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Carburetor or electronic fuel injection? The ideal fuel mixture for high-performance two-stroke UAV engines

Fuel treatment as a key factor in efficiency, power density, and reliability

High-performance two-stroke engines remain among the most efficient propulsion solutions for medium- and large-sized UAVs. Their excellent power-to-weight ratio, high specific power output, and comparatively simple design make them particularly attractive for long-range platforms, VTOL systems, and military UAV applications. The type of propulsion and engine power play a decisive role when it comes to mission success. However, the achievable engine power is not determined solely by displacement, valve timing, or resonance tuning.

The quality of fuel preparation has an equally significant impact. It determines combustion stability, specific fuel consumption, load-switching behavior, thermal stress, and ultimately the engine's service life. Generally, two different fuel metering systems are used in modern two-stroke UAV engines: the diaphragm carburetor and electronically controlled fuel injection (EFI). Both systems employ different technical approaches and demonstrate their strengths depending on the specific application profile.

Diaphragm carburetors – mechanical precision with high operational reliability

The diaphragm carburetor remains the most widely used fuel mixture preparation system for high-performance air-cooled two-stroke engines. Unlike a conventional float carburetor, it operates independently of engine speed and uses a fuel diaphragm to provide the necessary fuel pressure. This ensures a reliable fuel supply even during high acceleration, negative load changes, or rapidly changing flight attitudes.

Fuel metering is achieved exclusively through fluid dynamic interactions between the Venturi, vacuum, diaphragm system, and high- and low-speed jets. The system requires neither sensors nor electronic actuators and operates completely autonomously. It is precisely this design simplicity that makes the diaphragm carburetor extremely reliable. There are no electronic control units, sensors, or complex control algorithms whose failure could impair engine function. At the same time, the integration effort is significantly reduced, which is particularly advantageous for UAV platforms requiring high system robustness or with limited installation space.

Figure 1: Carburetor used by Sky Power

Another advantage is the very direct response. The fuel-air mixture is formed directly based on the air flow rate, which allows for rapid load changes. High-quality, precisely tuned diaphragm carburetors deliver excellent power output across a wide operating range and offer impressive reproducibility.

Limitations of purely mechanical mixture preparation

Despite its robustness, mechanical mixture preparation is subject to physical limitations. Since fuel metering depends exclusively on the pressure conditions in the intake system, the air-fuel ratio changes with increasing altitude, fluctuating temperatures, or varying air densities. The carburetor cannot actively compensate for these changes.

Changes in humidity or significant load variations also affect the mixture composition. While these effects are largely irrelevant in many industrial applications, they can influence specific fuel consumption and performance characteristics during long-range missions or operations at altitudes of several thousand meters. For this reason, the carburetor is primarily used in applications where maximum robustness, low system complexity, and a predictable operational profile are key factors.

Electronic fuel injection using map-based air-fuel ratio control

Electronic fuel injection systems take a fundamentally different approach. Instead of metering fuel solely through fluid dynamic effects, an electronic engine control unit calculates the ideal injection quantity. This is based on a multidimensional map that is continuously adjusted using various sensor signals.

Typically, the ECU processes information on engine speed, throttle position, intake pressure, air temperature, engine temperature, and the current operating condition. Based on this data, the required fuel quantity is calculated for each operating point and precisely metered via electrically controlled fuel injectors. In contrast to a carburetor, mixture formation is no longer exclusively passive but is actively controlled.

More precise combustion across the entire operating range

Map-controlled fuel injection allows for a significantly more precise adjustment of the air-fuel ratio to the respective operating point. Particularly in partial-load conditions or during dynamic load changes, the mixture composition can be adjusted much more precisely than with a purely mechanical system.

This results in several technical advantages:

- lower specific fuel consumption
- more uniform combustion
- fewer misfires
- smoother engine operation
- lower thermal stress on individual components
- optimized power delivery across the entire RPM range

Especially for BVLOS missions with flight times of several hours, even small improvements in fuel efficiency can add up to a significant increase in range or, alternatively, allow for higher payloads with the same amount of fuel.

Automatic compensation for changing environmental conditions

A key advantage of electronic fuel injection systems is their ability to continuously factor environmental parameters into mixture control. Decreasing air pressure with increasing altitude, high outside temperatures, or changing weather conditions alter air density and, consequently, the amount of oxygen actually available.

While a carburetor is tuned for a specific operating range, the ECU automatically compensates for these changes. The resulting air-fuel ratio remains constant over a significantly wider operating range. This significantly improves the reproducibility of engine performance, particularly for UAVs that climb several thousand meters in altitude during a single mission or are operated worldwide under varying climatic conditions.

More than just fuel metering

Electronic fuel injections also serve as the foundation for advanced engine functions. Since all operating parameters are recorded digitally anyway, comprehensive diagnostic and protection functions can be integrated. These include, for example, temperature monitoring, speed limiting, fault diagnosis, operational data logging, and the provision of telemetry data for flight control. As a result, the internal combustion engine is evolving from a purely mechanical propulsion unit into an intelligently networked subsystem within the overall UAV architecture.

This condition monitoring is becoming increasingly important, particularly in professional and military settings, as maintenance intervals can be planned based on the engine’s condition and potential faults can be detected early on.

Which technology is suitable for which application?

From a technical standpoint, there is no universally superior solution. Both systems have specific strengths. In some cases, the price is important, because engines with carburetors have a lower price point.

Carburetors are the preferred choice wherever maximum operational reliability, low system weight, easy integration, and high robustness are required. Typical applications include industrial UAVs with defined mission profiles, surveying platforms, training drones, or systems where ease of maintenance and simple commissioning are priorities.

Electronic fuel injection systems, on the other hand, demonstrate their advantages particularly in complex missions with rapidly changing operating conditions. Long-range UAVs, high-performance platforms, hybrid propulsion systems, BVLOS operations, and military applications benefit from precise fuel-air mixture control, automatic altitude compensation, and advanced diagnostic and telemetry functions.

Sky Power offers both technologies for different mission requirements

Sky Power deliberately takes an open-technology approach to its two-stroke engines and offers both carburetor-based and electronically controlled fuel injection systems, depending on the model series. This allows UAV manufacturers to tailor the propulsion system precisely to the platform’s aerodynamic characteristics, mission profile, and desired system functions.

While carburetor systems offer the advantages of simple design, robustness, and low integration complexity, EFI systems provide maximum control precision, adaptive engine management, and extensive diagnostic and communication capabilities. Both approaches share the same goal: a highly reliable, high-performance, and efficient power supply for professional UAV applications.

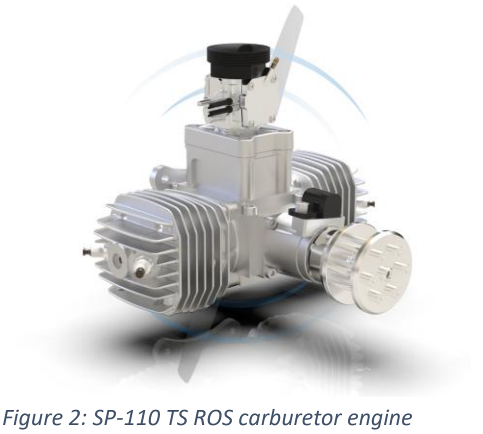

Figure 2: SP-110 TS ROS carburetor engine

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The choice between a carburetor and electronic fuel injection is not a fundamental decision, but rather a matter of system design. Sky Power offers its engines with both carburetors and fuel injection. For UAV manufacturers, this means the ability to specifically define and design the propulsion system to match the respective mission profile. Only the optimal interaction between engine characteristics, fuel preparation, and flight profile unlocks the full potential of modern two-stroke propulsion systems.

About Sky Power

Sky Power International is a leading manufacturer of 2-stroke combustion- and Wankel engines for UAS (Unmanned Aerial Systems) and hybrid applications. Besides in-house development and manufacturing, Sky Power International produces all engines in Germany. Custom adaptations, new developments and continuous performance improvements of the combustion engines are ongoing company objectives. More information: www.skypower.online

Figure 3: SP-110 FI TS ROS fuel-injected engine

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