Author Note:

This white paper serves as a preliminary report, offering an introductory look at the Dynamic Flow engine, a groundbreaking new technology with the potential to transform the field of 4-stroke engines. Our primary goal is to shed light on this exciting concept, outlining its core features and the significant benefits it promises.

It's important to acknowledge that the Dynamic Flow engine is currently in its pre-prototype stage. While this allows for unconstrained exploration of innovative ideas, it also means that the full range of features and benefits hasn't yet been fully realized or definitively quantified. Consequently, the focus of this report will be on the most prominent aspects and anticipated advantages. We believe this approach offers a clear and concise picture of the engine's core potential, paving the way for further investigation.

Think of this report as the first step on a fascinating journey. As we move beyond the conceptual stage and into prototype development, opportunities will arise to explore the engine's capabilities in greater detail. Through rigorous testing and collaboration with a wider team of engineers and researchers, we can delve into the multifaceted benefits the Dynamic Flow engine may offer. The features, ideas, and methods presented here represent the author's initial understanding and interpretation of the invention. This white paper lays the groundwork for future exploration, where collaboration will undoubtedly refine these initial concepts and unlock even more potential.

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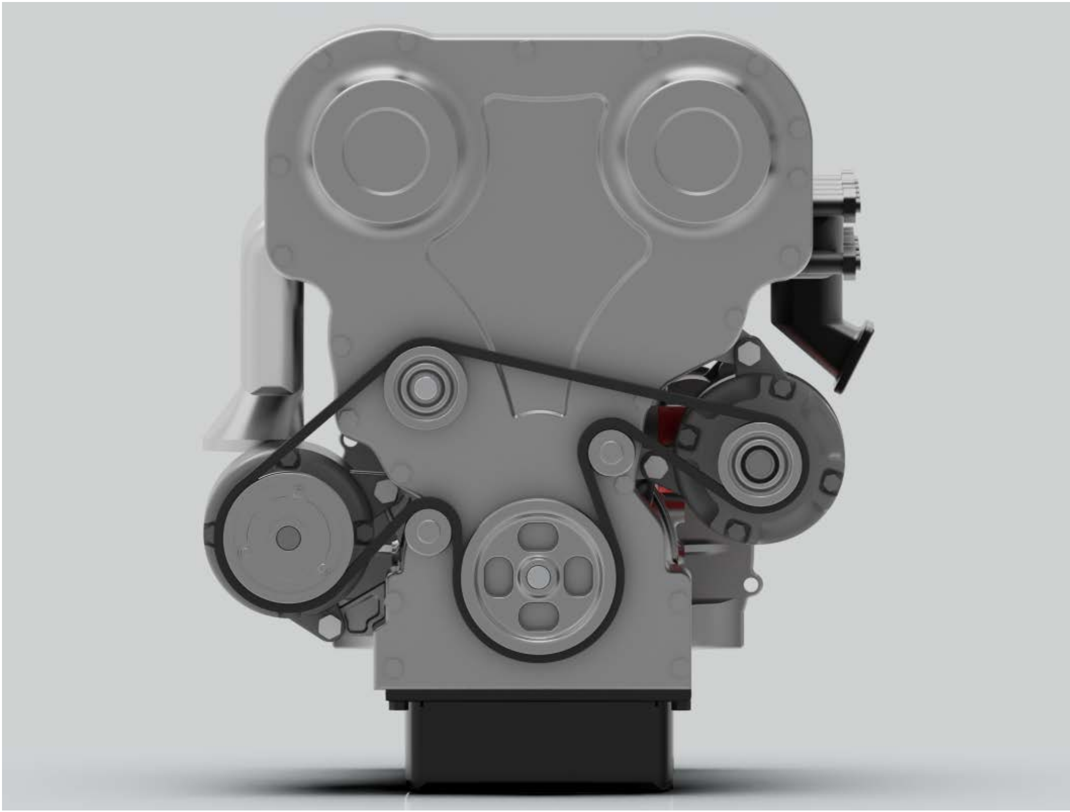

Dynamic Flow Engine

Intro

The internal combustion engine (ICE) stands as a pivotal component in the history of modern transportation and industrial development. Its invention and subsequent advancements fundamentally reshaped how we live, work, and travel. ICEs powered the industrial revolution, driving factories and machinery, while their reliable and efficient operation spurred economic growth and transformed numerous industries.

However, the environmental impact of traditional combustion engines, fueled by fossil fuels, presents a significant challenge. These engines contribute heavily to air pollution and greenhouse gas emissions. In response, interest in alternative propulsion technologies like electric vehicles, hydrogen fuel cells, and hybrid systems has surged, aiming to minimize the environmental footprint of transportation.

Despite these challenges, the combustion engine remains a cornerstone of our daily lives. It powers a vast array of vehicles and machinery critical to modern society. Ongoing research and innovation continue to refine these engines, focusing on improved efficiency and reduced environmental impact. This dedication ensures that combustion engines will maintain relevance in the ever-evolving landscape of transportation and industry.

1. Abstract

Existing internal combustion engines face various challenges that hinder their operational thermal efficiency. This report will delve into the technical intricacies of the Dynamic Flow engine, comparing its advantages to conventional combustion engines. The design and configuration of Dynamic Flow engines, along with their numerous superior aspects, will be explored.

These engines offer solutions to the issues limiting the efficiency of current combustion engines. Furthermore, the report will present the ideas of Atkinson cycles featuring a turbocharger, variable displacement, internal secondary air injection, and internal exhaust gas recirculation with a variable ratio.

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3. Background

The global economy relies heavily on combustion engines, powering everything from small motorbikes to large marine tankers. Improving the thermal efficiency of these engines could greatly reduce global pollution and emissions. Diesel engines are widely used across various transportation sectors, while gasoline engines dominate in passenger vehicles, small trucks, and two-wheelers.

Slow-speed 2-stroke marine diesel engines achieve a remarkable thermal efficiency of 48% at low RPMs, thanks to their higher gas flow rate and more efficient undersquare design compared to 4-stroke engines. In contrast, 4-stroke engines have smoother operation and lower emissions but are limited by lower intake air and exhaust gas flow rates, which reduce their power and peak thermal efficiency. Additionally, slow-speed marine engines benefit from constant loads at low RPMs, allowing them to maintain peak thermal efficiency, unlike other engines that operate under variable load conditions and lose efficiency due to load mismatches.

The primary difference between 2-stroke and 4-stroke engines lies in their gas flow rates and durations, which impact their thermal and volumetric efficiencies. Two-stroke engines generally have higher gas flow rates but shorter durations, leading to higher peak thermal efficiencies at lower RPMs. However, as RPMs increase, their efficiency drops, whereas 4-stroke engines maintain more constant thermal efficiency across varying speeds due to longer gas flow durations. This is why slow-speed 2-stroke engines can reach efficiencies of 48%, while medium-speed 4-stroke engines top out around 42%.

In real-world conditions, gasoline cars and trucks typically achieve around 25% thermal efficiency, while diesel trucks reach 28-38%. Medium-speed 4-stroke diesel marine engines can achieve up to 42% efficiency. If combustion engines could achieve 60% or higher thermal efficiency, it would save billions of gallons of fuel and significantly reduce greenhouse gas emissions.

To address these challenges, my proposed engine innovation focuses on enhancing 4-stroke engines by modifying the airflow and exhaust pathways. By increasing the intake airflow by 50% and exhaust expulsion by 135%, we can bring these engines closer to its peak theoretical thermal efficiency. This approach aims to achieve higher power output and better thermal efficiency across different engine sectors.

Additionally, my engine concept introduces two new features to enable Dynamic Flow engines of all sizes to achieve thermal efficiencies in the range of 60% to 75% under all load conditions. The development of Dynamic Flow engines seeks to improve power output, thermal efficiency, pollution reduction, and fuel economy, ultimately reducing environmental impact and helping mitigate climate change.

4. Dynamic Flow Engine

4.1. Engine Design

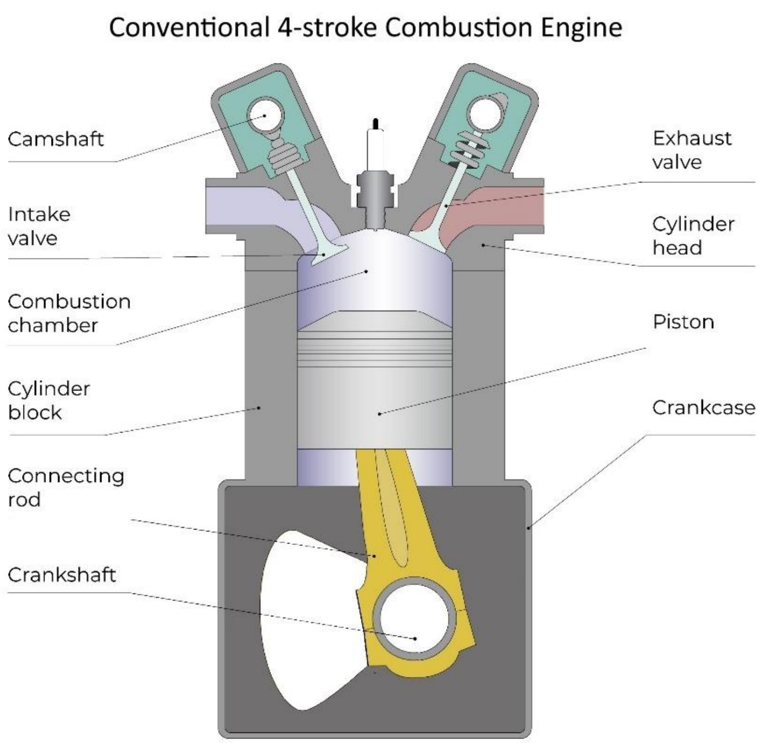


Figure 1 is a mid-cylinder cut view of a conventional 4-stroke engine.

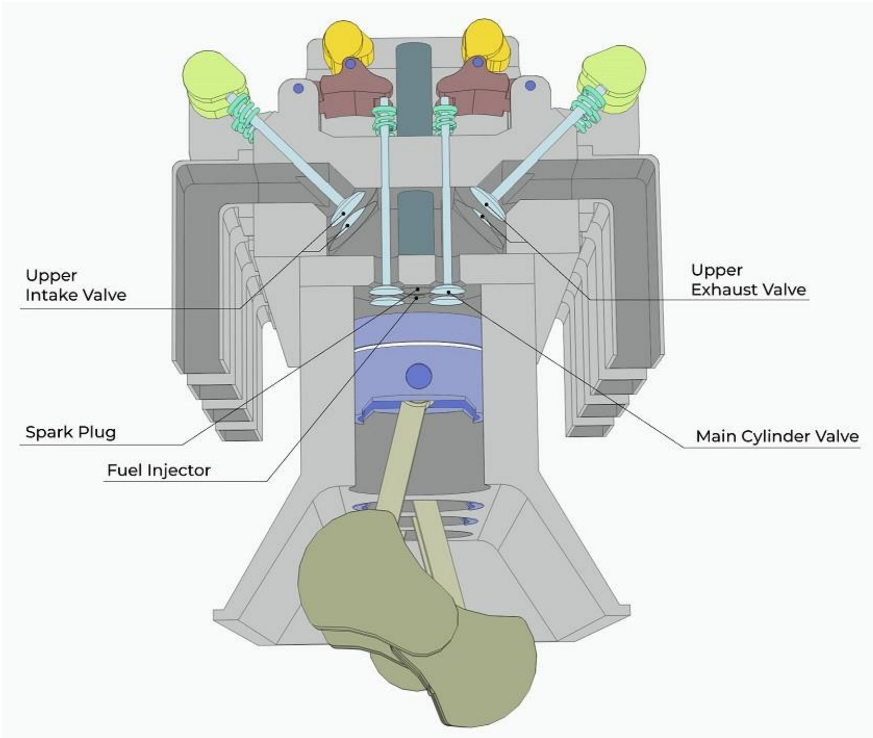


Figure 2 is an angle cut view a t the first set of valves of the Dynamic Flow engine.

Comparing to current combustion engine, the Dynamic Flow engine has additional parts:

1. Upper non-combustion chamber
2. Main cylinder valve
3. Upper intake valve
4. Upper exhaust valve
5. Main cylinder valve cam system
6. Main cylinder valve rocker
7. Upper intake valve cam system
8. Upper exhaust valve cam system
9. Variable valve apparatus for upper intake valve camshaft (optional)
10. Variable valve apparatus for upper exhaust valve camshaft (optional)

Some of the current combustion engine parts are removed and not needed for Dynamic Flow engine:

1. Intake valve
2. Intake valve cam system
3. Exhaust valve
4. Exhaust valve cam system
5. External throttle body system
6. External exhaust gases recirculation system
7. External secondary air injection system

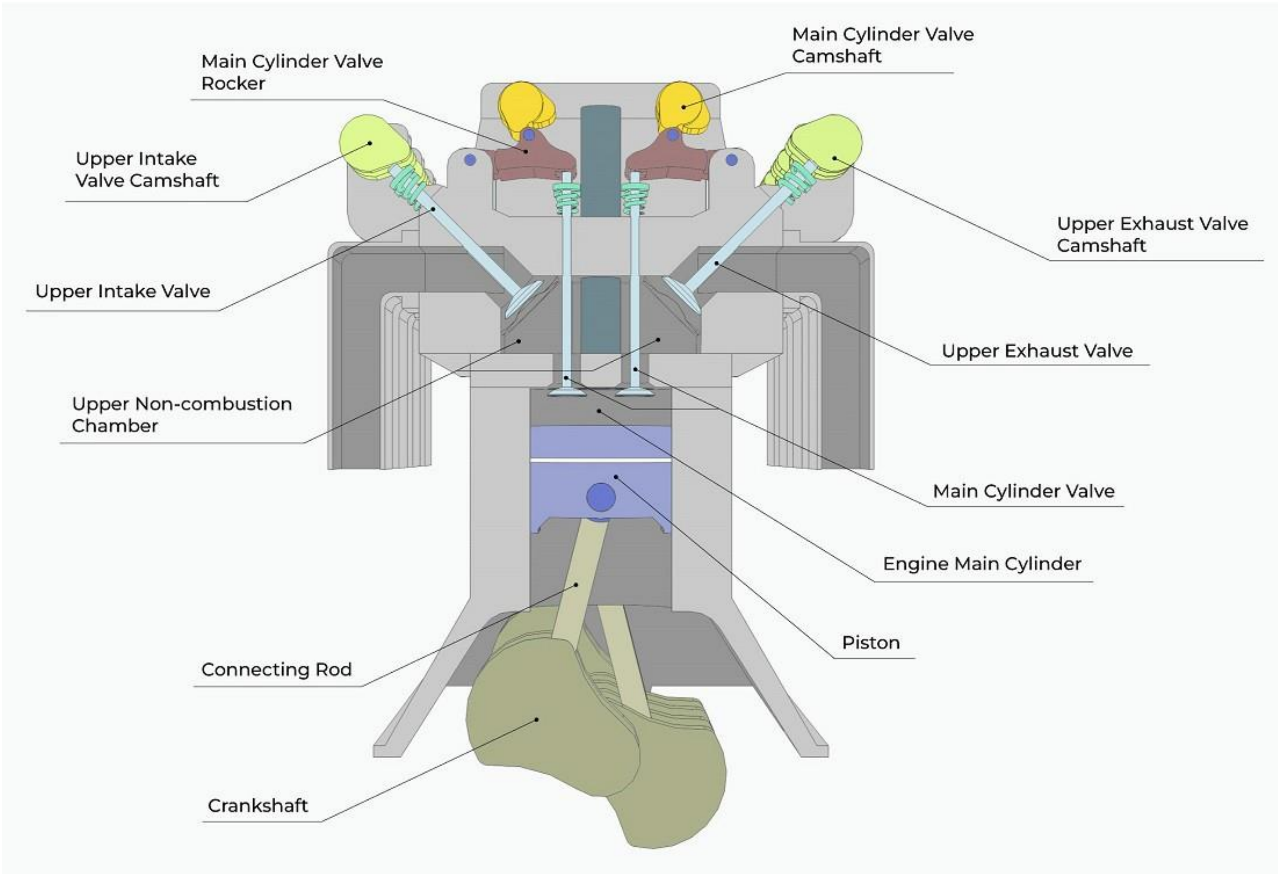


Figure 3 is a cut view at the first set of valves of the Dynamic Flow engine with part labels.

4.1.1. Upper Non-combustion Chamber

What is the purpose of employing the upper non-combustion chamber? The integration of an upper non-combustion chamber was implemented to enhance the gas flow into and out of the combustion chamber. Through the adoption of the upper non-combustion chamber configuration and the consolidation of two valve types into a unified dual-task valve, the airflow capacity is doubled. With a twofold increase in engine airflow capacity, there is a greater availability of airflow for power generation, contributing to a more efficient engine design. This design alteration facilitates a broader RPM range for increased power output and enhances thermal efficiency by accommodating a more undersquare combustion chamber. Incorporating and deploying an upper non-combustion chamber allows the engine to effectively replace the throttle valve function with an intake poppet valve and valve timing mechanism, utilizing internal variable EGR and passive internal secondary air injection functions.

4.1.2. Upper Intake Valve System

The primary function of the upper intake valve system is to facilitate the flow of intake air

from the intake manifold into the upper non-combustion chamber. By utilizing a variable timing mechanism, this system precisely controls the volume of intake air entering both the non-combustion chamber and the combustion chamber, effectively replacing the throttle valve function. Integrating variable valve timing mechanisms into the upper intake valve system allows the engine computer to smoothly switch between the Otto cycle or Diesel cycle and the Atkinson cycle. The broad range of intake valve timing includes the ability to advance or retard up to 180 degrees of phase shift without any restrictions or physical interference.
A variable valve lift system is not necessary in a Dynamic Flow engine; the functionality of variable valve lift can be achieved by implementing variable valve timing on the upper intake valve.

4.1.3. Upper Exhaust Valve System

The upper exhaust valve system primarily functions to facilitate the flow of exhaust gases from the non-combustion chamber to the exhaust manifold. When equipped with variable valve timing, this system introduces a variable EGR ratio and a variable displacement feature. The variable EGR ratio, dictated by valve timing, entails early closure of the upper exhaust valve to trap exhaust gases in the upper non-combustion chamber during the exhaust stroke and reintroduce them into the combustion chamber during the intake stroke. Unlike other EGR systems, the precise control provided by the variable timing mechanism allows the Dynamic Flow engine internal EGR to have a variable EGR ratio, making it more effective at controlling emissions than an external cooled EGR system. The broad range of upper exhaust valve timing includes the ability to advance or retard up to a 180-degree phase shift without any restrictions or physical interference.

4.1.4. Main Cylinder Valve System

The introduction of the upper non-combustion chamber necessitates the inclusion of a main cylinder valve to facilitate the flow of intake air and exhaust gases between the upper non-combustion chamber and the main cylinder chamber. This main cylinder valve efficiently manages both intake air inflow and exhaust gas outflow, enabling the transfer of gases between the upper non-combustion chamber and the main cylinder. The incorporation of the main cylinder valve system allows for an 50% increase in intake airflow and a 135% increase in exhaust gas expulsion rate compared to conventional 4-stroke engines. With additional increase in intake air and exhaust gas flow capacity, Dynamic Flow engine can have greater engine power output, thermal efficiency or both compare to current 2-stroke and 4-stroke. Notably, the main cylinder valve operates without the need for a variable valve timing system. Additionally, spark plugs and a direct fuel injector are positioned at the top center of the main cylinder chamber.

4.2. Comparison of Engine

4.2.1. Current Combustion Engine Design

In today's conventional 4-stroke combustion engines, both intake and exhaust valves are positioned at the upper section of the engine cylinder. Each valve governs a distinct path for engine intake air and exhaust gases to travel in and out of the combustion cylinder. The magnitude of engine power output is directly influenced by the size of both intake and exhaust valves. Larger valves facilitate increased gas flow, contributing to elevated power output especially at higher RPM levels. The sizing and quantity of these valves are contingent upon the diameter of the cylinder head, a dimension dictated by the engine cylinder bore size. Modern 4-stroke combustion engines grapple with physical limitations, necessitating a compromise between power and fuel efficiency. This compromise arises from the constraints imposed by the physical location of intake and exhaust valves in relation to gas flow dynamics. For simplicity, "gas flow" here refers to both intake air and exhaust gas flow. In general, an engine with greater power output tends to show lower efficiency due to considerations in gas flow dynamics. Diminished gas flow capacity can adversely affect power output and efficiency, while increased gas flow dynamics have the potential to enhance both power output and efficiency.

4.2.2. Dynamic Flow Engine Design

The Dynamic Flow engine incorporates a main cylinder valve situated at the top of the engine main cylinder. Functioning during both intake and exhaust strokes, this valve serves a dual purpose as an intake and exhaust valve for the combustion chamber. By consolidating two distinct valve types into a singular valve, the main cylinder valves in Dynamic Flow engines can be engineered to be more numerous compared to those in conventional engines.
Unlike conventional engines, the upper intake and exhaust valves in the Dynamic Flow engine are external to the engine main cylinder, enabling their movement, timing, and size to operate independently of piston movement and bore diameter. Consequently, these valves can be designed with substantial timing movement and larger dimensions, enhancing their gas flow capacity. The valve configuration of the Dynamic Flow engine is invented to maximize gas flow capacity, allowing for superior power output and efficiency across all RPM ranges as compared to conventional combustion engines. The valve design and operation of the Dynamic Flow engine differ from those of conventional engines, effectively eliminating the need for a throttle valve and the associated pumping loss inefficiencies.

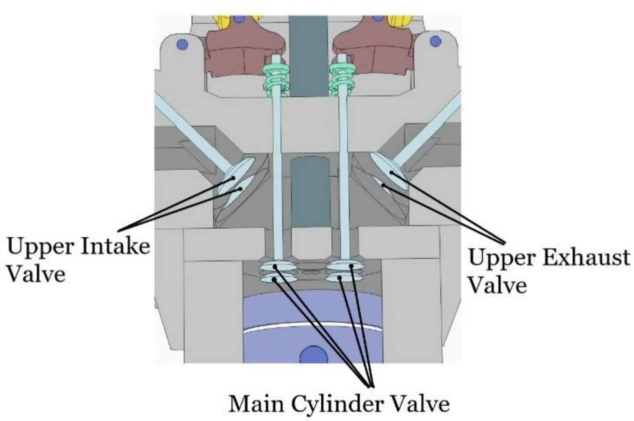


Figure 4 is a view of the Dynamic Flow engine with main cylinder valves, upper intake valves, and upper exhaust valves.

4.2.3. Dynamic Flow Engine Operation and Gases Flow

A 4-stroke Dynamic Flow engine undergoes a sequence of four successive strokes: Intake, Compression, Expansion, and Exhaust. The cycle commences with the intake stroke and concludes with the exhaust stroke.

Figure 5A to Figure 5D is a cut view of the Dynamic Flow engine at the first set of valves, depicting the engine gases flow during each stroke. The light blue dot and arrow symbolize atmospheric oxygen (O2), while the light red dot and arrow denote the presence and flow of exhaust gases.

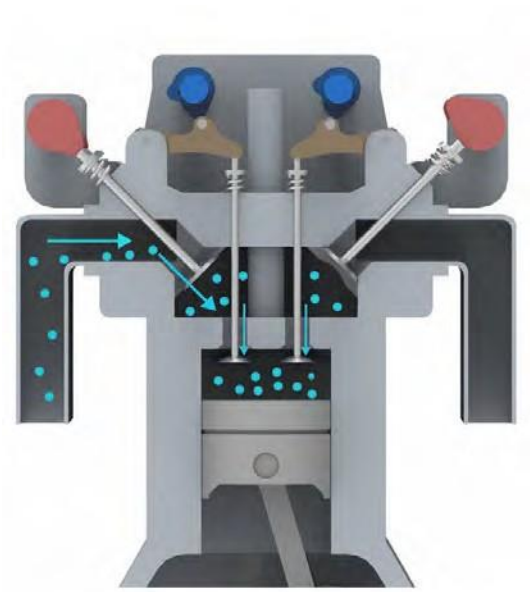


Figure 5A is Dynamic Flow engine operation during intake stroke.

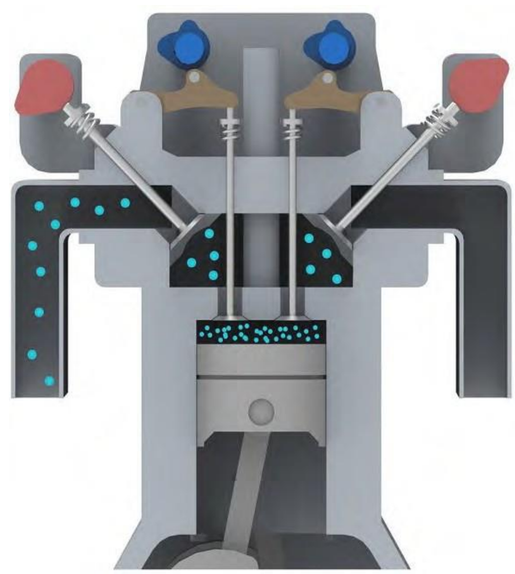


Figure 5B is Dynamic Flow engine operation during compression stroke.

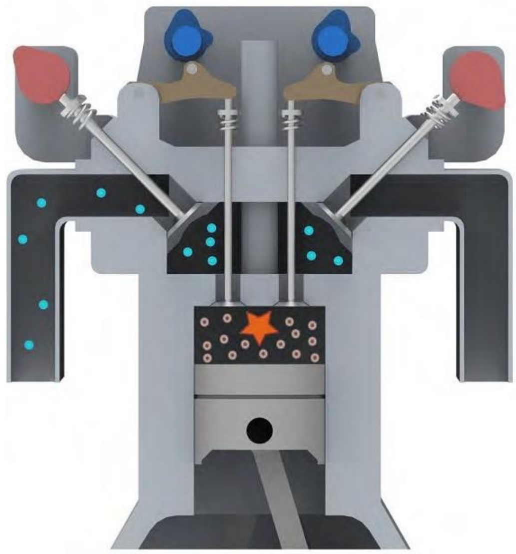


Figure 5C is Dynamic Flow engine operation during expansion stroke.

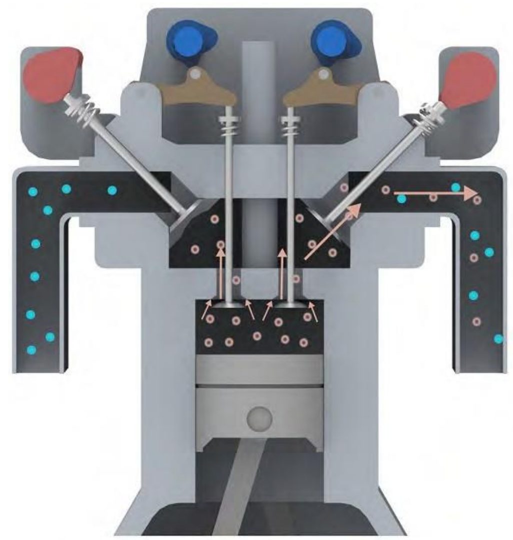


Figure 5D is Dynamic Flow engine operation during exhaust stroke.

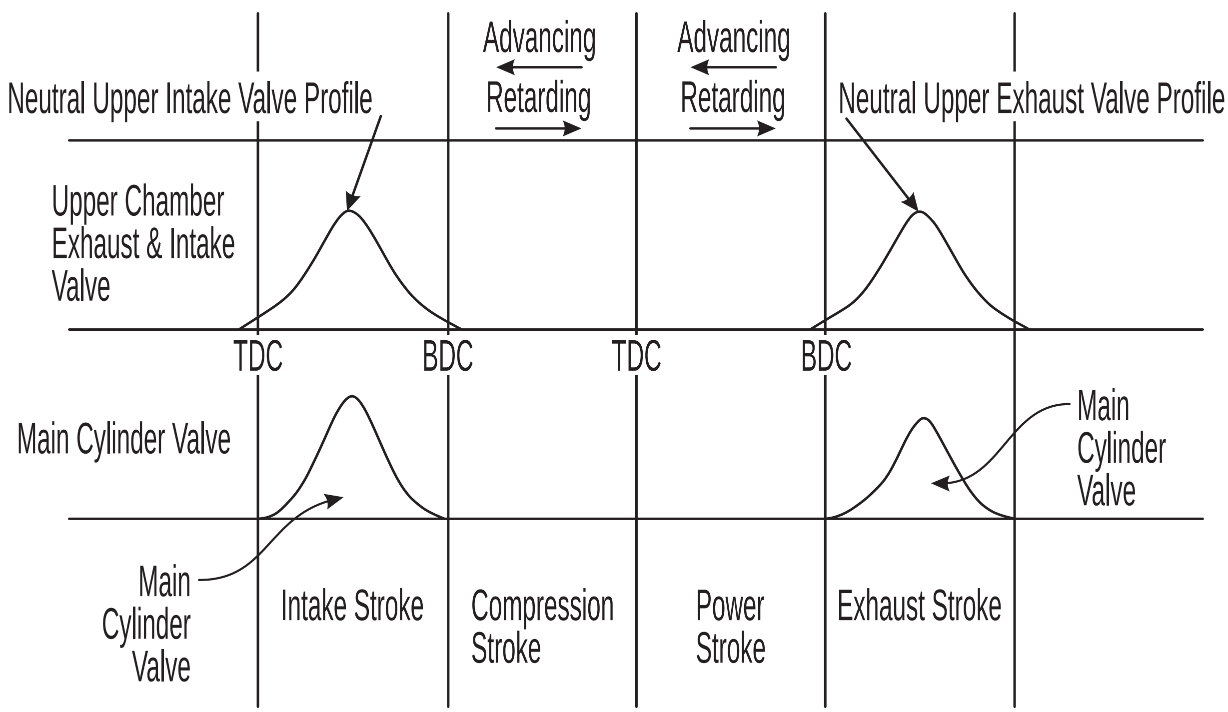


Figure 6 is Dynamic Flow engine valve profile for one cycle. The cycle starts with the intake stroke and ends with the exhaust stroke.

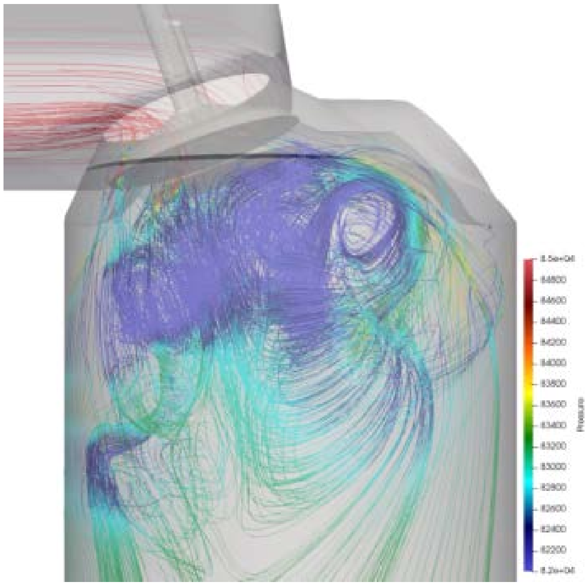


Figure 7A illustrates the intake airflow in a conventional 4-stroke engine, modeled through OpenFOAM CFD simulation.

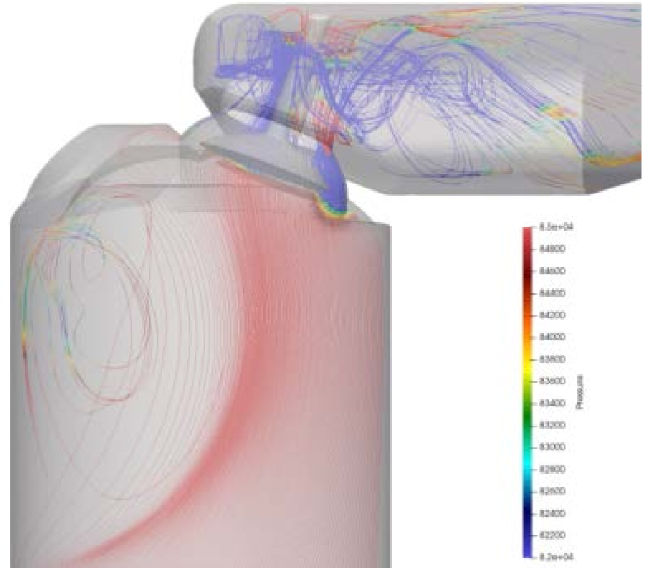


Figure 7B illustrates the exhaust gas flow in a conventional 4-stroke engine, modeled through OpenFOAM CFD simulation.

In our OpenFOAM computational fluid dynamics (CFD) study of a single-cylinder, conventional 4-stroke engine with a bore diameter of 5.5 inches, the intake and exhaust valves were set to the maximum size allowed by the cylinder bore, with a volumetric flow rate of 200 liters per second. We observed a 10.13% pressure drop in the intake airflow and a 30.67% pressure drop in the exhaust gases flow. These pressure drops indicate restrictions in gas flow, with lower pressure drops being more favorable. Higher pressure drops signal increased valve restrictions, which negatively impact engine efficiency and performance.

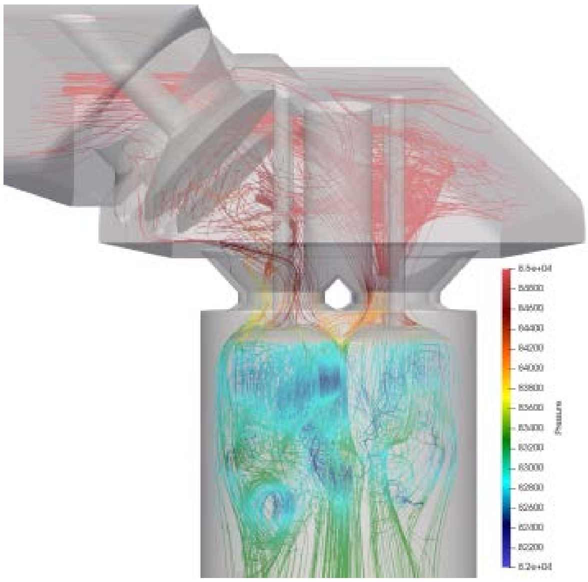


Figure 8A illustrates the intake airflow in a Dynamic Flow engine, modeled through OpenFOAM CFD simulation.

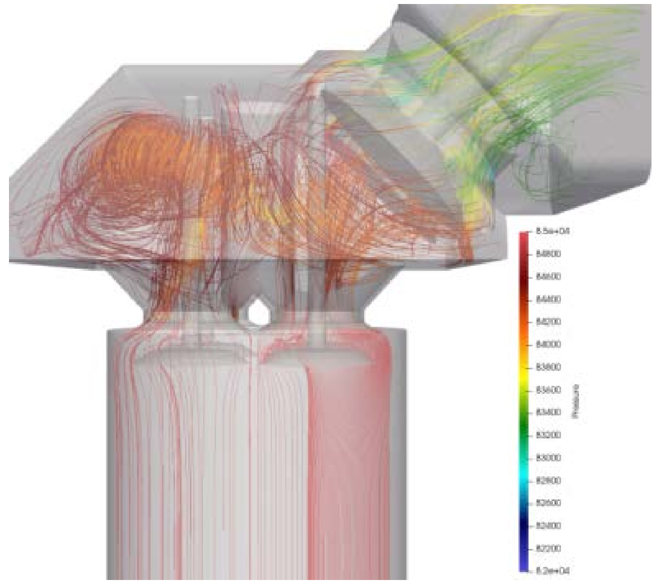


Figure 8B illustrates the exhaust gas flow in a Dynamic Flow engine, modeled through OpenFOAM CFD simulation.

Our OpenFOAM CFD study of a single-cylinder Dynamic Flow engine with a bore diameter of 5.5 inches, the main cylinder valve was set to the maximum size permitted by the cylinder bore, with a volumetric flow rate of 200 liters per second. We observed a 3.79% pressure drop in the intake airflow and a 4.16% pressure drop in the exhaust gas flow. By comparing the CFD pressure data between the conventional 4-stroke engine and the Dynamic Flow engine, we can conclude that the Dynamic Flow valve system is superior in gas flow compare to conventional 4-stroke engine with a similar bore size.

4.2.4. Higher Thermal Efficiency with Undersquare Engine Design

4.2.4.1. Challenges in Current Conventional 4-Stroke Engines

Over the past 10 to 15 years, there has been little improvement in the thermal efficiency of conventional combustion engines, whether in laboratory settings or real-world applications. At Dynamic Alpha Automotive Technology (DAAT), we have identified that the flow capacity of gases in conventional 4-stroke and 2-stroke engines is a key factor limiting their potential for achieving higher thermal efficiency and power output.

Two-stroke engines have approximately 50% greater intake air flow and 135% greater exhaust gas flow compared to conventional 4-stroke engines. However, the operational cycles of 2-stroke engines have significantly shorter gas flow durations than 4-stroke engines. For simplicity, we refer to both intake air and exhaust gas flow as “gas flow.” The capacity for gas flow determines an engine’s power generation and efficiency, and this capacity is the product of the gas flow rate and the flow duration.

In modern engines, the flow of intake air and exhaust gases plays a crucial role in both rapid high-power generation (high horsepower) and slower, more efficient power generation (high torque). Engines designed for higher acceleration and horsepower tend to be less efficient than those designed for slower acceleration and higher torque. This is because the design elements that enhance engine efficiency often conflict with those that increase power output in terms of gas flow.

In conventional 4-stroke engines, the intake and exhaust valves are located at the top of the cylinder within the cylinder head, occupying the available surface area. The operational nature of 4-stroke engines requires that these valves be in close proximity to each other, and the surface area of the cylinder head is limited by the diameter of the cylinder. Consequently, engines with larger cylinder diameters have more surface area available for larger or more numerous intake and exhaust valves. Larger or more numerous valves can reduce gas flow restriction at higher RPMs, translating into higher power generation.

One mechanical approach to increasing combustion engine thermal efficiency is to adopt a more undersquare engine design, characterized by a smaller bore-to-stroke ratio, where the bore is smaller than the stroke. To maintain a similar compression ratio, any change in stroke length requires a corresponding change in bore size. The bore diameter must decrease as the stroke length increases to retain the same compression ratio. As a result, more efficient engines typically have smaller bore diameters, which indirectly reduces the surface area available at the cylinder head for intake and exhaust valves. This reduction leads to smaller valves, which restrict gas flow at higher RPMs and thus decrease horsepower.

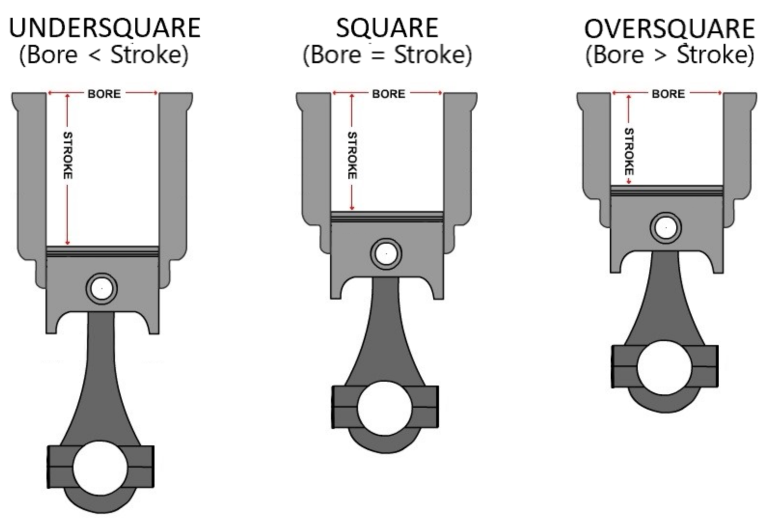


Figure 9 is illustration of engine with different bore to stroke ratio.

4.2.4.2. Adopting a More Undersquare Engine

The Dynamic Flow engine revolutionizes valve placement by moving the intake and exhaust valves outside of the cylinder and combustion chamber. This allows for larger valves with higher gas flow rates and longer flow durations, unhindered by the constraints of the engine's operational process. The Dynamic Flow engine introduces a new type of valve, the "main cylinder valve," which performs dual tasks—acting as both an intake valve during the intake stroke and an exhaust valve during the exhaust stroke. This dual functionality allows for more numerous valves with a higher gas flow rate, comparable to that of a 2-stroke engine. However, as a 4-stroke engine, it retains the longer gas flow duration characteristic of 4-stroke engines. This combination results in a significantly higher gas flow capacity compared to both conventional 4-stroke and 2-stroke engines.

Thanks to its larger gas flow capacity, the Dynamic Flow engine can adopt a more undersquare design for improved efficiency while still achieving higher horsepower at higher RPMs. An undersquare engine, characterized by a longer stroke and smaller bore diameter, is more efficient at converting fuel energy into work and experiences lower heat loss compared to an oversquare engine [11]. While a smaller bore typically requires smaller valves, the Dynamic Flow engine's higher number of main cylinder valves allows for smaller valve sizes without compromising performance, even at higher RPMs. For example, a 3.0-liter I6 Dynamic Flow engine with an undersquare design can deliver similar horsepower to an oversquare 3.0-liter I6 conventional engine while offering significantly better thermal efficiency.

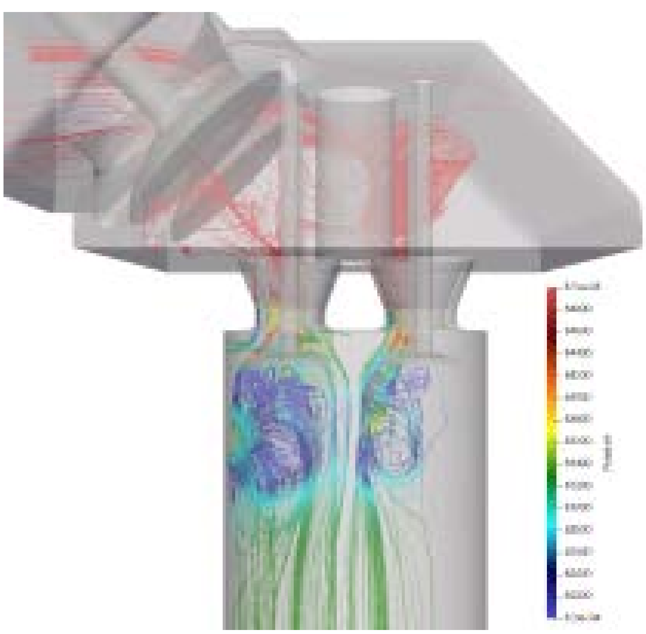


Figure 10A illustrates the intake airflow in a Dynamic Flow engine with an undersquare design, modeled using OpenFOAM CFD.

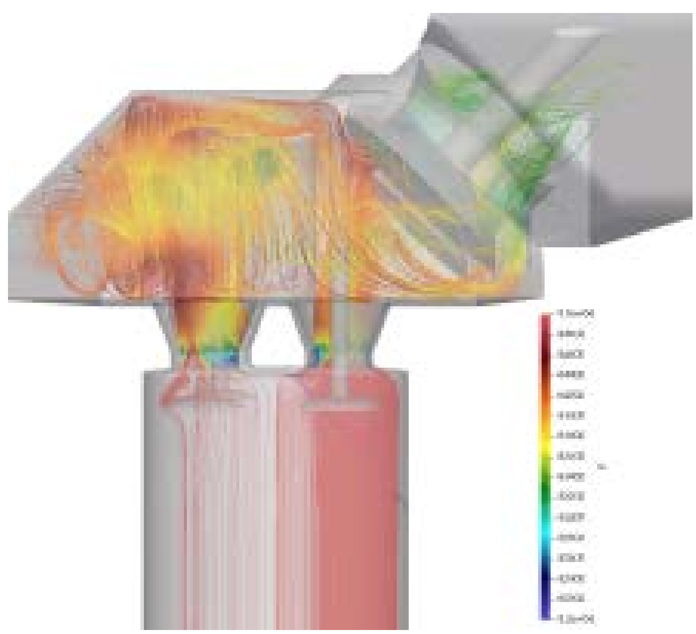


Figure 10B illustrates the exhaust gas flow in a Dynamic Flow engine with an undersquare design, modeled using OpenFOAM CFD.

Our OpenFOAM CFD study of a single-cylinder Dynamic Flow engine with a bore diameter of 4.57 inches, we reduced the main cylinder valve size by 33.4% to imitate engine with smaller undersquare bore design, volumetric flow rate were set at 200 liters per second. This bore size and valves size adjustment resulted in a 7.09% pressure drop in intake airflow and a 7.54% pressure drop in exhaust gas flow. Comparing the CFD pressure data between the conventional 4-stroke engine with a 5.5-inch bore and the Dynamic Flow engine with the reduced bore size of 4.57 inches, we found that the Dynamic Flow valve system, even with a smaller bore, surpasses the conventional 4-stroke engine valve system in gas flow capacity.

4.2.4.3. Core Advantages of Dynamic Flow Engine Higher Gases Flow Valve System

The Dynamic Flow engine's larger gas flow capacity allows it to achieve significantly higher thermal efficiency than current 4-stroke engines. Dynamic Flow gasoline and diesel engines can reach thermal efficiencies of 48% or higher, marking a substantial improvement in 4-stroke engine technology. The ability to adopt more undersquare engine design further enhances the engine's efficiency without performance penalty, making it a game-changer in the pursuit of engine maximum theoretical thermal efficiency.

4.3. Dynamic Flow Engine Atkinson Cycle

4.3.1. Dynamic Flow Engine Valve Profile Chart

The operation of the Dynamic Flow engine and many of its methods require observing the engine over two consecutive operational cycles. To simplify this, valve profiles will be depicted to include the second half of the previous cycle and the first half of the next cycle.

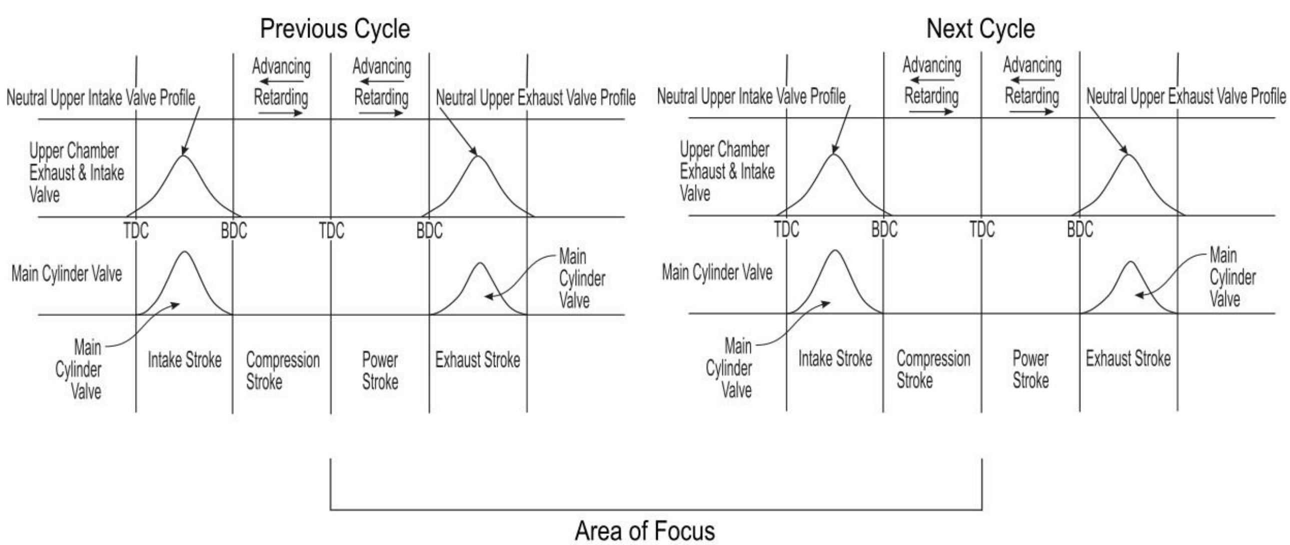


Figure 11 shows the valve profile for two consecutive cycles, emphasizing the key areas where most of the Dynamic Flow engine's features occur. Notice the close proximity between the exhaust stroke and the intake stroke.

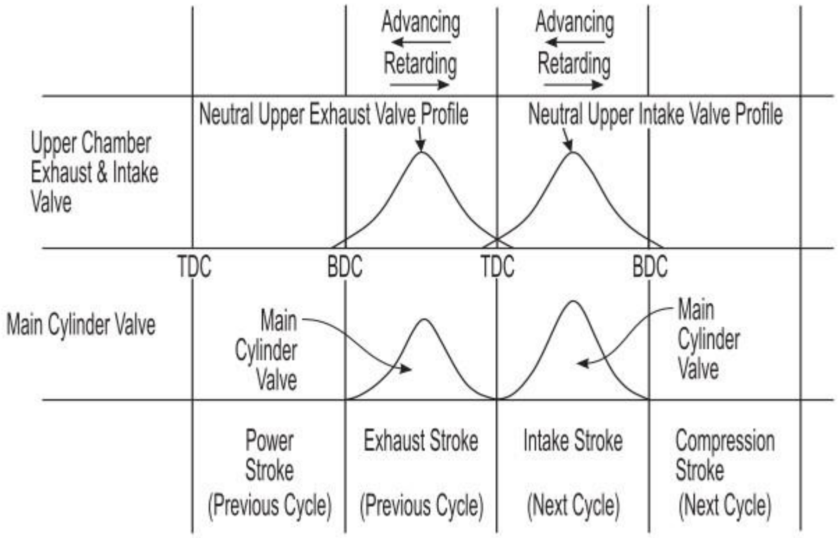


Figure 12 presents a condensed version of the valve profile for two consecutive cycles combined into a single chart. From this point forward, all valve profile charts will be drawn in this format to save space.

4.3.2. More Efficient EIVC Atkinson Cycle

Conventional 4-stroke and 2-stroke engines have reached their maximum potential for thermal efficiency improvements. Large 2-stroke diesel engines can achieve up to 48% thermal efficiency, but further significant gains are unlikely. Smaller conventional 4-stroke diesel engines typically operate at 28-38% thermal efficiency, while 4-stroke gasoline engines achieve around 25%. The Atkinson cycle, when simulated within Otto or diesel cycles, has the theoretical potential to boost thermal efficiency to 75% [12]. However, the standard valve configurations in conventional 4-stroke engines prevent the implementation of the highly efficient Atkinson cycle, limiting their ability to achieve such high efficiency levels.

The Atkinson cycle is a unique method for increasing combustion engine thermal efficiency by lowering the compression ratio relative to the expansion ratio. This cycle is designed to provide efficiency at the expense of power density. Modern 4-stroke engine technology can switch between the Otto or diesel cycle and the Atkinson cycle using variable valve timing mechanisms. This capability means the lower power density of the Atkinson cycle is not a significant problem, as engine management computers can utilize the Otto or diesel cycle during high-performance needs and switch to the Atkinson cycle for fuel efficiency.

4.3.2.1. Problems with Conventional Engines Atkinson Cycle

Conventional 4-stroke engines can simulate the Atkinson cycle by using late intake valve closing (LIVC). However, this method introduces "parasitic pumping losses" that reduce efficiency and performance. LIVC extends the intake valve closure past top dead center (TDC) into the compression stroke. During this phase, the upward movement of the piston partially expels intake air from the combustion chamber back into the intake manifold. Consequently, the engine must expend mechanical energy to draw air from the intake manifold into the combustion chamber during the intake stroke and additional energy to pump some of the same air out during the early compression stroke. These parasitic pumping losses increase as the prominence of the LIVC Atkinson cycle grows, resulting in only modest improvements in thermal efficiency compared to the Otto or Diesel cycles.

Another drawback of simulating the Atkinson cycle with LIVC is its incompatibility with forced induction systems. During the compression stroke, the reversal of intake air flow works against the intended benefits of turbochargers or superchargers, which are designed to increase intake air density and boost performance and efficiency. Modern diesel engines, for instance, depend heavily on turbochargers for sufficient power generation. Since the LIVC Atkinson cycle gains little benefit from forced induction, 4-stroke engines utilizing this approach are primarily used in niche hybrid vehicles. In these applications, the reduced power output of the LIVC Atkinson cycle is compensated by the electric motor.

Another method for simulating the Atkinson cycle is early intake valve closing (EIVC). This approach avoids the parasitic pumping losses associated with the LIVC method and allows for effective use of turbochargers and superchargers. However, conventional 4-stroke Otto or diesel engines cannot use EIVC to simulate the Atkinson cycle due to the physical interference between the piston head at top dead center (TDC) and the open intake valve. For the intake valve to close early, it must open during the exhaust stroke and remain open even at TDC. This early opening interferes with the exhaust valve's open position in penta-roof combustion chamber designs and the piston's position at TDC.

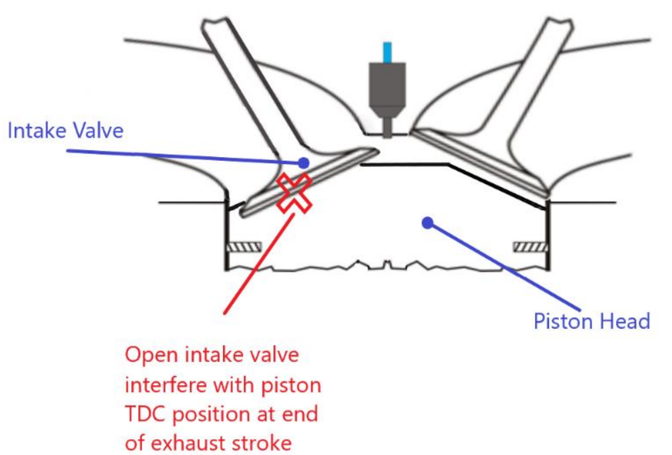


Figure 13 is illustration of conventional 4-stroke engine with opened intake valve at piston top dead center.

The operational characteristics of the 2-stroke engine cycle make it unsuitable for simulating the Atkinson cycle, which is only achievable with 4-stroke engines. As a result, current large 2-stroke marine engines have reached their maximum thermal efficiency limits, with limited potential for future improvements. Methods for enhancing thermal efficiency that are available to 4-stroke engines do not apply to 2-stroke engines. While 2-stroke engines are simpler to build and operate, achieving the same environmental benefits and lower pollution levels as 4-stroke engines requires more expensive after-treatment systems to ensure clean burning.

4.3.2.2. Dynamic Flow Engine EIVC Atkinson Cycle

The Dynamic Flow valve configuration enables the engine to employ EIVC for simulating the Atkinson cycle in Otto or diesel cycle engines. This approach involves closing the intake valve early during the intake stroke, cutting off the flow of intake air into the combustion chamber from the intake manifold. By avoiding the additional pumping work required in the LIVC Atkinson method, the EIVC approach eliminates the parasitic pumping losses associated with LIVC.

A Dynamic Flow engine utilizing the EIVC Atkinson cycle requires significantly less mechanical energy for pumping intake air compared to Otto and Diesel cycles. Among these cycles, the conventional 4-stroke LIVC Atkinson cycle demands the most mechanical energy for intake air pumping, while the Dynamic Flow engine EIVC Atkinson cycle requires the least. This reduced energy requirement allows the Dynamic Flow engine operating with the EIVC Atkinson cycle to achieve much greater thermal efficiency than conventional 4-stroke engines using the LIVC method.

Unlike the LIVC method, the EIVC Atkinson cycle does not require intake air to be expelled from the combustion chamber during the compression stroke. This eliminates reverse intake air flow, avoiding conflicts with the operation of turbochargers and superchargers. As a result, the Dynamic Flow engine operating on the EIVC Atkinson cycle can fully benefit from forced induction systems, much like Otto and Diesel cycles. Furthermore, Dynamic Flow engines running on Otto or Diesel cycles can seamlessly switch to EIVC Atkinson cycle mode while maintaining the active use of turbochargers and superchargers.

Despite its advantages, the EIVC Atkinson cycle method is not widely adopted in conventional engines. This limitation arises from the physical interference between the piston head at top dead center (TDC) and the intake valve in its open position, making EIVC incompatible with current conventional 4-stroke Otto or Diesel engines. Additionally, the inherent characteristics of the 2-stroke engine cycle prevent it from simulating the Atkinson cycle altogether. The unique valve configuration of the Dynamic Flow engine overcomes these limitations, enabling it to simulate the Atkinson cycle using EIVC.

The EIVC Atkinson cycle feature allows for incremental adjustments to the intake air volume and real-time control of the engine compression rate through a variable valve timing mechanism, effectively simulating a variable compression ratio without needing physical or mechanical modifications to the combustion chamber, crankshaft, or connecting rods.

This capability enables the Dynamic Flow 4-stroke engine to operate over a wide range of compression rates. Real-time adjustment of the compression ratio also enhances the engine's versatility, enabling it to operate on multiple fuel types by switching between different engine control programs. Previous attempts at designing multifuel engines for military applications have often resulted in sluggish performance. The Dynamic Flow engine, with its enhanced Atkinson cycle method, facilitates multifuel operation without compromising performance or requiring extensive physical design changes.

4.3.2.3. Core Advantage of EIVC Atkinson Cycle

Presently, conventional gasoline 4-stroke engines employing the Atkinson cycle are primarily found in hybrid vehicles, attributed to their lower horsepower output and slower acceleration in comparison to the Otto cycle. The application of a Dynamic Flow engine with the EIVC Atkinson cycle can further elevate the capabilities of gasoline engines by enabling their use with a turbocharger, thereby enhancing efficiency and power output.

The application of the EIVC Atkinson cycle and its methodology can extend to diesel engines. Diesel engines typically function with a compression ratio ranging from 14:1 to 25:1, a range determined by the inherent characteristics of compression ignition. Notably, the compression ratio of a diesel engine cannot go below 14:1 due to this combustion mechanism.

Theoretically, a diesel engine with a 25:1 compression ratio can transition to lower compression levels by impeding airflow into the combustion chamber through early intake valve closing during the intake stroke.

Historically, diesel engines did not employ the Atkinson cycle because simulating it using LIVC brought minimal benefits due to substantial pumping loss and the absence of a turbocharger benefit. The Dynamic Flow valve configuration, however, enables EIVC Atkinson cycle without physical limitations or drawbacks. EIVC eliminates pumping loss and allows for the utilization of a turbocharger in conjunction with the Atkinson cycle. While turbochargers have traditionally boosted the top-end performance of diesel engines, their application in combination with the EIVC Atkinson cycle also contributes to notable increases in efficiency.

Implementing the Atkinson cycle in diesel engines can further raise thermal efficiency by incorporating the overexpansion principle. A diesel engine designed for a physical compression ratio of 40:1 can be operated at a 25:1 compression ratio using the Atkinson cycle's overexpansion principle. Adjusting the intake valve for early closing allows the engine to function in an aggressive overexpansion state, maintaining the 40:1 expansion ratio.

Simulating the EIVC Atkinson cycle in Dynamic Flow gasoline and diesel engines can further boost thermal efficiency by an additional of 10 to 27% on top of the existing 48%. This would enable the Dynamic Flow 4-stroke engine to achieve up to 75% thermal efficiency, a level that current 4-stroke and 2-stroke engines struggle to reach, rarely exceeding 50%. This innovative approach also supports multi-fuel compatibility, allowing the engine to easily adapt to future fuel types such as synthetic fuels, ammonia, and hydrogen.

4.3.2.4. Dynamic Flow Valve Profile and Engine Operation in Atkinson Cycle

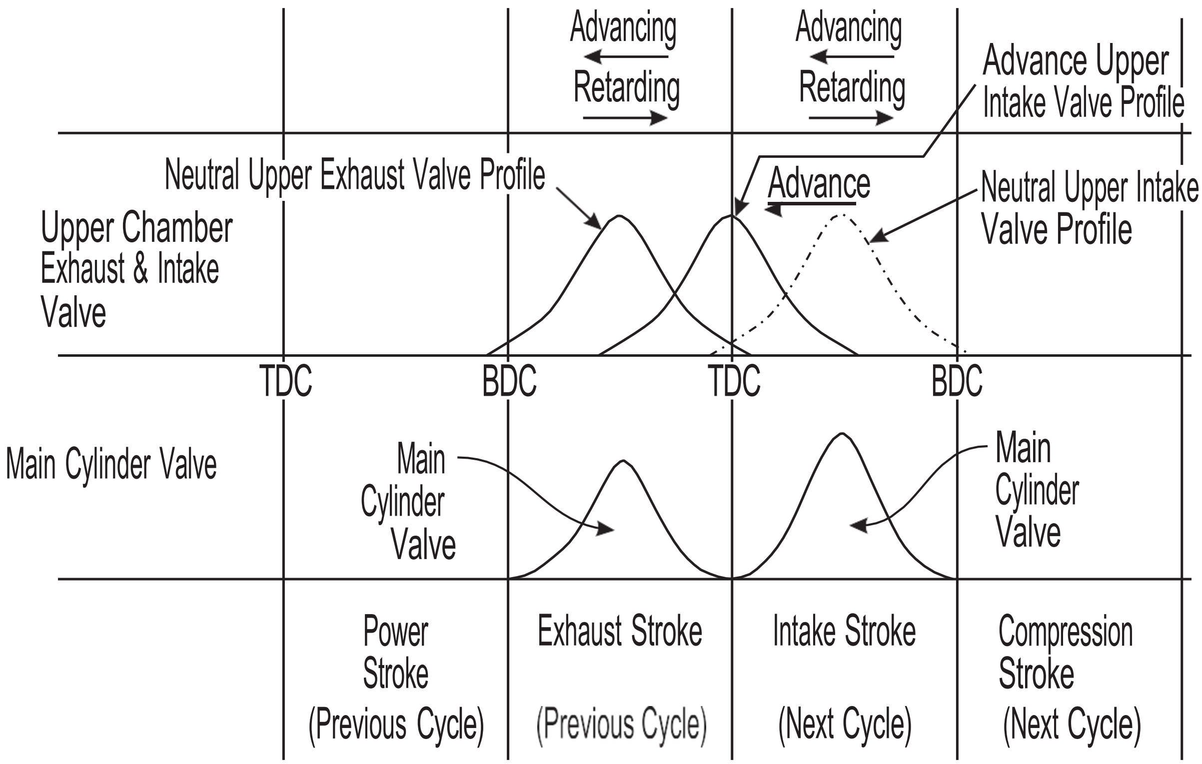


Figure 14 is a valve profile of the combustion engine operating in an Atkinson cycle mode – with exhaust neutral and intake advanced. The above valve profile graph doesn't portray one complete cycle, it portrays the valve's timing change during the period of power stroke of previous cycle to compression stroke of the next cycle.

Maintaining neutral timing for the upper exhaust valve enables the unhindered flow of exhaust gas from the main combustion cylinder into the upper non-combustion chamber through the main valve. Advancing the timing of the upper intake valve allows it to open during the exhaust stroke.

The simultaneous opening of the upper exhaust valve and the upper intake valve results in an overlap, causing the fast-moving exhaust gas to draw intake air into the exhaust manifold via the upper intake valve, upper non-combustion chamber, and upper exhaust valve. This process replaces the exhaust gas in the upper non-combustion chamber, allowing the exhaust gas to exit the engine through the upper exhaust valve. Aggressively advancing the timing of the upper intake valve can increase the influx of intake air into the exhaust manifold, thereby lowering the overall temperature of the exhaust system and augmenting the O2 content in the exhaust system.

During the intake stroke, gases require the entire duration of the stroke to fill the main combustion cylinder through the main valve and upper intake valve. Advanced timing of the upper intake valve results in its early closure during the intake stroke. This leads to a reduction in the gas volume entering the main combustion cylinder and results in a compression stroke smaller than the expansion stroke, resembling the Atkinson engine.

4.4. Infinitely Variable Internal Exhaust Gas Recirculation

4.4.1. Background of Current EGR Technology

Exhaust Gas Recirculation (EGR) is commonly employed in conventional engines primarily aimed at reducing nitrogen oxides (NOx) emissions. The primary factor controlling NOx is the EGR dilution effect, wherein carbon dioxide from exhaust gases displaces O_2 molecules in the charge air. External cooled EGR systems, which are more prevalent than their internal hot EGR counterparts, are employed to collect hot exhaust gases post-exhaust manifold. These gases undergo cooling through an EGR cooler before being reintroduced into the intake system alongside charge air before reaching the intake manifold [3]. This approach effectively reduces NOx emissions under specific conditions, such as constant speed and constant partial load situations. However, challenges arise when the exhaust gases are reintroduced into the intake system before the intake manifold, resulting in delayed combustion chamber entry and sluggish engine response during EGR activation and deactivation.

Cooled exhaust gases, which include traces of thermophoretic carbon, condensed hydrocarbons, and acids, have the potential to produce soot upon cooling. This process can result in the progressive contamination of the intake system over an extended period [4]. Uneven charge air and exhaust gases ratios can occur in engines with multiple combustion chambers, causing some cylinders to receive more charge air and others more exhaust gases. This imbalance, particularly noticeable at low RPM, results in rough engine operation. The uneven ratios in conventional engines with external EGR prevent deviation from the full fuel injection strategy in gasoline engines, making it difficult to reduce fuel consumption and carbon dioxide emissions under partial load conditions.

4.4.1.1. Dynamic Flow Engine Infinitely Variable Internal EGR

The previous approach to internal EGR in conventional combustion engines faces challenges related to intake charging inefficiency and control issues, hindering its widespread adoption [3]. In contrast to conventional engines employing internal EGR, Dynamic Flow engines with internal EGR present advantages such as an infinitely variable EGR ratio to effectively regulate NOx and hydrocarbon emissions during partial load conditions. The valve timing mechanism in Dynamic Flow engines allows for swift adjustments to exhaust recirculation characteristics without any sluggishness. This capability enables Dynamic Flow engines to achieve high operational efficiency, power output, and superior emission control across a broad range of load conditions. Additionally, by utilizing hot exhaust gases, Dynamic Flow engines circumvent issues related to soot that can clog the intake system in engines with external EGR system [4]. The utilization of hot exhaust gases enhances thermal efficiency during partial operation, retaining more heat and promoting scavenging in the heat engine, resulting in increased efficiency, particularly in diesel engines.

In contrast to the earlier internal EGR method, Dynamic Flow engines utilize early exhaust valve closure to control their internal EGR system. When coupled with variable valve timing technology, Dynamic Flow engines can incrementally adjust the volume of exhaust gases in its EGR system to align with current engine load conditions. The capability of Dynamic Flow engines to make incremental changes to the EGR ratio, ranging from 0% to 100%, is noteworthy. In contrast, current conventional engines can only use external EGR at a fixed ratio. Therefore, the ability of Dynamic Flow engines to swiftly change the EGR ratio on demand represents a significant improvement over current conventional engines in emission control. Engines running at higher EGR ratios demonstrate lowered NOx emissions but concurrently encounter a decline in power output [5]. Consequently, employing a variable EGR ratio allows for enhanced control over NOx emissions without adversely impacting engine performance.

Unlike the Dynamic Flow engine, a conventional 4-stroke engine cannot effectively control EGR using its exhaust valve timing. The valve configuration and operation prevent the exhaust valve from advancing, as early exhaust valve closure during the exhaust stroke would require opening it during the expansion stroke. In a conventional 4-stroke engine, opening the exhaust valve during the expansion stroke disrupts the expansion process, hindering full expansion and potentially leading to operational failure.

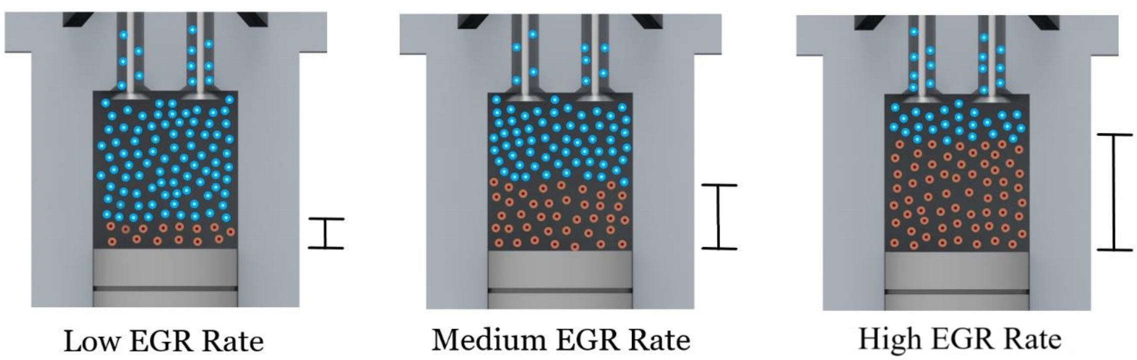


Figure 15 illustrates the various EGR rates that the Dynamic Flow engine can switch between. Blue dots represent intake air, while red dots represent exhaust gases.

4.4.1.2. Method for Dynamic Flow Engine Operation without EGR Active

In the scenario of engine operation without an active internal EGR system, Figure 7A – 7E visually depicts gas flows during each stage of the engine stroke. Particularly, the emphasis is placed on the exhaust stroke of the preceding cycle and the intake stroke of the subsequent cycle, as these stages witness the majority of interactions.

Figure 16A to 16E depicts gases flow and interaction at each stroke cycle for the engine operating without EGR. The light blue dot and arrow symbolize atmospheric O2, while the light red dot and arrow denote the presence and flow of exhaust gases.

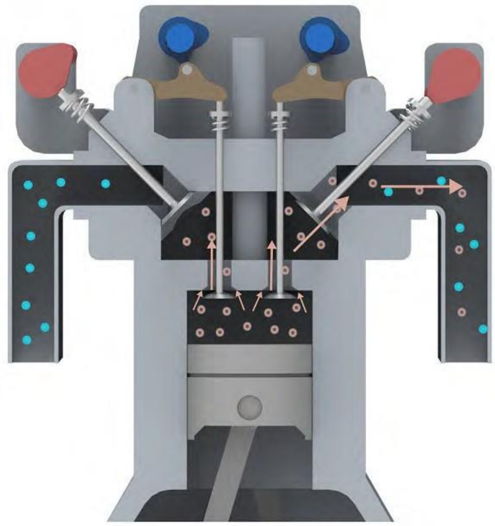


Figure 16A is Dynamic Flow engine operation without EGR at previous cycle exhaust stroke. Following piston reaching Bottom Dead Center (BDC), the main valve and upper exhaust valve both initiate opening. The upward stroke of the piston expels exhaust gases from the main cylinder, directing them into the upper non-combustion chambers and subsequently releasing them into the exhaust manifold.

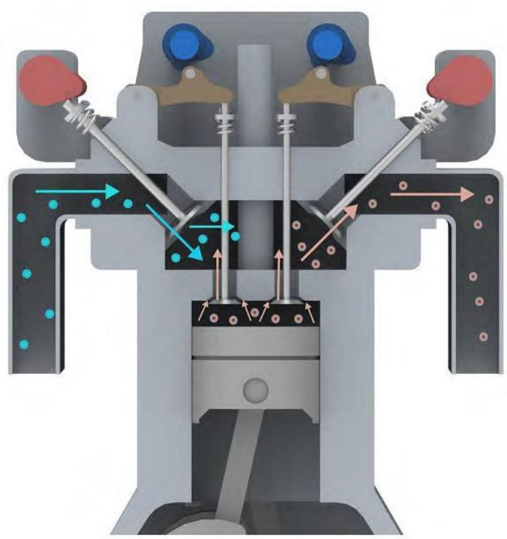


Figure 16B is Dynamic Flow engine operation without EGR at the late stage of exhaust stroke. The upper exhaust valve remains in an open position, allowing the upward motion of the piston to expel the residual exhaust gases into the upper non-combustion chamber and subsequently discharge them through the exhaust manifold. At this point, the upper intake valve initiated its opening. The swift movement of exhaust gases generates a vacuum, drawing intake air into the non-combustion chamber and displacing the exhausted gases.

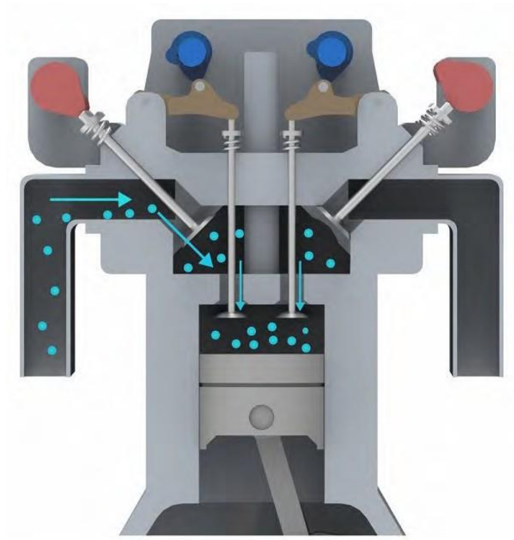


Figure 16C is Dynamic Flow engine operation without EGR at next cycle intake stroke. The upper exhaust valve closes shortly after the commencement of the intake stroke. The downward motion of the piston induces the intake of air into the upper non-combustion chamber, subsequently channeling it into the combustion chamber of the cylinder.

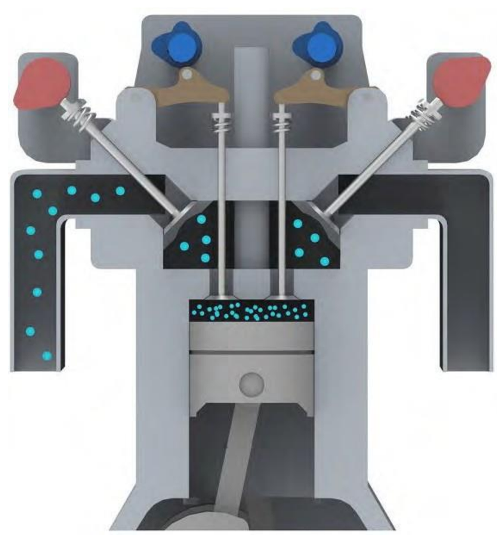


Figure 16D is Dynamic Flow engine operation without EGR at next cycle compression stroke. At this stroke, all valves are closed shut. The intake air undergoes compression and becomes prepared for combustion during the expansion stroke.

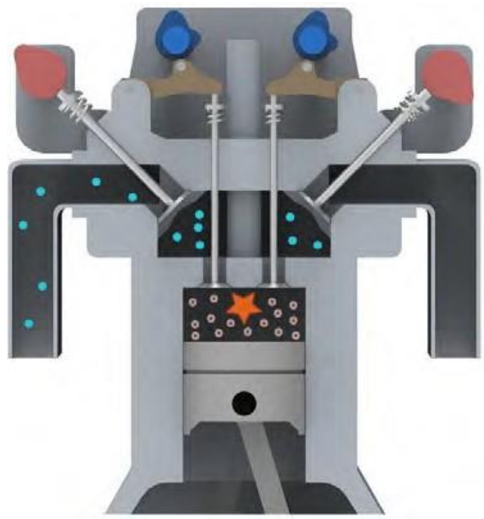


Figure 16E is Dynamic Flow engine operation without EGR at next cycle expansion stroke. During this stroke, all valves are in a closed position. Combustion ignition exerts force on the piston, which in turn indirectly rotates the crankshaft.

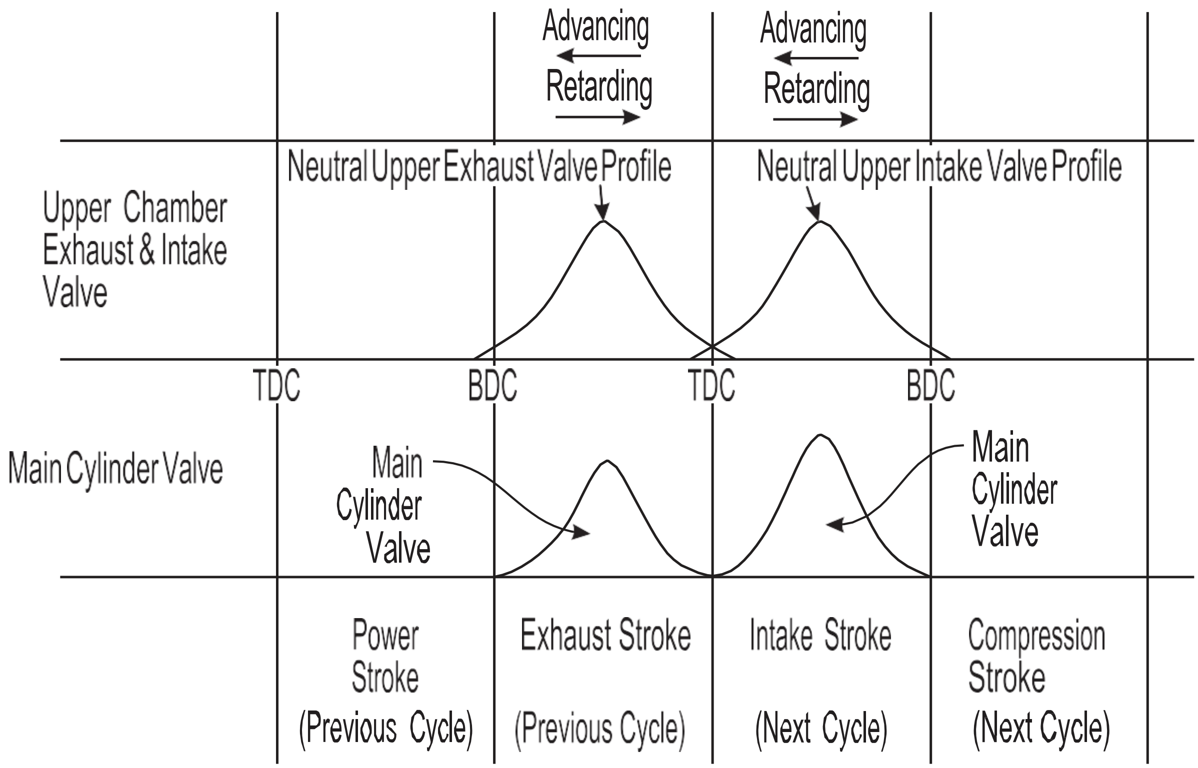


Figure 17 is a valve profile of the variable displacement combustion engine operating i n an Otto Cycle without EGR active. The valve profiles of the exhaust stroke in the preceding cycle and the intake stroke in the subsequent cycle are illustrated to be in close proximity, allowing observation of their timing and overlap.

4.4.1.3. Method for Dynamic Flow Engine Operation with EGR Active

In the scenario of engine operation with an active internal EGR system, the pivotal gas interactions take place between the exhaust stroke of the previous cycle and the intake stroke of the subsequent cycle. Consequently, the primary focus revolves around events occurring during the exhaust stroke of the previous cycle and the intake stroke of the subsequent cycle. This sequencing underscores the inherent EGR operation in such engines. The sequence of events for an EGR system includes the exhaust stroke of the preceding cycle, the late-stage exhaust stroke of the preceding cycle, the intake stroke of the subsequent cycle, the compression stroke of the subsequent cycle, and the expansion stroke of the subsequent cycle.

Figures 18A to 18E depict the flow and interaction of gases during each stroke cycle for engines operating with EGR. The light blue dot and arrow symbolize atmospheric O2, while the light red dot and arrow denote the presence and flow of exhaust gases.

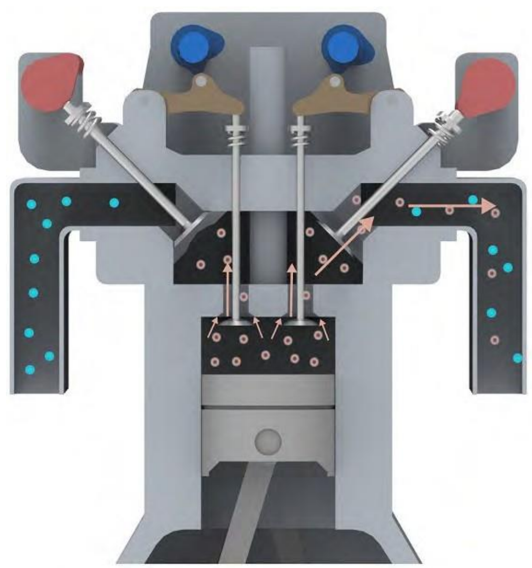


Figure 18A is Dynamic Flow engine operation with EGR at previous cycle exhaust stroke. The exhaust valve initiates opening prior to piston reaching Bottom Dead Center (BDC). Shortly after BDC, the main cylinder valve begins to open. The upward motion of the piston expels exhaust from the main cylinder, directing it into the upper non-combustion chamber and subsequently releasing it into the exhaust manifold.

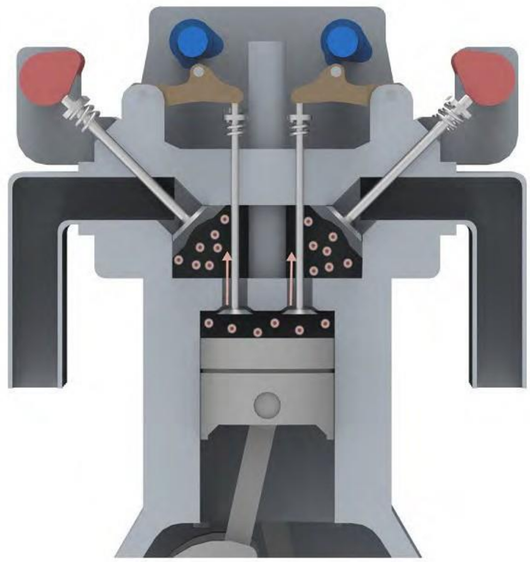


Figure 18B is Dynamic Flow engine operation with EGR at the previous cycle late-stage of exhaust stroke. The advancing of the upper exhaust valve timing results in the closure of the upper exhaust valve at this juncture. With both the upper exhaust and intake valves closed, the upward motion of the piston expels exhaust gases into the upper non-combustion chamber.

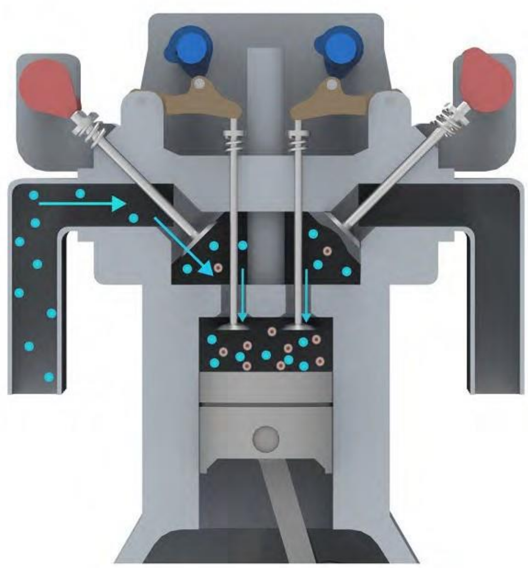


Figure 18C is Dynamic Flow engine operation with EGR at next cycle intake stroke. The upper intake valve commences, opening slightly prior to Top Dead Center (TDC) and before the initiation of the intake stroke. Concurrently, the main cylinder valve begins t o open after TDC. During the downward motion of the piston, exhaust gases confined in the upper non- combustion chamber, along with intake air from the intake manifold, are drawn into the main cylinder. The exhaust gas displaces a portion of the incoming intake air.

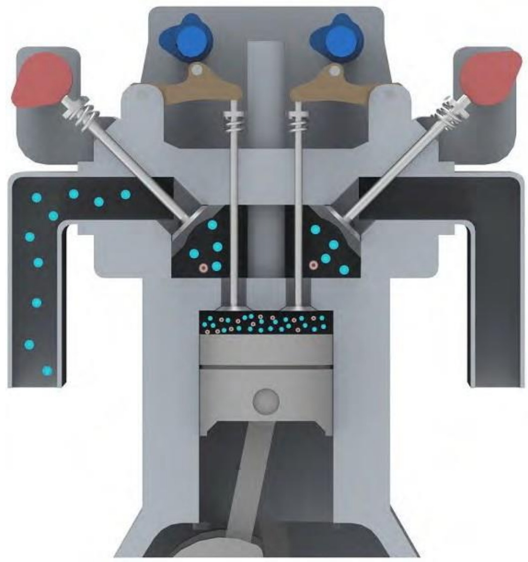


Figure 18D is Dynamic Flow engine operation with EGR at next cycle compression stroke. During this stroke, all valves are in a closed position. The upward motion of the piston results in the compression of exhaust gases mixed with intake air, preparing the mixture for combustion.

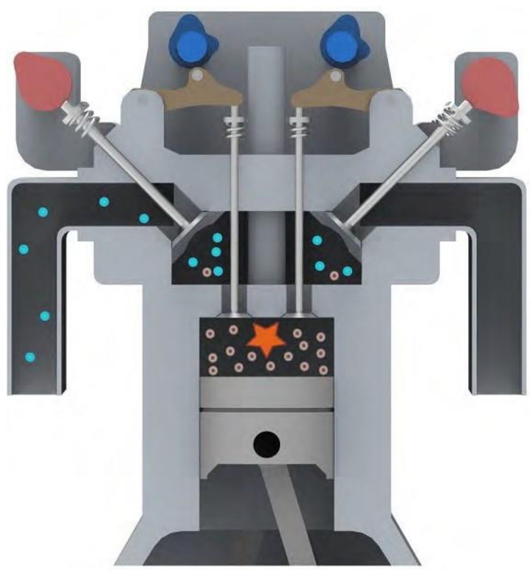


Figure 18E is Dynamic Flow engine operation with EGR at next cycle expansion stroke. During this stroke, all valves remain in the closed position. Combustion takes place, exerting force on the piston, causing it to move downward and, in turn, indirectly rotating the crankshaft.

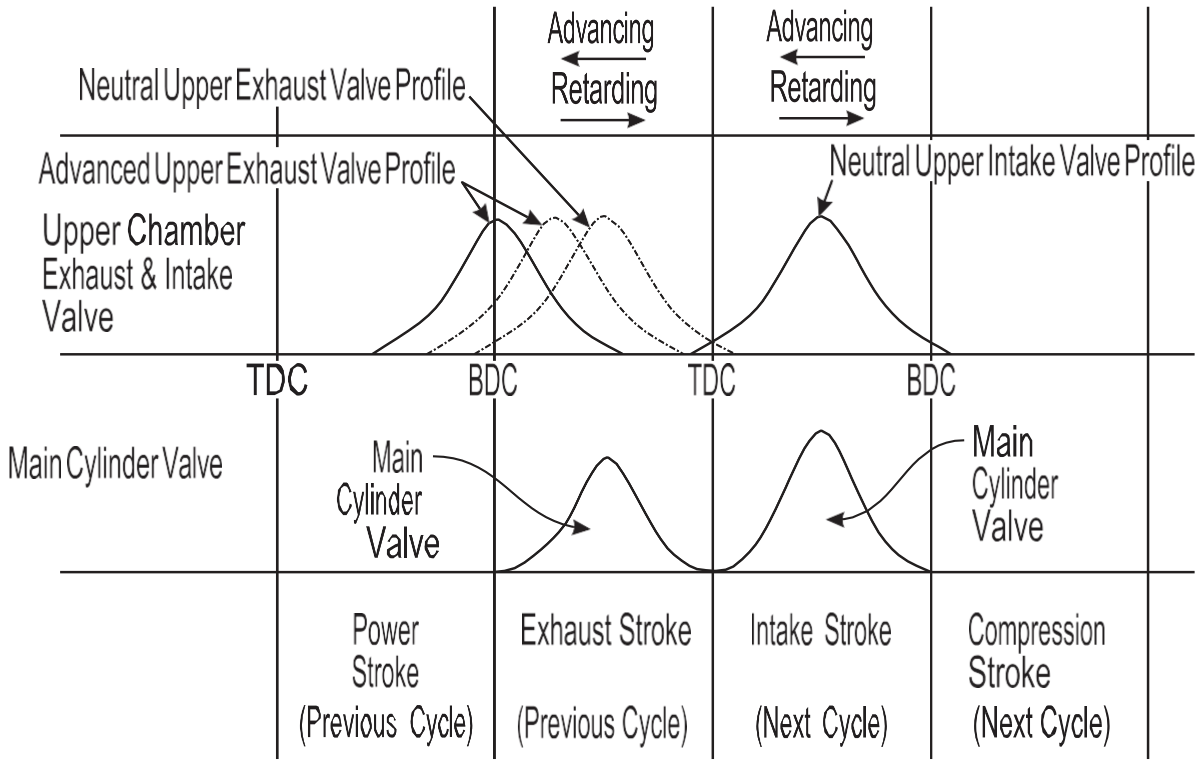


Figure 19 is a valve profile of the combustion engine operating in an Otto cycle mode with internal EGR active – with exhaust advanced and intake neutral.

Advancing the timing of the upper exhaust valve during the expansion and exhaust strokes results in an early opening during the expansion stroke and an early closure during the exhaust stroke. The early opening of the upper exhaust valve in the expansion stroke has no discernible effect on engine operation. However, the early closure of the upper exhaust valve during the exhaust stroke imposes restrictions on the expulsion of exhaust gas through the main valve and upper exhaust valve. This early closure causes some exhaust gas to be retained in the upper non-combustion chamber, and a portion may be redirected into the intake manifold when the upper intake valve opens. The residual exhaust gas persists in the intake manifold until the subsequent intake stroke.

An aggressive advancement of the upper exhaust valve timing results in a larger volume of exhaust gas in the upper non-combustion chamber, whereas minimal advancement leads to a smaller volume.

During the intake stroke, the exhaust gas in the upper non-combustion chamber is reintroduced into the main combustion cylinder through the main valve. The downward force of the piston creates a vacuum, pulling exhaust gas from the upper non-combustion chamber and intake air from the intake manifold into the main combustion cylinder through the main valve and upper intake valve. The presence of exhaust gas in the main combustion cylinder acts as a filler, displacing intake air O_2. Since the exhaust gas does not undergo combustion, the greater its presence in the upper non-combustion chamber during the intake stroke, the more intake air O_2 is displaced. Consequently, less fuel is required for combustion with the intake air O_2, and vice versa. This displacement of intake air O_2 by exhaust gas during the intake and compression strokes results in the engine operating at a partial displacement capacity.

The upper intake valve timing is neutral, thereby not imposing any restriction or shortening of the intake stroke duration. Thus, the engine operates in the Otto cycle mode.

4.4.1.4. Core Advantage of Infinitely Variable Internal EGR

The Dynamic Flow engine's infinitely variable internal EGR allows for real-time adjustments in the EGR ratio to intake air, enabling highly effective emission control across all engine load conditions. Using hot exhaust in its EGR system can increase Dynamic Flow thermal efficiency compared to the cooled external EGR used in conventional engines. Implementing an internal EGR system also reduces costs and saves space typically occupied by bulky external cooled EGR systems. Additionally, diesel engines can significantly reduce NOx emissions by operating at a stoichiometric fuel/air mixture instead of a lean mixture during partial load conditions.

4.5. Variable Displacement Feature

Conventional engines rely on external EGR to manage NOx during partial load operation. This method injects a fixed ratio of cooled exhaust gases back into the intake stream to reduce available O_2 for NOx formation. However, this approach suffers from uneven distribution of exhaust gas to charge air across all cylinders in multi-cylinder engines. This imbalance, particularly noticeable at low RPM, results in rough engine operation and limits the effectiveness of NOx control in diesel engines.

The uneven ratios in conventional engines with external EGR prevent deviation from the full fuel injection strategy in gasoline engines, making it difficult to reduce fuel consumption and carbon dioxide emissions under partial load conditions. Diesel engines operate lean at partial load to save fuel but at the cost of increased NOx emissions.

Additionally, current 4-stroke and 2-stroke gasoline engines waste a lot of fuel during partial load, which is why gasoline engines can only achieve about 25% thermal efficiency in real-world settings, despite reaching 40% in ideal laboratory conditions. Diesel engines have higher thermal efficiency than gasoline engines due to their ability to operate lean, but this results in greater NOx emissions.

Dynamic Flow’s new and unique valve configuration allows its engine to use hot exhaust gases as an emission control medium in its infinitely variable internal EGR system and as a filler agent to displace intake charge air for its variable displacement feature. The methodology for both features is the same except for the fuel injection strategy. Infinitely variable EGR will use a static fueling strategy, whereas the variable displacement feature uses a dynamic fuel injection strategy. The variable displacement feature is more beneficial because it can control NOx emissions, hydrocarbons, and lower fuel and carbon emissions, whereas the internal variable EGR system focuses only on controlling NOx and hydrocarbon emissions.

In the Dynamic Flow engine, the internal variable EGR and variable displacement feature use the timing of the upper exhaust valve to control exhaust gas recirculation. More advanced timing of the upper exhaust valve increases exhaust gas recirculation, while neutral timing results in no exhaust gas recirculation. Using a variable valve mechanism on the upper exhaust valve camshaft allows the engine management computer to infinitely control EGR rate. With Dynamic Flow, EGR occurs at the cylinder level eliminates the uneven distribution of exhaust gas to charge air in engines with multiple cylinders.

The key to variable displacement lies in the Dynamic Flow engine's precise control over the infinitely variable internal EGR system. By meticulously managing the upper exhaust valve timing, the engine can regulate the intake O_2 volume with exceptional precision, allowing the engine to modify the amount of O_2 available for combustion without impacting the compression ratio. Essentially, the engine pulls in less O_2 during partial loads, imitating the behavior of an engine with a smaller cylinder size. By precisely controlling the EGR at the cylinder level using the variable valve mechanism, the Dynamic Flow engine can optimize fuel injection strategy for different load conditions, reducing fuel consumption, CO_2, NO_x, and hydrocarbon emissions. The variable displacement feature allows the engine to dynamically adjust its power output to match fluctuating load conditions without the need for physically modifying the engine's crankshaft and piston connecting rod mechanism. Utilizing exhaust gas to displace intake air O_2 does not impact the engine compression ratio.

The Dynamic Flow engine can uniquely employs variable internal EGR and variable displacement features using advanced upper exhaust valve timing. In conventional engines, the valve configuration prevents the exhaust valve from advancing, as advancing the exhaust valve for early closing during the exhaust stroke necessitates opening it during the expansion stroke. In a conventional engine, opening the exhaust valve during the expansion stroke can negatively impact the expansion process, preventing full expansion and potentially leading to operational failure.

To achieve optimal performance, the Dynamic Flow engine dynamically adjusts the fuel injection strategy in tandem with the varied air intake O_2 volume. This ensures that the air-fuel mixture remains optimized even when the intake air volume is reduced. This precise coordination between air intake O_2 volume and fuel injection contributes significantly to the engine's ability to operate at peak thermal efficiency across a broad spectrum of load conditions and RPM levels.

Transitions between full and partial displacement occur smoothly and instantaneously within the Dynamic Flow engine, ensuring seamless adaptation to diverse operating needs and allowing the engine to consistently deliver peak performance regardless of the load placed upon it.

In essence, the Dynamic Flow engine leverages a clever infinitely variable internal EGR and fuel injection strategy to achieve the benefits of variable displacement without the added complexity and potential reliability concerns of physically modifying the engine's core rotational power generation mechanism, such as the crankshaft or piston connecting rod mechanism.

Technology	Fueling Strategy	Engine Efficiency Improvement	Fuel and Carbon Dioxide Reduction	Nitrogen Oxide Control Level
Infinitely Variable Internal EGR	Marginal	Marginal	Marginal	High
Infinitely Variable Displacement Feature	Aggressive	Significant	Significant	High

Table #1 is a comparation between infinitely variable internal EGR and infinitely variable displacement feature.

4.5.1. Concept and Technique for Variable Displacement

The variable displacement concept involves adjusting the engine cylinder displacement (size) to modify engine output, independent of engine RPM. A Dynamic Flow engine achieves this by employing internal variable EGR and managing the flow of intake air O2 to simulate variable displacement operation without physically altering the characteristics of the cylinder, crankshaft, and connecting rod. The variable displacement feature enables incremental control of engine output by altering the internal EGR volume to displace the intake air O2 volume in the combustion cylinder and regulating fuel injection strategy in relation to the intake air O2 volume. The valve configuration of Dynamic Flow engines can facilitate precise control of the internal EGR ratio and intake air O2 volume through early valve closing timing.

Unlike previous EGR technologies, whether external or internal, Dynamic Flow engines possess the unique capability to vary the EGR ratio. This capacity allows the engine to adjust the EGR ratio on demand using the valve cam timing mechanism. To achieve variable displacement, a Dynamic Flow engine first modifies and sets the EGR ratio by adjusting the exhaust cam timing. Once the EGR ratio is established, the engine recirculates an exhaust gases volume corresponding to the set EGR ratio, displacing an equal volume of atmospheric intake air O2 with the EGR gases. Fuel is then injected to combust with the modified intake air O2 volume.

The objective of the variable displacement concept is to simulate variable engine size displacement without altering the physical characteristics of the engine's cylinder, crankshaft, and connecting rod. This approach allows reciprocating combustion engines to maintain their high-reliability design while gaining enhanced capabilities for improved fuel efficiency and emission control. With variable displacement, gasoline engines would see significantly improved operational efficiency, reduced fuel consumption, and lower carbon emissions. For diesel engines, this feature would notably decrease NOx and hydrocarbon emissions, enabling them to operate at a stoichiometric air-fuel mixture without compromising performance or fuel economy. The variable displacement feature ensures that both gasoline and diesel engines can consistently operate at peak thermal efficiency.

What drives the necessity for Variable Displacement?

In the realm of large, low-speed marine diesel engines, operating at 48% thermal efficiency is the norm, particularly during high-load and constant-rate scenarios. On the contrary, high-speed diesel engines, such as those found in semi-trucks, heavy industrial vehicles, and consumer cars, contend with a more dynamic operational landscape. These engines frequently undergo RPM shifts to modulate power output in response to varying operational conditions. Current combustion technology confines high-speed diesel engines to a narrow RPM band where peak thermal efficiency is achieved. Consequently, these engines often operate in RPM ranges that are suboptimal in terms of thermal efficiency, leading to mismatched engine power output and operational loads, resulting in fuel wastage and higher emission. Combustion engines exhibit their highest thermal efficiency within the 75% to 100% load range, representing a load equivalent to 75% to 100% of the engine's power output [6]. The variable displacement feature of Dynamic Flow engines addresses this challenge by dynamically adjusting engine HP and torque output to align with load conditions, independent of RPM. By tailoring engine power output to match road load conditions, Dynamic Flow engines can consistently operate at peak thermal efficiency, akin to large, low-speed marine diesel engines running at constant load and speed. This adaptive approach yields substantial fuel savings and emissions reduction. The variable displacement feature is governed by the variable valve timing of the upper exhaust valve, ensuring instantaneous shifts in engine variable displacement size. Dynamic Flow engines can variably control hot exhaust gases volume, intake air O2 volume, and fuel injection quantity, mitigating heat-related problems associated with conventional engines utilizing internal hot EGR systems. Higher engine loads necessitate increased quantities of intake air O2 and fuel, while lower engine loads require reduced quantities. Scaling intake air O2 and fuel directly influences power output. Adapting power output in response to load conditions directly diminishes fuel consumption and lowers carbon emissions. This adaptability enables the engine to operate at peak thermal efficiency at all the time.

In practical terms, consider a 6.0-liter combustion engine containing 3.0 liters of EGR exhaust gases and 3.0 liters of intake air O2 volume. The engine's fuel management system, in theory, only needs to inject fuel that will combust with the 3.0 liter of intake air O2 for stoichiometric combustion. In scenarios where engines operate under medium to low load conditions, fuel consumption can be reduced by increasing the displacement of intake air O2 in the combustion cylinder. This allows for injecting less fuel to achieve stoichiometric combustion with the available O2 in the intake air.

4.5.2. Example of Variable Displacement

A Dynamic Flow engine, featuring a 6.0-liter 6-cylinder configuration, exhibits the ability to adjust its displacement across a range from 0 liters to the maximum 6.0 liters. Operating the engine at 100% size displacement, or 6.0 liters, proves advantageous in scenarios demanding heightened power output for substantial loads, such as accelerating onto a freeway, navigating inclines, or accelerating from a standstill at traffic lights.

Opting for 60% size displacement, equivalent to 3.6 liters, during freeway cruising serves to conserve fuel efficiently, given that maximum power is unnecessary under medium load conditions. Operating the engine at its full power during such instances would result in fuel wastage, dissipating as excess heat.

Reducing the size displacement to 20%, corresponding to 1.2 liters, is viable during idle periods when the vehicle is stationary at stoplights or in park. In these situations, the engine runs to power auxiliary systems like the air conditioning and alternator.

An intriguing application is the ability of the engine to operate at 0 size liters displacement, a valuable feature in diesel engines. This mode serves as a preventive measure against a runaway diesel engine, where vaporized foreign fuel in atmospheric intake air could lead to uncontrolled acceleration. Shifting to 0 liters displacement effectively shuts down the engine, mitigating the risk of a runaway scenario.

4.5.3. Variable Displacement and Operation in High Fuel Vapor Environment

A conventional diesel engine relies on compression ignition, which makes it susceptible to runaway conditions. This issue can arise if foreign fuel vapors from the environment or a malfunctioning oil system leak into the intake manifold, setting off a runaway chain reaction. Dynamic Flow engine addresses this vulnerability by precisely controlling the exhaust valve and EGR ratio. By advancing the exhaust timing, the engine increases the EGR rate to a point where the engine shuts down, as the power output falls below the required load. Increasing the EGR ratio reduces the engine's effective size displacement, decreasing the available volume in the combustion chamber for vaporized fuel to fill and ignite. When the engine computer detects foreign fuel, it can reduce or cut off fuel injection while simultaneously increasing the EGR ratio to control runaway engine occurrences.

The Dynamic Flow engine valve system also allows the engine to operate on foreign fuel vapor. To do this, the engine management computer adjusts the EGR ratio, modifies the Atkinson cycle to change the compression ratio, and alters the fuel injection strategy in unison. This capability to function in high vapor fuel conditions enables heavy-duty diesel machinery to operate in more hazardous areas without the need for large, bulky external systems that are commonly used today.

4.5.4. Core Advantage of Infinitely Variable Displacement Feature

Gasoline engines are set to undergo major advancements in operational efficiency, enabling them to consistently operate at peak thermal efficiency under all real-world conditions. This enhanced efficiency will lead to reduced fuel consumption and lower CO_2 emissions, with NOx emissions also being lower than those of current 4-stroke gasoline engines. By combining an undersquare design, the Atkinson cycle, and variable displacement feature, the real-world thermal efficiency of small 4-stroke gasoline engines could potentially improve from the current 25% to the range of 60% to 75% in the future. The small engine sector stands to gain the most from Dynamic Flow variable displacement technology. For example, a 6.0-liter Dynamic Flow engine with variable displacement can offer significantly higher performance and fuel efficiency compared to a conventional 2.0-liter 4-stroke or 2-stroke engine. Building larger, more fuel-efficient engines also enhances engine reliability. A larger engine doesn’t need to operate at high RPMs to produce the same power as a smaller engine, and running at lower RPMs can contribute to greater longevity.

Diesel engines will see a dramatic reduction in NOx and hydrocarbon emissions, allowing them to operate at a stoichiometric air-fuel mixture without sacrificing performance or fuel economy. These engines will require fewer emissions after-treatment systems compared to today's diesel systems. Additionally, diesel engines will gain the capability to operate in high vapor fuel environments, making diesel runaway problems a thing of the past.

4.6. Internal Secondary Air Injection

The implementation of the upper non-combustion chamber in the engine system leads to the occurrence of internal secondary air injection. This injection occurs as a portion of atmospheric air travels from the intake manifold to the upper non-combustion chamber and is subsequently expelled into the exhaust manifold without undergoing combustion.
The process of internal secondary air injection introduces additional O2 molecules into the exhaust system.

Internal secondary air injection plays a role in reducing carbon monoxide and NOx in exhaust gases by converting them into carbon dioxide and nitrogen dioxide within the exhaust system. The volume of internal secondary air injection can be adjusted by modifying the size of the upper non-combustion chamber.

Example of passive internal secondary air injection during engine operation

Figure 20A to 20D depicts the atmospheric gases movement during each stroke cycle. The light blue dot and arrow symbolize atmospheric O2, while the light red dot and arrow denote the presence and flow of exhaust gases.

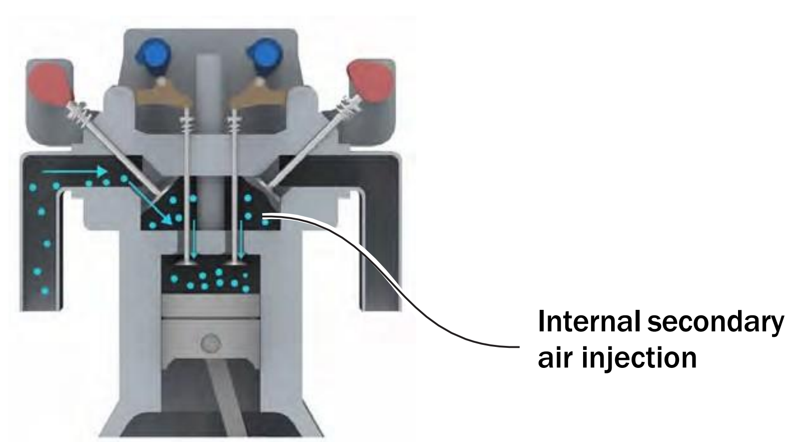


Figure 20A is Dynamic Flow engine operation a t intake stroke. The atmospheric air filled the upper non-combustion chamber and combustion chamber.

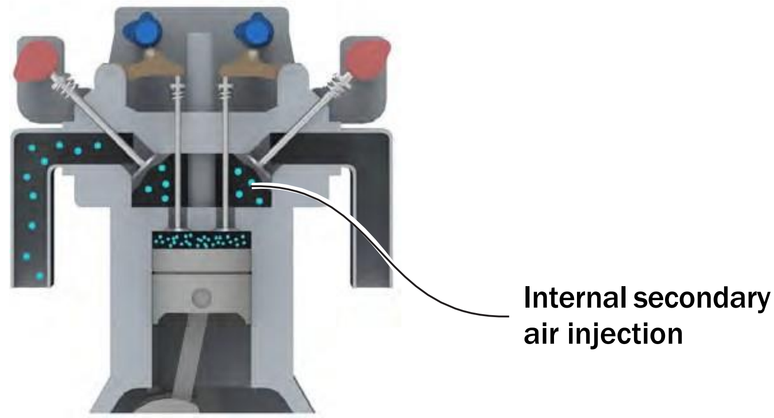


Figure 20B is Dynamic Flow engine operation at compression stroke. The atmospheric air is trapped and collected in the upper non-combustion chamber.

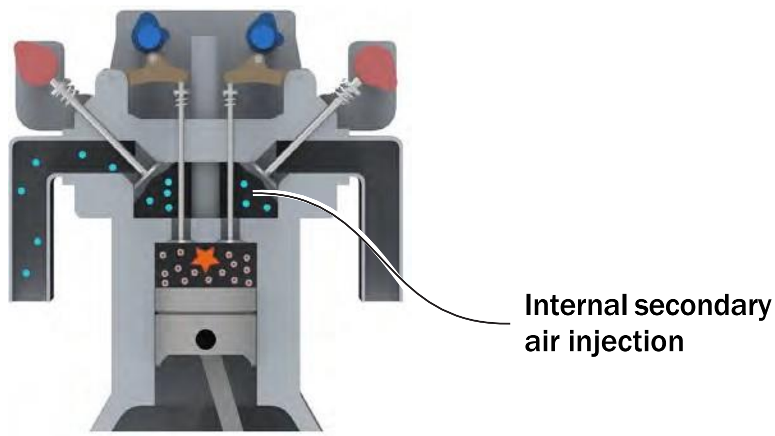


Figure 20C is Dynamic Flow engine operation at expansion stroke. Atmospheric air remains in the upper non-combustion chamber during this stroke.

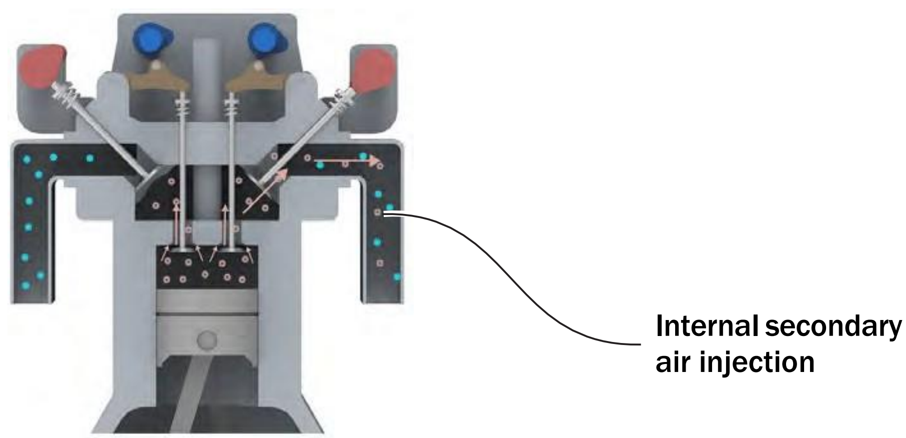


Figure 20D is Dynamic Flow engine operation at exhaust stroke. Atmospheric air expels out the upper non-combustion chamber into the exhaust manifold during this stroke and mixes with the exhaust gases in the exhaust system.

4.6.1. Blow Back Technique for Small Upper Non-Combustion Chamber

The volume of internal secondary air injection is directly correlated to the volumetric size of the non-combustion chamber, with a smaller non-combustion chamber resulting in reduced secondary air injection effects. The variable EGR can be effectively implemented with a smaller non-combustion chamber through the utilization of the blowback technique. This technique comes into play when the upper non-combustion chamber volume is incapable of containing all the requisite exhaust gases from the exhaust stroke for variable EGR operation. In such cases, the intake manifold pipe serves as a reservoir for the exhaust gases during the exhaust stroke.

Opting for a smaller upper non-combustion chamber is preferable for engines aiming to minimize the impact of passive secondary air injection. A smaller upper non-combustion chamber possesses a diminished volumetric area for the collection of intake air O_2, thereby resulting in reduced secondary air injection effects.

4.6.2. Blow Back Technique Operation:

Figure 21A to 21E depicts gases movement and interaction utilizing blow back technique with the engine operating in partial displacement mode. The light blue dot and arrow symbolize atmospheric O_2, while the light red dot and arrow denote the presence and flow of exhaust gases.

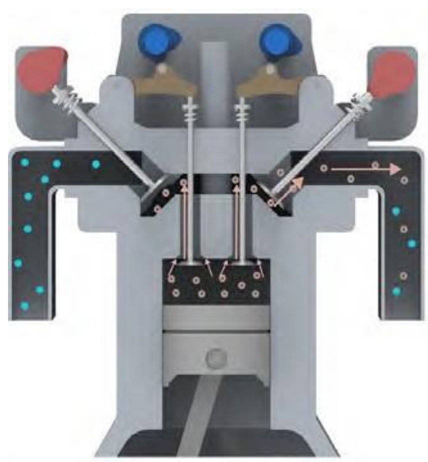


Figure 21A is a Dynamic Flow engine with small upper non-combustion chamber operation at previous cycle exhaust stroke. The piston's upward motion expels the exhaust gas from the main cylinder, directing it into the upper non-combustion chamber and ultimately into the exhaust manifold.

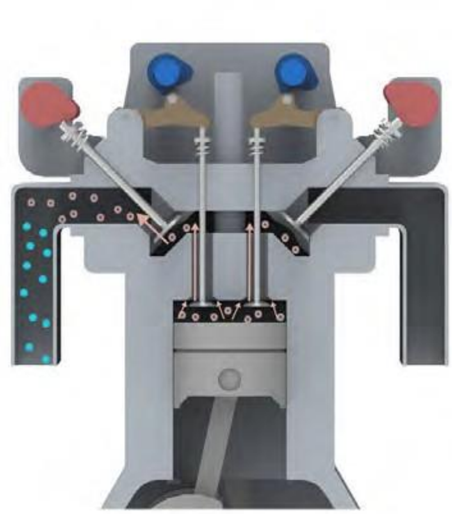


Figure 21B is a Dynamic Flow engine with small upper non-combustion chamber operation at previous cycle late-stage exhaust stroke. The early closure of the upper exhaust valve and the early opening of the upper intake valve result in the redirection of exhaust gas from the main cylinder into the upper non-combustion chamber, followed by its flow into the intake manifold. The intake manifold pipes serve as a reservoir for the exhaust gases until the intake stroke begins.

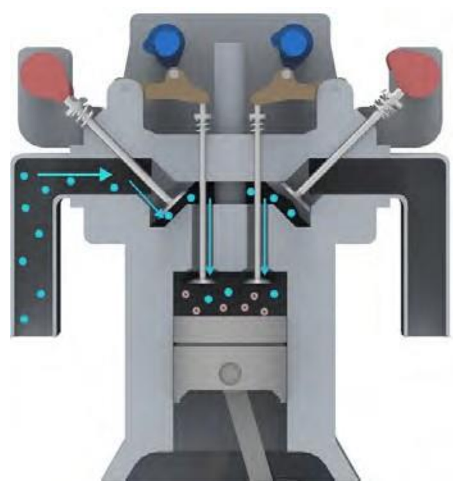


Figure 21C is a Dynamic Flow engine with small upper non-combustion chamber operation at next cycle intake stroke. The piston's downward motion draws in both exhaust gas and intake air from the intake manifold into the upper non-combustion chamber, subsequently directing them into the main cylinder.

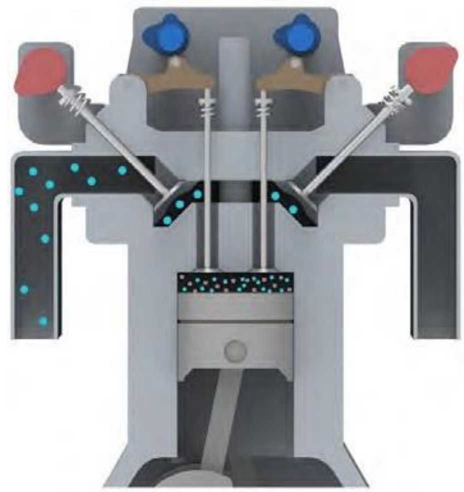


Figure 21D is Dynamic Flow engine with small upper non-combustion chamber operation at next cycle compression stroke. The piston's upward motion results in the compression of both exhaust gas and intake air.

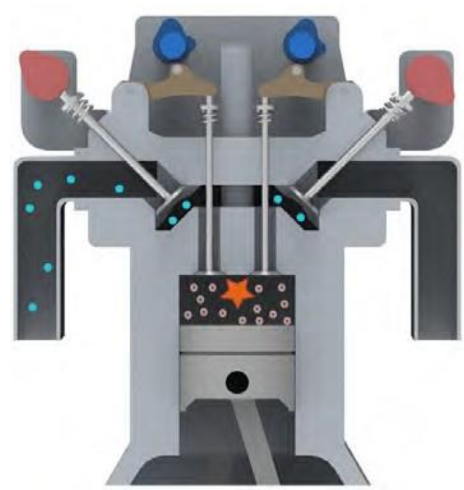


Figure 21E is a Dynamic Flow engine with small upper non-combustion chamber operation at next cycle expansion stroke. Fuel injection initiates combustion, propelling the piston in a downward direction.

4.6.3. Core Advantage Internal Secondary Air Injection

Dynamic Flow’s built-in passive internal secondary air injection eliminates the need for an external secondary air system, including its pump and piping. This design not only reduces costs but also improves efficiency by eliminating the energy losses associated with running an external secondary air injection pump.

5. Supporting Technology - Advance Variable Valve Timing

The Dynamic Flow engine relies on variable valve timing for the seamless transition between Otto and Atkinson cycles and for the activation of the variable EGR feature. The current variable valve timing mechanisms in conventional engine lack incremental valve timing phasing and a stop-and-hold functionality. The advanced variable valve timing system described below introduces incremental phasing capabilities, allowing for both advance and retard adjustments, and includes the ability to stop and securely lock in position.

For the Dynamic Flow engine to fully leverage all its features, an advanced variable valve timing system with incremental capabilities is imperative. It is noteworthy that the variable valve timing system detailed below is developed and patented by the same company that originated the Dynamic Flow engine.

5.1. Advance Variable Valve Timing Apparatus Using Electric Motor Activation

This variable valve timing mechanism utilizes an electric gear motor for precise control of camshaft phasing. The innovative design enables incremental adjustments, allowing for both advancing and retarding the camshaft position. Additionally, it boasts the advanced capability of stopping and holding the camshaft at any desired position.

Patent number: 11614004

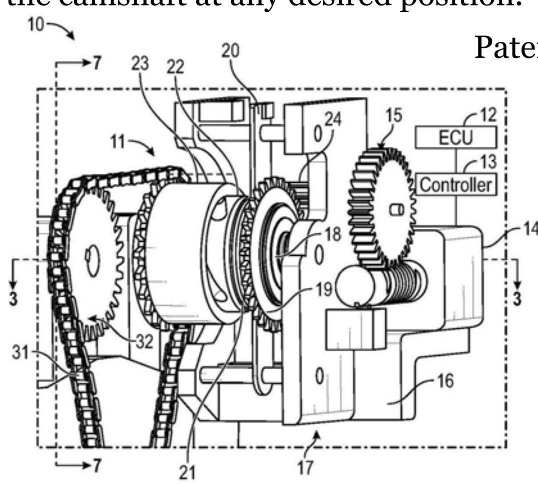


FIG. 1

Figure 22A is a front view of a patented variable valve timing mechanism controlled by an electric gear motor.

Patent number: 11614004

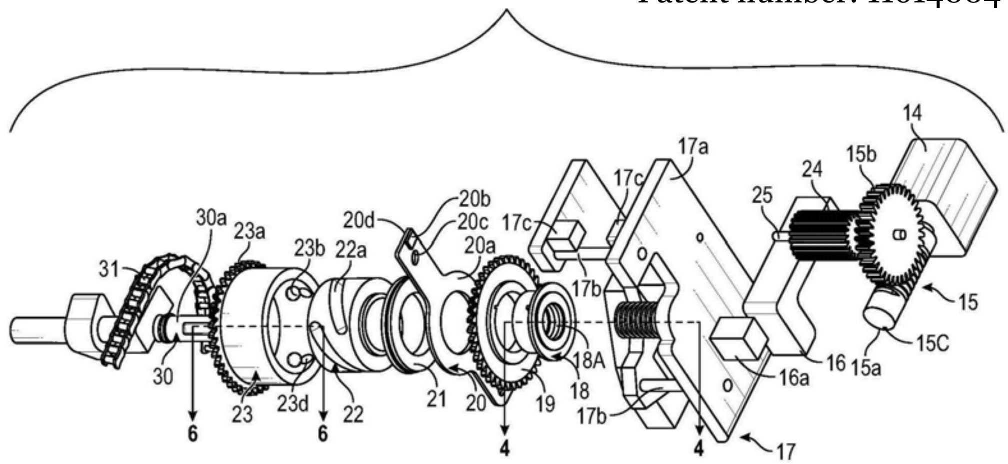


Figure 22B is an exploded view of a patented variable valve timing mechanism controlled by an electric gear motor.

5.2. Advance Variable Valve Timing Apparatus Using Oil System

Traditional Variable Valve Timing (VVT) systems leverage engine oil to adjust camshaft phasing. While widely used and reliable, these systems offer limited phasing capabilities and operate with a fixed phasing rate.

Unlike conventional VVT systems with a single phasing rate, this technology allows for dynamic adjustments, tailoring the phasing speed to engine conditions for optimal performance. This system delivers exceptional precision in camshaft positioning, exceeding the capabilities of traditional oil-controlled VVT systems. This unique feature actively holds the camshaft at any desired phase angle, further enhancing engine performance and control.

These advancements offer significant advantages over conventional oil-controlled VVT systems:
- Precise and dynamic control of camshaft phasing allows for optimal engine performance across a wider range of operating conditions.
- Variable phasing rate and active stop-and-lock features contribute to improved fuel efficiency and reduced emissions.
- The system's advanced capabilities enable wider engine tunability, meeting diverse application demands.

This novel VVT technology represents a significant leap forward in camshaft control, offering superior performance, efficiency, and flexibility compared to traditional oil-controlled systems.

Patent number: 12000314

Figure 23A is an exploded view of a patented variable valve timing mechanism system utilizing engine oil for cam phasing.

Patent number: 12000314

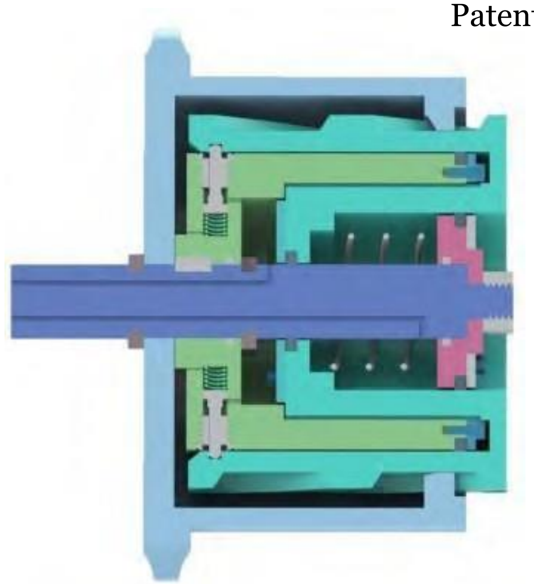


Figure 23B is a mid-cut view of a patented variable valve timing mechanism system utilizing engine oil for cam phasing.

6. Combustion Engine Type and Characteristic

Industrial Sector	Engine Type & Fuel Type	EGR Type	Throttle Body	Turbocharger or Supercharger Compatible	Pumping Loss Level	Multi-fuel Capacity
Marine – Large slow-speed diesel	2-stroke, diesel	Fixed, External	No	Turbocharger	Low	No
Marine – medium-speed diesel	4-stroke, diesel	Fixed, External	No	Turbocharger	Low	No
Industrial Truck – high-speed diesel	4-stroke, diesel	Fixed, External	No	Turbocharger	Low	No
Automobile	4-stroke, gasoline	Fixed, External	Yes	Turbocharger, supercharger, Or naturally aspirated	High	No
Toyota Atkinson Cycle engine	4-stroke, gasoline	Fixed, External	No	Naturally aspirated	Medium	No
Motorbike	2-stroke, gasoline	None	Yes	Naturally aspirated	High	No
Dynamic Flow engine	4-stroke, diesel or gasoline	Infinite Variable, Internal	No	Turbocharger, supercharger, or naturally aspirated	Low	Yes

Table 2: Comparison of Different Types of Combustion Engine Characteristic

Industrial Sector	Engine Type & Fuel Type	Airflow Capacity, Gases exchange Duration	Atkinson Cycle	Variable Displacement	Susceptible Runaway Engine Problem	Hazardous High Vapor Fuel Environment Operation
Marine – Large slow-speed	2-stroke, diesel	High airflow, short duration	No	No	Yes	No
Marine – medium-speed	4-stroke, diesel	Medium airflow, long duration	No	No	Yes	No
Industrial Truck - high-speed diesel	4-stroke, diesel	Medium airflow, long duration	No	No	Yes	No
Automobile	4-stroke, gasoline	Medium airflow, long duration	No	No	No	Yes
Toyota Atkinson Cycle engine	4-stroke, gasoline	Medium airflow, long duration	Yes	No	No	Yes
Motorbike	2-stroke, gasoline	High airflow, short duration	No	No	No	Yes
Dynamic Flow engine	4-stroke, diesel or gasoline	High airflow, long duration	Yes	Yes	No	Yes

Table 3: Comparison of Different Types of Combustion Engine Characteristics continue…

7. Implication of Dynamic Flow Engine Technology

Fuel and Carbon Dioxide Emission Reduction Benefits:

Industrial Sector	Engine Type & Fuel Type	Current Engine Thermal Efficiency	Dynamic Flow Engine Thermal Efficiency	Thermal Efficiency Improvement with Dynamic Flow Engine Technology	Estimated U.S. Annual Carbon Dioxide Emission reduction with Dynamic Flow Engine Technology (Tg CO Equivalent)	Estimated U.S. Annual Fuel Saving with Dynamic Flow Engine Technology
Marine – Large slow-speed diesel	2-stroke, diesel	48%	60% to 75%	12%	4.44 million metric tons	0.11 billion gallons of gasoline equivalent
Marine – medium-speed diesel	4-stroke, diesel	42%	60% to 75%	18%	6.66 million metric tons	0.16 billion gallons of gasoline equivalent
Industrial Truck – high-speed diesel	4-stroke, diesel	28-38%	60% to 75%	22%	157.41 million metric tons	15.47 billion gallons of gasoline equivalent
Light Truck & passenger car	4-stroke, gasoline	23-25%	60% to 75%	35%	586.54 million metric tons	66.15 billion gallons of gasoline equivalent
Motorbike	2-stroke, gasoline	13-17%	60% to 75%	43%	5.30 million metric tons	0.57 billion gallons of gasoline equivalent

Table 4: U.S. annual fuel and carbon dioxide emission reduction with Dynamic Flow engine technology.

***U.S. Annual CO2 emission and fuel estimation is based on EPA Fast Facts U.S. Transportation Sector for 2022.*

***The Industrial Truck sector includes Medium- and Heavy- Duty Trucks, and buses.*

The Dynamic Flow 4-stroke engine achieves an intake air flow rate that is 50% greater and an exhaust flow rate that is 135% greater than current 4-stroke engines, making it comparable to current 2-stroke engines gas flow rate. However, Dynamic Flow has a significant advantage over 2-stroke engines because its intake air and exhaust gas flow durations are much longer, resulting in greater overall gas flow capacity. This increased gas flow capacity, combined with EIVC Atkinson cycle, allows Dynamic Flow 4-stroke engines to achieve thermal efficiencies in the range of 60% to 75% across a wide range of engine sizes.

This improvement in thermal efficiency translates to a 30% reduction in carbon dioxide emissions and fuel usage for the marine medium-speed 4-stroke diesel sector, a 36.6% reduction for the high-speed diesel industrial truck sector, a 58.3% reduction for the light truck and passenger car sector, and a 71.6% reduction for the motorcycle and motorbike sector. Dynamic Flow engine technology has the potential to deliver significant economic and environmental benefits for the United States. This innovative technology could translate to substantial cost savings through billions of gallons of fuel saved annually. Additionally, it offers the potential to make a major contribution to a cleaner environment by reducing U.S. carbon dioxide emissions by hundreds of millions of metric tons each year.

Nitrogen Oxide Emission Benefits:

Industrial Sector	Engine Type & Fuel Type	Current Engine Fuel Injection Strategy at Partial Load Operation	Current Engine NOx Emission Level at Partial Load Operation	Dynamic Flow Engine Fuel Injection Strategy at Partial Load Operation	Dynamic Flow Engine NOx Emission Level at Partial Load Operation	NOx Reduction with Dynamic Flow Engine Technology
Marine - Large slow-speed diesel	2-stroke, diesel	Lean, lowered fuel injection	High	Stoichiometric air–fuel ratio, lowered fuel injection	Low	Significant
Marine - medium-speed diesel	4-stroke, diesel	Lean, lowered fuel injection	High	Stoichiometric air–fuel ratio, lower fuel injection	Low	Significant
Industrial Truck - high-speed diesel	4-stroke, diesel	Lean, lowered fuel injection	High	Stoichiometric air–fuel ratio, lower fuel injection	Low	Significant
Automobile	4-stroke, gasoline	Stoichiometric air–fuel ratio, full fuel injection	Low	Stoichiometric air–fuel ratio, lower fuel injection	Low	Not significant
Motorbike	2-stroke, gasoline	Stoichiometric air–fuel ratio, full fuel injection	Low	Stoichiometric air–fuel ratio, lower fuel injection	Low	Not significant

Table 5: Nitrogen Oxide Emission reduction with Dynamic Flow Technology

Current diesel engines run lean to save fuel and reduce carbon dioxide emissions during partial load. The Dynamic Flow 4-stroke engine, with its internal infinitely variable EGR system and variable displacement feature, allows the diesel engine to operate at a stoichiometric air-fuel ratio at all times while maintaining the fuel efficiency of current lean-running diesel engines. Consequently, the Dynamic Flow engine achieves a significant reduction in NOx emissions compared to current diesel engines.

Developed Country:
In developed nations, governments aim to phase out combustion engine vehicles for small passenger cars, replacing them with electric vehicles (EVs). However, global consumers have shown less enthusiasm for this transition. As of November 2024, global EV sales growth has stagnated, slowing to single-digit increases over recent quarters. EVs are generally more expensive to purchase, incur higher long-term operational costs, are less convenient to operate, and offer only marginal environmental benefits compared to conventional four-stroke gasoline vehicles. In contrast, developing and implementing Dynamic Flow engine technology could have a more substantial environmental impact while requiring significantly lower infrastructure investment than EV adoption.
Consumer preferences are increasingly shifting toward hybrid and plug-in hybrid vehicles, with sales showing consistent quarter-over-quarter growth. Combining hybrid systems with Dynamic Flow engine technology could dramatically reduce greenhouse gas emissions and lower operational fuel costs for consumers.
In sectors reliant on larger engines, such as delivery trucks, semi-trucks, industrial machinery, and marine vessels, diesel engines remain essential. Integrating Dynamic Flow engine technology in these applications can improve thermal efficiency, reduce fuel consumption, and cut emissions. This is critical, as the global economy continues to depend heavily on combustion engines and fossil fuels.

Developing Country:
In developing countries, small two-stroke motorbikes are a primary mode of transportation, while larger diesel engines are crucial for cargo transport. Dynamic Flow engine technology offers these nations a pathway to reduce greenhouse gas emissions and fuel costs without incurring the significant infrastructure expenses associated with transitioning to EVs.

Application

The Dynamic Flow 4-stroke engine has a high level of versatility, making it suitable for a broad spectrum of vehicles and equipment applications.

Large 2-stroke Slow-speed Marine Diesel Engine Sector:
Conventional large marine diesel engines, primarily two-stroke designs, achieve thermal efficiencies of approximately 48%, thanks to their ability to handle large air volumes. However, a key limitation is their inability to simulate the Atkinson cycle, which has the potential to significantly enhance thermal efficiency. The Dynamic Flow engine overcomes this limitation by combining the high gas flow rates typical of two-stroke engines with the extended gas flow duration of four-stroke engines. This extended duration enables the engine to simulate the Atkinson cycle within its diesel operation, achieving thermal efficiencies in the range of 60% to 75%.

Another notable feature of the Dynamic Flow engine is its infinitely variable exhaust gas recirculation (EGR) system. Conventional diesel engines operate in a "lean mode" at partial load to conserve fuel, but this mode generates higher nitrogen oxide emissions, a significant contributor to greenhouse gases. The Dynamic Flow engine's advanced EGR system maintains an ideal stoichiometric air-fuel ratio, even at partial load, while requiring lower fuel injection. This results in significantly reduced nitrogen oxide emissions, paving the way for cleaner operation and a more sustainable future for maritime transport.

Medium-Speed Diesel Marine Engine Sector:
Medium-speed 4-stroke marine diesel engines could gain a 18% increase in thermal efficiency with Dynamic Flow engine technology. This improvement could translate to a 30% reduction in fuel usage and carbon dioxide emissions. The potential for billions in annual fuel cost savings makes the adoption of this technology economically appealing. Dynamic Flow engines share many parts with current combustion engine technology, resulting in low development and implementation costs.
Dynamic Flow engines offer cleaner operation by eliminating the need for lean burn operation in diesel. Their internal infinitely variable EGR system allows diesel engines to operate at the ideal stoichiometric air-fuel ratio with lower fuel injection under various partial loads. This optimization not only improves fuel usage but also significantly reduces NOx emissions, leading to cleaner operation and a more sustainable future for maritime transportation.

High-Speed Road Diesel Heavy- and Medium-Duty Truck Sector:
The high-speed 4-stroke diesel engine sector could see a 22% increase in thermal efficiency with Dynamic Flow engine technology. This improvement could lead to a 36.6% reduction in fuel consumption and carbon dioxide emissions. In addition to these benefits, Dynamic Flow engine technology also significantly reduces NOx and hydrocarbon emissions in diesel engines.

High-speed Gasoline Light-Truck and Passenger Car:
Dynamic Flow engine technology will enhance the current real-world thermal efficiency of small high-speed 4-stroke gasoline engines from 25% to a significantly higher level. This increase in thermal efficiency could lead to a 58.3% or more reduction in fuel consumption and carbon dioxide emissions in light trucks and passenger cars.
Historically, manufacturers of light trucks and passenger cars have used larger displacement naturally aspirated gasoline engines for their reliability, leveraging the ability to overbuild engines for enhanced longevity. However, due to stricter government fuel economy regulations and emission standards, there has been a shift toward smaller, more fuel-efficient turbocharged engines in the automotive industry.
Currently, automakers use small displacement turbocharged engines to achieve lower fuel consumption during low to medium loads, utilizing turbocharged forced air for high loads. Smaller engines experience heightened operational stress compared to their larger counterparts when producing similar power outputs. Additionally, these smaller engines operate at higher RPMs compared to larger size displacement engines, leading to increased wear and decreased

longevity. Conversely, a Dynamic Flow engine, characterized by its variable displacement feature, enables a larger engine to operate at lower RPMs, promoting prolonged longevity. Furthermore, it can achieve superior fuel efficiency compared to smaller conventional 4-stroke engines. The superior gas flow of Dynamic Flow engines provides manufacturers with increased flexibility in designing engines with higher power output and superior thermal efficiency, all without compromising design focus. The variable displacement feature can simplify engine production and design, enabling automakers to create fewer engine types and sizes capable of powering a diverse range of vehicles. With superior gas flow and variable displacement, automakers can implement larger size displacement engines that combine high low-end torque and horsepower without fuel fuel efficiency penalty.

Motorcycle and Motorbike:
The compactness and versatility of the Dynamic Flow engine will enable motorbikes and smaller vehicles to achieve an unprecedented 43% increase in thermal efficiency. This improvement could lead to a 71.6% reduction in fuel consumption and carbon dioxide emissions.
Notably, motorcycles emit hydrocarbons at a rate 16 times higher, carbon monoxide at three times the amount, and a considerable quantity of other airborne pollutants compared to passenger cars with 4-stroke engine. This is largely due to the fact that current motorcycles do not incorporate EGR systems, primarily because a bulky external EGR system is impractical to be used in motorcycle. The compact design specifications of motorbike make it challenging to employ an external EGR system. However, by utilizing Dynamic Flow engines with internal EGR, it becomes feasible to integrate EGR functionality into smaller combustion engines like those found in motorcycle and motorbikes.
This integration has the potential to reduce fuel consumption significantly, cutting it in half, and substantially decrease carbon and NOx emissions in small combustion engines.
Emerging economies, which heavily rely on small motorbikes for transportation, could benefit greatly from this technology, as it would significantly reduce pollution and improve economic impact through lower fuel usage.

Hydrogen Combustion Engine:
The conventional combustion engine can be modified to operate using hydrogen as its fuel source. Hydrogen combustion offers a cleaner transportation solution with a minimal global warming impact, as its tailpipe exhaust consists of water vapor and NOx. Despite being cleaner in terms of greenhouse emissions compared to conventional internal combustion engines, hydrogen combustion engines still face challenges with high NOx emissions under partial load conditions [10]. The solution to the NOx emission issue in hydrogen combustion engines lies in Dynamic Flow engines, which introduce a novel internal variable EGR method. This system and method in Dynamic Flow engines enable precise control of the EGR ratio without incurring charging inefficiencies. The internal variable EGR system in Dynamic Flow engines makes them well-suited for hydrogen combustion applications.

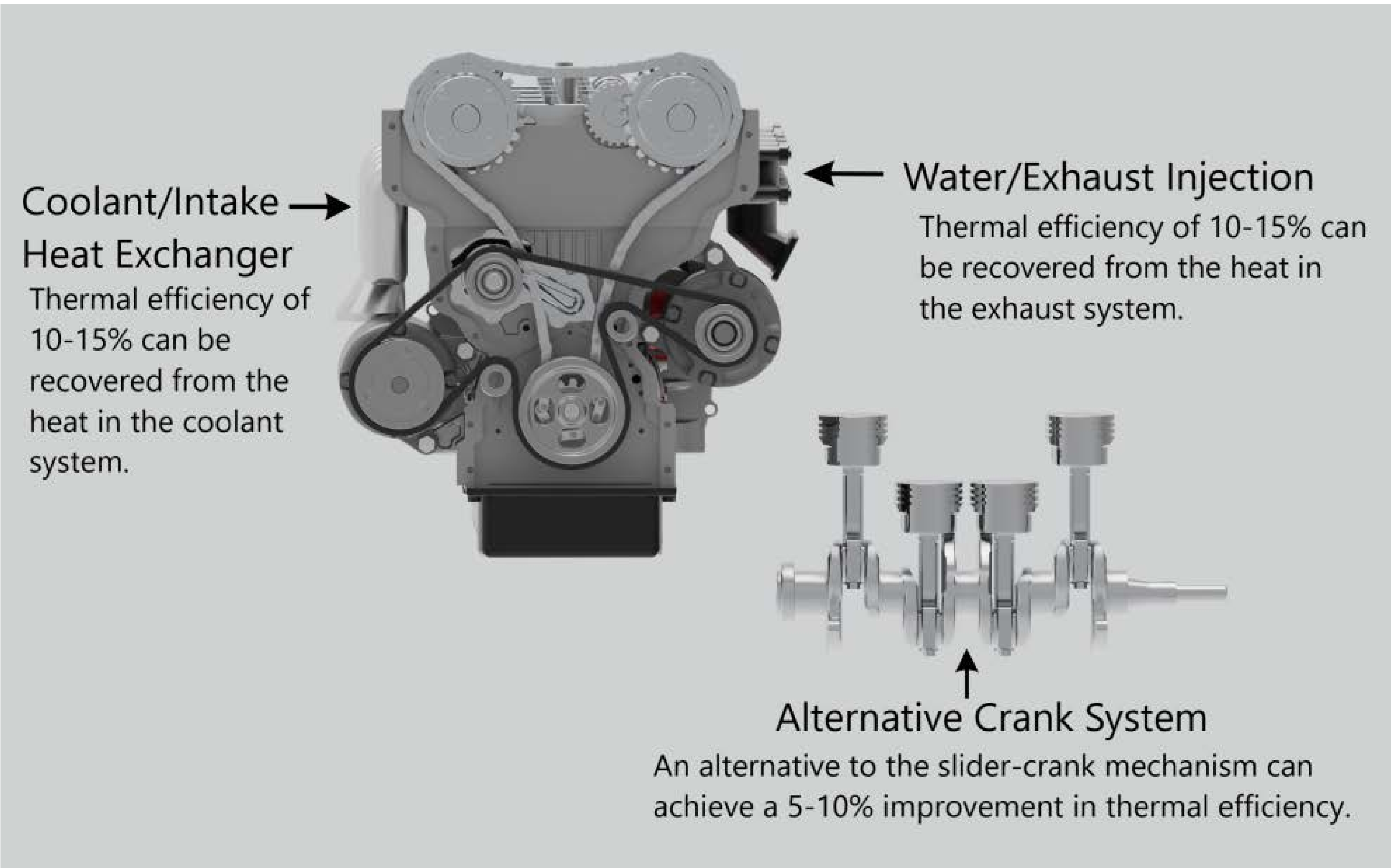
Multi-Fuel Engine:
The Dynamic Flow engine offers adaptability and versatility in utilizing multi-fuels. Each type of fuel demands a specific compression ratio, which the Dynamic Flow engine can address by employing the Atkinson cycle to simulate various compression ratios to suit different fuel types. Additionally, its internal variable EGR system can effectively mitigate knock across diverse fuel types. Unlike previous multi-fuel engine designs plagued by performance issues, the Dynamic Flow engine overcomes these limitations by integrating the Atkinson cycle with a turbocharger, enhancing overall performance. Moreover, transitioning to multi- fuel usage doesn't necessitate a complete physical redesign; instead, the Dynamic Flow engine can seamlessly operate on multi-fuels through adjustments to the intake and exhaust valve timing tuning programs.

Hazardous Environment and Diesel Runaway Engine Problem:
The Dynamic Flow compression ignition engine stands out for its exceptional control over the flow of intake air O2 and exhaust gases, effectively eliminating the risk of runaway problems. Its superior regulation of intake O2 and exhaust gases flow prevents the occurrence of runaway engine issues, even in the presence of foreign gas vapor fuel in the intake system. This unique feature enables the Dynamic Flow engine to operate safely in hazardous environments where conventional diesel engines would struggle, thus mitigating the possibility of engine runaway.

Military Application:
The heightened real-world operating thermal efficiency of Dynamic Flow engines results in a 36.6% reduction in fuel consumption and carbon dioxide emissions in military 4-stroke diesel land vehicles. In marine vessels, these engines decrease fuel consumption and carbon dioxide emissions by 30%. This advancement allows military vehicles and equipment to operate longer in the field with fewer refueling needs. Diesel generators, essential for field operations, can run for extended periods before refueling. The improved efficiency of diesel engines enhances the military's ability to conduct more extensive and rapid campaigns, reducing downtime associated with waiting for refueling trucks. This increased operational efficiency contributes to a more effective and resource-conserving military deployment. Additionally, the incorporation of variable displacement features enables the military to utilize larger, higher output engines without fuel and emission penalties, significantly boosting the capabilities of military vehicles.

8. Path Forward with Dynamic Flow Engine

Combustion engines have long been associated with inefficiencies, losing 58% to 62% of thermal energy through heat dissipation in the coolant and exhaust systems. At DAAT, we recognize the potential to address these losses and improve performance. By developing advanced heat recovery techniques, it is possible to reclaim up to 30% or more of the wasted thermal energy. Additionally, adopting alternatives to the traditional slider-crank crankshaft system can further reduce heat losses, increasing thermal efficiency by an additional 10%.



One key innovation is the integration of a coolant/intake heat exchanger in the Dynamic Flow engine. This system can recover 10% to 15% of thermal efficiency from heat lost in the coolant system, converting wasted energy into useful power. The Dynamic Flow engine's design makes it possible to harness this energy in a way that conventional engines cannot.

Another breakthrough is the use of a water/ammonium injection system in the exhaust. This technique can reclaim another 10% to 15% of thermal efficiency by cooling the exhaust system while simultaneously reducing emissions. Unlike direct water injection into the combustion chamber, which requires precise timing and advanced components, exhaust system water injection avoids common pitfalls such as water vapor contaminating the engine's oil system or condensing in the combustion chamber during abrupt shutdowns. In the Dynamic Flow engine, any condensed water in the exhaust system is easily vented upon engine restart, ensuring reliability and longevity.

The current slider-crank mechanism, while robust and reliable, has been a staple of engine design for over a century. However, it imposes a physical limitation on thermal efficiency, capping it at around 60%, as noted by the Department of Energy. At DAAT, we aim to surpass this barrier by enhancing or replacing the slider-crank mechanism. This improvement could enable the extraction of up to 70% thermal efficiency from fuel, representing a significant leap forward in engine performance.

These advancements—coolant heat recovery, water/exhaust injection, and an alternative crank system—are exclusive to the Dynamic Flow engine. Its unique valve configuration makes these techniques possible, setting it apart from conventional 4-stroke and 2-stroke engines and paving the way for unprecedented thermal efficiency and performance.

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