantity of fuel in each cylinder at the right time.

MPFI includes a fuel pressure regulator, fuel injectors, cylinders, pressure spring and a control diaphragm. It uses multiple individual injectors to insert fuel in each cylinder through intake port situated upstream of cylinder's intake value. The fuel pressure regulator, connected to the fuel rail by means of an inlet and outlet, directs the flow of the fuel. While the control diaphragm and pressure spring controls the outlet valve opening and the amount of fuel that can return. The pressure in the intake manifold significantly changes with the engine speed and load.

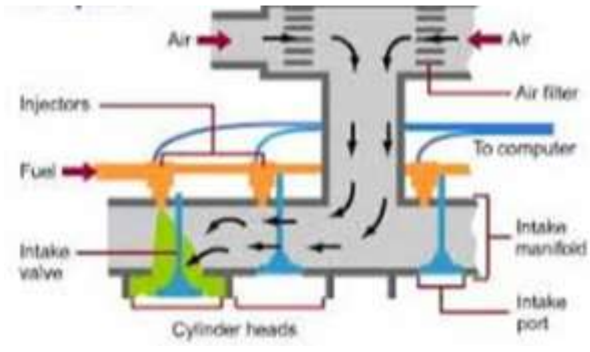

Fig 3: Multi-Point Fuel Injection

3.3 Advantages of multi point fuel injection system

• The multi-point fuel injection technology improves fuel efficiency of the vehicles. MPFI uses individual fuel injector for each cylinder, thus there is no gas wastage over time. It reduces the fuel consumption and makes the vehicle more efficient and economical.

- The vehicles with MPFI automobile technology have lower carbon emissions than a few decades old vehicles. It reduces the emission of the hazardous chemicals or smoke, released when fuel is burned. The more precise fuel delivery cleans the exhaust and produces fewer toxic byproducts. Therefore, the engine and the air remain cleaner.
- MPFI system improves the engine performance. It atomizes the air in small tube instead additional air intake, and enhances the cylinder-to-cylinder fuel distribution that aid to the engine performance.
- It encourages distribution of more uniform air-fuel mixture to each cylinder that reduces the power difference developed in individual cylinder.
- The MPFI automobile technology improves the engine response during sudden acceleration and deceleration.
- The MPFI engines vibrate less and don't require to be cranked twice or thrice in cold weather.
- It improves functionality and durability of the engine components.
- The MPFI system encourages effective fuel utilization and distribution.

3.4 Common Rail Direct Injection

CRDI or common rail direct injection system is a method of injection of fuel into the engine cylinders of petrol and diesel engines. In the engines, a high-pressure common rail used to inject the fuel in individual valves. In the modern generation engines this fuel injection system is used mostly because of technological advancement. In this method a common and single line is used to inject the fuel. This common line is connected to all the fuel injectors in the system, this common line is known as common rail.

The difference between conventional injection method and CRDI is that in the conventional method the system needs to build the pressure again and again for every cycle of fuel injection process and CRDI is able to maintain the required pressure constantly for every cycle of injection i.e. CRDI will provide the same pressure in the common rail system.

The ECU (electronic control unit) control the pressure as per the requirement. ECU uses sensors on the crankshaft and cam. The injection pressure is controlled or regulated on the factors like engine speed and load. The whole process makes the injection to be happened as per the requirement. It makes the system efficient, economical eco-friendly. Nowadays piezoelectric injectors are being used to get the higher pressure precisely.

3.5 Advantages of CRDI System

The vehicle engines with CRDI technology offers following advantages-

- The engine with CRDI produces more power and torque then conventional direct injection system
- It has the ability to increase the power and torque of engine by 25%.
- It increases the power and efficiency and reduces the emission.
- It decreases the noise and vibration and provides improved pick up.
- It increases the fuel efficiency and decrease the fuel consumption i.e. mileage of the engine would be increased.
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4. Variable valve timing and lift

After multi-valve technology became standard in engine design, Variable Valve Timing becomes the next step to enhance engine output, no matter power or torque.

As you know, valves activate the breathing of engine. The timing of breathing, that is, the timing of air intake and exhaust, is controlled by the shape and phase angle of cams. To optimize the breathing, engine requires different valve timing at different speed. When the rev increases, the duration of intake and exhaust stroke decreases so that fresh air becomes not fast enough to enter the combustion chamber, while the exhaust becomes not fast enough to leave the combustion chamber. Therefore, the best solution is to open the inlet valves earlier and close the exhaust valves later. In other words, the Overlapping between intake period and exhaust period should be increased as rev increases.

Without Variable Valve Timing technology, engineers used to choose the best compromise timing. For example, a van may adopt less overlapping for the benefits of low speed output. A racing engine may adopt considerable overlapping for high speed power. An ordinary sedan may adopt valve timing optimize for mid-rev so that both the low speed drivability and high-speed output will not be sacrificed too much. No matter which one, the result is just optimized for a particular speed.

With Variable Valve Timing, power and torque can be optimized across a wide rpm band. The most noticeable results are:

- The engine can rev higher, thus raises peak power. For example, Nissan's 2-litre Neo VVL engine output 25% more peak power than its non-VVT version.
- Low-speed torque increases, thus improves drivability. For example, Fiat Barchetta's 1.8 VVT engine provides 90% peak torque between 2,000 and 6,000 rpm.

Fig 4: Variable Valve Timing

4.1 Variable Valve-Timing and Lift Electronic Control

A 4-stroke engine goes through induction, compression, combustion and exhaust strokes to generate power. Before the advent of VTEC, the valves controlling the intake and exhaust strokes were operated according to fixed rules.

If the intake valves were opened a relatively small amount to increase drivability at low engine speeds (as used in normal driving conditions), the engine could not intake enough air at higher engine speeds, sacrificing outright performance. On the other hand, if the intake valves were opened wide to increase breathing at higher engine speeds, performance at low engine speeds would be compromised. This is a dilemma that had plagued engines for over a century.

The switch is made using hydraulic pressure to push/release the sliding pin, locking/unlocking the middle rocker arm and the other rocker arm.

At low engine speeds, the pin is retracted, disengaging the middle rocker arm. The valves are operated by the two outside, low-profile cams for a low valve lift.

At higher engine speeds, increased hydraulic pressure pushes the pin, engaging the middle rocker arm. The valves are operated by the middle, high profile cam for high valve lift.

4.2 Advantages of Variable Valve Timing

- Internal exhaust gas recirculation. By allowing for more direction for internal gases, the variable valve timing system can cut down on emissions, which is critical for auto makers working to get their cars and trucks in compliance with federal or state emissions controls
- Increased torque. Variable valve timing systems can provide better torque for an engine
- Better fuel economy. with more precise handling of engine valves, some auto makers have shown that VVT can produce better fuel economy for vehicles

5. Super chargers and Turbo chargers

Since the invention of the internal combustion engine, automotive engineers, speed junkies and racecar designers have been searching for ways to boost its power. One way to add power is to build a bigger engine. But bigger engines, which weigh more and cost more to build and maintain, are not always better.

Another way to add power is to make a normal-sized engine more efficient. You can accomplish this by forcing more air into the combustion chamber. More air means more fuel can be added, and more fuel means a bigger explosion and greater horsepower. Adding a supercharger is a great way to achieve forced air induction. In this article, we'll explain what superchargers are, how they work and how they compare to turbochargers.

A supercharger is any device that pressurizes the air intake to above atmospheric pressure. Both superchargers and turbochargers do this. In fact, the term "turbocharger" is a shortened version of "turbo-supercharger," its official name.

The difference between the two devices is their source of energy. Turbochargers are powered by the mass-flow of exhaust gases driving a turbine. Superchargers are powered mechanically by belt- or chain-drive from the engine's crankshaft.

Fig 5: Turbocharger and Supercharger

5.1 Types of super chargers

1: Root type

As the rotating meshing lobes spin in different direction right side lobe in clock wise and left one in anti-clock wise. Air comes from outside through the inlet fill side, the two rotors can trap the air by these lobes and actually pushes the air down towards the discharge outlet. Each time it compresses the fixed amount of air at outlet during each rotation. Air gets compressed below the rotary lobes while inlet only sucks the air. Eventually pushing it more pressurized air at the inlet manifold.

Pros:

- Excellent reliability.
- Low rpm big boost; at low engine speed it can produce greater boost.
- Simple in design.

Cons:

- Creates lots of heat.
- Heavy in weight and due to bigger in size it can comes out of the hood.
- Least efficient.

2: Twin type

In these types of supercharger, two spiral rotors have screw shape and worm gear which pushes air towards to inlet manifold. Rotation of rotors are different from the roots type supercharger, the direction of right side of rotor is take anticlockwise and left side rotor in clockwise direction. Air get start suction at fill side and convert it to pressurized air due to rotation of both the screw types rotor lobes. Air compresses in rotor housing because of conical taper and air moves from fill side to discharge side.

Pros:

- It provides Instant boost.

Cons:

- Noisy, it means it more noise during its working.

3: Centrifugal type

Its look like a turbocharger; when air sucks through impeller having high speed and low pressure thrown towards to diffuser can converts into low speed and high pressure. Impeller and diffuser blades are different in construction. From diffuser air moves towards to volute casing and air pressure further increased. This high-pressure air goes to outlet and then inlet manifold of the engine.

Pros:

- High thermal efficiency and creates less heat.
- Small and compact in size.

Cons:

• Noisy, it means it more noise during its working.

Fig 6: Turbo, Roots type and Centrifugal Supercharger

6. Hybrid Engines

A hybrid vehicle uses two or more distinct types of power, such as internal combustion engine to drive an electric generator that powers an electric motor, e.g. in diesel-electric trains using diesel engines to drive an electric generator that powers an electric motor, and submarines that use diesels when surfaced and batteries when submerged. Other means to store energy include pressurized fluid in hydraulic hybrids.

The basic principle with hybrid vehicles is that the different motors work better at different speeds; the electric motor is more efficient at producing torque, or turning power, and the combustion engine is better for maintaining high speed (better than typical electric motor). Switching from one to the other at the proper time while speeding up yields a win-win in terms of energy efficiency, as such that translates into greater fuel efficiency,

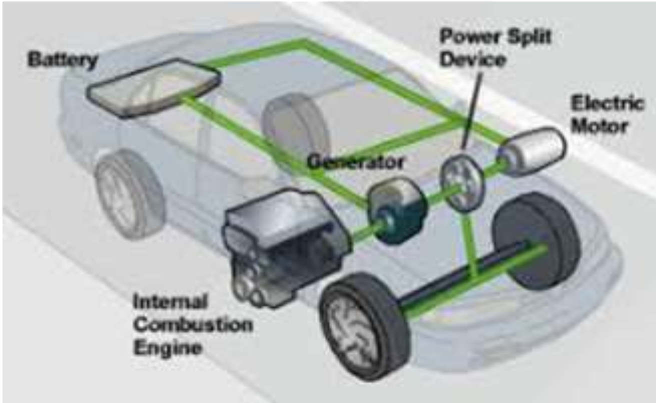

Fig 6: Hybrid Engine

6.1 Types of Hybrid Vehicles

1. Hybrid electric-petroleum vehicles

When the term hybrid vehicle is used, it most often refers to a Hybrid electric vehicle. These encompass such vehicles as the Saturn Vue, Toyota Prius, Toyota Yaris, Toyota Camry Hybrid, Ford Escape Hybrid, Toyota Highlander Hybrid, Honda Insight, Honda Civic Hybrid, Lexus RX 400h and 450h, Hyundai Ioniq and others. A petroleum-electric hybrid most commonly uses internal combustion engines (using a variety of fuels, generally gasoline or Diesel engines) and electric motors to power the vehicle. The energy is stored in the fuel of the internal combustion engine and an electric battery set. There are many types of petroleum-electric hybrid drivetrains, from Full hybrid to Mild hybrid, which offer varying advantages and disadvantages.

William H. Patton filed a patent application for a gasoline-electric hybrid rail-car propulsion system in early 1889, and for a similar hybrid boat propulsion system in mid1889. There is no evidence that his hybrid boat met with any success, but he built a prototype hybrid tramand sold a small hybrid locomotive.

In 1899, Henri Pieper developed the world's first Petro-electric hybrid automobile. In 1900, Ferdinand Porsche developed a series-hybrid using two motor-in-wheel-hub arrangements with an internal combustion generator set providing the electric power; Porsche's hybrid set two speed records. While liquid fuel/electric hybrids date back to the late 19th century, the braking regenerative hybrid was invented by David Arthurs, an electrical engineer from Springdale, Arkansas in 1978–79. His home-converted Opel GT was reported to return as much as 75 mpg with plans still sold to this original design, and the "Mother Earth News" modified version on their website.

The plug-in-electric-vehicle (PEV) is becoming more and more common. It has the range needed in locations where there are wide gaps with no services. The batteries can be plugged into house (mains) electricity for charging, as well being charged while the engine is running.

2. Continuously outboard recharged electric vehicle (COREV)

Some battery electric vehicles (BEVs) can be recharged while the user drives. Such a vehicle establishes contact with an electrified rail, plate or overhead wires on the highway via an attached conducting wheel or other similar mechanism. The BEV's batteries are recharged by this process—on the highway—and can then be used normally on other roads until the battery is discharged. For example, some of the battery-electric locomotives used for maintenance trains on the London Underground are capable of this mode of operation.

Developing a BEV infrastructure would provide the advantage of virtually unrestricted highway range. Since many destinations are within 100 km of a major highway, BEV technology could reduce the need for expensive battery systems. Unfortunately, private use of the existing electrical system is almost universally prohibited. Besides, the technology for such electrical infrastructure is largely outdated and, outside some cities, not widely distributed. Updating the required electrical and infrastructure costs could perhaps be funded by toll revenue or by dedicated transportation taxes.

3. Hybrid fuel (dual mode)

In addition to vehicles that use two or more different devices for propulsion, some also consider vehicles that use distinct energy sources or input types ("fuels") using the same engine to be hybrids, although to avoid confusion with hybrids as described above and to use correctly the terms, these are perhaps more correctly described as dual mode vehicles:

- Some electric trolleybuses can switch between an on-board diesel engine and overhead electrical power depending on conditions (see dual mode bus). In principle, this could be combined with a battery subsystem to create a true plug-in hybrid trolleybus, although as of 2006, no such design seems to have been announced.
- Flexible-fuel vehicles can use a mixture of input fuels mixed in one tank — typically gasoline and ethanol, methanol, or biobutanol.
- Bi-fuel vehicle: Liquified petroleum gas and natural gas are very different from petroleum or diesel and cannot be used in the same tanks, so it would be impossible to build an (LPG or NG) flexible fuel system. Instead vehicles are built with two, parallel, fuel systems feeding one engine. For example, some Chevrolet Silverado 2500 HDs can effortlessly switch between petroleum and natural gas, offering a range of over 1000 km (650 miles). While the duplicated tanks cost space in some applications, the increased range, decreased cost of fuel, and flexibility where LPG or CNG infrastructure is incomplete may be a significant incentive to purchase. While the US Natural gas infrastructure is partially incomplete, it is increasing at a fast pace, and already has 2600 CNG stations in place. With a growing fueling station infrastructure, a large-scale adoption of these bi-fuel vehicles could be seen in the near future. Rising gas prices may also push consumers to purchase these vehicles. When gas prices trade around $4.00, the price per MMBTU of gasoline is $28.00, compared to natural gas's $4.00 per MMBTU. On a per unit of energy comparative basis, this makes natural gas much cheaper than gasoline. All of these factors are making CNG-Gasoline bi-fuel vehicles very attractive.
- Some vehicles have been modified to use another fuel source if it is available, such as cars modified to run on Autogas (LPG) and diesels modified to run on waste vegetable oil that has not been processed into biodiesel.
- Power-assist mechanisms for bicycles and other human-powered vehicles are also included (see Motorized bicycle).

6.2 Advantages of hybrid engine

1. Environmentally Friendly: One of the biggest advantages of hybrid car over gasoline powered car is that it runs cleaner and has better gas mileage which makes it environmentally friendly. A hybrid vehicle runs on twin powered engine (gasoline engine and electric motor) that cuts fuel consumption and conserves energy.
2. Financial Benefits: Hybrid cars are supported by many credits and incentives that help to make them affordable. Lower annual tax bills and exemption from congestion charges comes in the form of less amount of money spent on the fuel.
3. Less dependence on Fossil Fuels: A Hybrid car is much cleaner and requires less fuel to run which means less emissions and less dependence on fossil fuels. This in turn also helps to reduce the price of gasoline in domestic market.
4. Regenerative Braking System: Each time you apply brake while driving a hybrid vehicle helps you to recharge your battery a little. An internal mechanism kicks in that captures the energy released and uses it to charge the battery which in turn eliminates the amount of time and need for stopping to recharge the battery periodically.
5. Built from Light Materials: Hybrid vehicles are made up of lighter materials which means less energy is required to run. The engine is also smaller and lighter which also saves much energy.
6. Higher Resale Value: With continuous increase in price of gasoline, more and more people are turning towards hybrid cars. The result is that these green vehicles have started commanding higher than average resale values. So, in case you are not satisfied with your vehicle, you can always sell it at a premium price to buyers looking for it.

7. CONCLUSIONS

Yet electric cars are nowhere near ready for such a takeover. As Tesla struggles to build the mass-market Model 3 at scale, the rest of the auto industry is talking a big game about a battery-powered onslaught, but most won't start rolling out models in real numbers for years. In the US, electric cars still make up less than 1 percent of new car sales. The path to 100 percent will be a long one, and the engine won't cede such ground without a fight.

Internal combustion engines will continue to be the primary mode of power generation for vehicles for decades to come. As discussed, internal combustion engines operate on differing cycles depending on the application, technology, etc. Typical operating cycles are two and four strokes, with different applications and advantages in processes, including, for example, scavenging for charge-gas intake and exhaust (two-stroke) and intake and exhaust strokes (four-stroke), along with compression and expansion strokes.
Internal combustion engines need to continue to adapt and improve in order to reduce emissions, reduce fuel consumption, and retain performance and power. Furthermore, as fuel sources change, engines will also need to transition to utilize these novel fuel sources. There are various trends for the future of internal combustion engines.

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