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COMBUSTION ENGINE PISTON MODIFICATIONS FOR BETTER PERFORMANCE IN UAV APLICATION

Peter Lubják
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
Lubjak1@stud.uniza.sk

Jozef Čerňan
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
jozef.cernan@uniza.sk

Radoslava Nichtová
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
radoslava.nichtova@uniza.sk

Abstract

The issues described in the article are largely an overview and explanation of the functions of various modern modifications to internal combustion engine pistons, which significantly increase the performance and reliability of current power units with a minimum amount of technical implementation. Especially the modification in the form of gasporting can indicate the direction that will soon be possible to take when modifying engines.

Keywords

Unmanned aerial vehicle, piston ring, optimization

1. Introduction

With recent growth in UAV sector, UAVs are progressively used more than ever before. With growth of UAV use is closely tied growth of possible uses of such aircraft. Missions conducted by any aircraft put requirements on the aircraft engine. Electric motors are still not applicable for bigger unmanned aircrafts. Therefore is still important to use piston engines with better performance/weight ratio.

These days, society is working to make every sector more efficient. This is particularly evident in the transportation sector, where hybrid and particularly electric vehicles are being pushed. Low thermal efficiency is the main drawback of internal combustion engines. We shall discuss several technologies, though, that can boost the efficiency of internal combustion engines and, consequently, hybrid motors.

2. Piston ring

Accordin to (JE Auto – Blog, 2025) a piston is a part that allows us to drive a variety of devices by transferring the force produced by combustion to other parts of the rotating assembly. However, the internal combustion engine would operate very poorly and have an efficiency that would be very near to very low if we only had the piston. A significant pressure leak via the space between the cylinder and the piston would be the cause. They would encounter an issue when the piston began to rub against the cylinder wall, and the resulting friction would heat up, expand the piston, and cause a critical failure when our engine seizes. This would happen if someone proposed that we make the given piston with smaller tolerances in order to close this gap. We need a seal of some sort since we don't want this. Rubber and other organic materials were tested in the first internal combustion engines, but the high temperatures produced by the fuel-air mixture's combustion quickly degraded the sealing material. These sealing rings were continuous and single piece. It seemed sense to use gray cast iron. Making them continuous will result in the same issue as having too-low tolerance pistons in the cylinder. As a result, the piston ring needs to be made to look like the letter C. Nevertheless, this design leaves a gap that allows some expanded gases to escape. The specified piston ring will expand while in operation, and the gap will narrow but not completely vanish. Because of this, two so-called compression rings are used in the majority of internal combustion engines.

Cast iron rings are still used in many engines today. The material's insufficiently high hardness is a major drawback for them. Combining them with coatings of chromium elements can boost the contact surface's hardness by up to three times. Drawback of this is that it prolongs the break-in period, during which the rings adjust to the piston's form. The fragility of cast iron rings, which made installation extremely difficult because the mechanics had to be extra cautious to prevent the rings from breaking, is another reason they were discontinued. The piston rings' size, which were typically 2-3 mm thick, are the last explanation. Because of this, they produced more friction and consequently more losses than contemporary piston rings, which are, as stated in (Saccone, G. et al,2021), composed of 1-2 mm thin steel and have ceramic coatings applied to their surface that have a low friction coefficient and high hardness.

Another crucial element is the operation of the piston rings. The piston rings expanded up and had a wider diameter in the relaxed position than the cylinder bore when the piston was removed from the cylinder, as many readers who have ever disassembled an engine may have observed. Many people think that the material's elastic strength is what causes the piston rings to seal as described. This is a reasonable assertion, though. The expansion of the gases in the combustion chamber generates the force acting on the piston ring. When the pressure reaches the piston ring, it travels around the piston wall and acts from the upper side of the ring, ensuring tightness against the lower edge of the piston ring groove, while also pressing on it from the inside of the piston, ensuring tightness against the cylinder wall.

Figure 1. A cut of the piston together with the piston ring, engine P65, we would like to draw attention to the minimum distance between the piston ring and the upper edge of the groove

3. Gasporting

Since we are already familiar with the fundamentals of piston devices, we would like to expose you to the ones that were utilized in engine plants to improve tightness efficiency. This is referred to as gas porting, when attempting to increase the pressure acting on the piston ring. We differentiate between two fundamental forms of gas porting: vertical and horizontal.

A drilled holes in piston sits between the inside of the top piston ring's groove and the combustion chamber's surface when vertical gasporting is used. Because of this, there is less resistance as the pressure from the combustion chamber travels to the rear of the ring. This approach, however, has a number of drawbacks. The first is that sludge produced during engine running clogs these holes. As a result, they work well with engines that require little maintenance. An further drawback is the ringland's weakening in the piston's upper section, which, when combined with detonations, may rupture and result in a catastrophic engine failure.

According to (Micah Wright, 2022) the so-called horizontal gasporting is the second kind of this technology. These are tiny notches that run parallel to the piston ring groove. They facilitate the easier penetration of the required pressure behind the piston ring and are situated on the upper side of the piston ring groove. Similar to vertical gasporting, this kind also somewhat weakens the ringland. The piston can tolerate these locations even in the event of detonations, and cracks shouldn't appear. Although soot is an issue with this approach as well, it is not as bad as with vertical gasporting. Given these facts, it is reasonable to wonder why vertical gasporting is employed when horizontal has so many benefits. Vertical gas porting increased effectiveness of gas penetration behind the ring. Vertical gas porting is utilized in special engines with service intervals measured in hours.

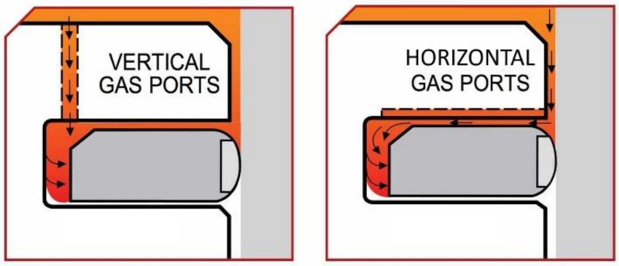

Figure 2. Demonstration of the functionality of vertical and horizontal gas porting

According to (Aeroplane Tech, 2024) a hybrid of both technologies is also available, in which the piston's notches line up with the piston wall's notches that make contact with the cylinder. This is known as vertical-horizontal gasporting, and it should take advantage of both methods' benefits. It is evident from this data that accurate tools are necessary for machining, which will raise the cost of manufacturing individual parts.

Gasporting can be accomplished on an engine without this technology, though. These unique piston rings function similarly to horizontal gasporting and have grooves carved into them. The reduction of sludge is their greatest benefit. Unless it has a lock, as in two-stroke engines, the piston ring is always moving in its groove. Its continuous motion causes the sludge to be mechanically removed from its surface. The ability of engine oil to effectively remove dirt from iron surfaces is another feature that helps prevent sludge.

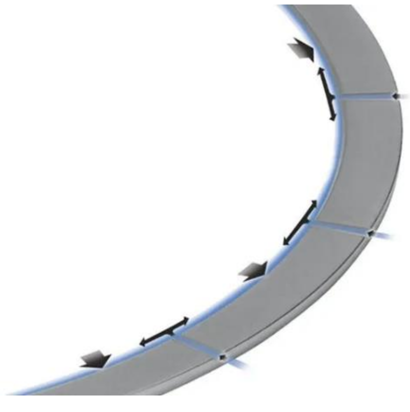

Figure 3. Demonstration of the functionality of a gasporting piston ring

However, when in operation, piston rings create a significant amount of friction. Potential method of sealing the combustion chamber without causing too much friction exist. This is the process of applying a labyrinth seal between the piston's top and upper ring. The idea behind these shallow grooves is to produce turbulence as gases enter, which gives the gases resistance. As a result, the labyrinth should form a partially frictionless sealing barrier. As a result, there is less pressure on the piston ring, which lowers friction. If gasporting is used, friction should be reduced and the sealing effect increased.

The primary element that transfers heat from the piston to the cylinder walls is the piston rings. This implies that there will be less heat transmission if the piston rings are thinner. Better oil spraying from the lubricating system or enriching the fuel-air mixture are two ways to address this issue; nevertheless, doing so would lead to incomplete combustion, increased sludge production, and, most importantly, a larger percentage of emissions. Enhancing the cooling system's ability to dissipate heat from the cylinder walls is the answer. The usage of a cast iron cylinder liner, which has good qualities in retaining geometric dimensions throughout temperature cycles, is the issue with earlier engines. Another benefit is that, because the bonded liners are between 2 and 7 mm thick, the engine can be repaired in the event that the top layer is damaged. Unfortunately, this is a drawback because their thermal conductivity is around 30% lower than that of aluminum. In order to improve heat dissipation and increase cooling efficiency, different high-hardness coatings were applied to engines with a rake of 0.05-0.15mm of applied material. This allowed engines to run at a stoichiometric ratio for longer periods of time without the need for enriching the mixture to cool. Additionally, these coatings have less friction, which lowers friction and, consequently, temperatures on vital parts like piston rings. To a specific degree and depth of damage to the cylinder surface, a new coating can be applied to an engine cylinder. Additionally, in correspondingly tiny craters, the coatings produce microscopic surface roughness that keeps oil on the cylinder surface throughout engine operation. The so-called honing, which produces a much rougher surface with continuous depressions where oil is stored, was required for cast iron liners. This is among the elements that significantly influences the friction that results.

4. Application of gasporting

We made the decision to test the P65 engine in light of this information. In the 1980s, in what was then Czechoslovakia, this two-stroke car engine was frequently utilized as an engine for hang gliders or ultralight aircraft, as was stated in (Longauer, Čerňan, 2024). It should be mentioned that the engine's primary components remained nearly unchanged from its development in the 1950s until the end of the 1980s. Three 2mm cast iron piston rings are part of the original design. Critical locations are not perfectly lubricated because the engine is lubricated using a fuel-oil combination. The main issue, though, is that while the outer rings are suitably lubricated, the middle ring is not. This lowers the engine's efficiency and service life by increasing friction. The testing aims to apply gasporting to the piston ring's upper groove and alter the piston to operate with just two piston rings.

Before we start modifying the engine in special design described in (Lubják, Čerňan, 2024), we need to find out the critical engine data. We will start by finding out what pressure the individual cylinders have. The test was done at operating temperature after adequate use of the engine. The speed with the starter turned on was kept at 380-400 rpm. During testing, the spark plugs were removed from both cylinders and the throttle was in the open position to avoid unnecessary pumping losses. The engine was revved for 10 seconds and the achieved value was subsequently read. Cylinder number one reached a value of 6.1 ATM, cylinder number two reached a value of 5.9 ATM. Subsequently, a series of test runs were made over a longer period of time during which we recorded consumption and engine head temperatures.

After the initial testing, we disassembled the engine and marked the individual components to avoid part changing. After removing the piston rings from the piston, we started modifying the pistons so that they work with only two rings. Someone might say that it is enough to remove it and there is nothing more to solve. However, the problem arises that through the given groove, fresh mixture can penetrate through the transfer channels into the exhaust channel and vice versa. Therefore, we need some type of barrier to prevent this gas exchange from occurring. We solved this problem by drilling two 1.8mm holes approximately 3 mm from the edge of the exhaust channel on both sides of the piston. Then, we cut rollers of the correct length from 2mm drills, which we gently tapped into the drilled holes. To secure these rollers, we tapped the lower part of the ringland directly below these rollers. Subsequently, the excess material was removed from the rollers, thus achieving adequate sealing in the given locations.

This modification will convert 3-ring pistons to 2-ring ones. Another modification is to create a gasporting on the upper piston ring groove. First, we mark the calculated equal distances with a marker. Then we have two options for creating the notches. Either we take a drill with an adequate drill bit and carefully drill out the excess material using a jig. In our case, we used a milling machine with which we carefully created the aforementioned notches by hand. However, it should be emphasized that if you create these grooves at home, you must be especially careful not to damage the lower edge of the piston ring groove. If it is damaged, repair is almost impossible and the damage may cause a leak in the upper piston ring, which would ultimately mean that we have done a counterproductive job. After completing all the modifications, we thoroughly clean all components from aluminum shavings and other material. When assembling, we ensure proper lubrication of individual components to prevent premature damage.

After completing the engine, we performed a rotation test without the spark plugs inserted and were quite surprised that the engine could only be turned over with a screwdriver with an extension, since before that the engine could only be turned over using a ratchet. After approximately 15 hours of operation, we performed a cylinder pressure test, making sure that the test conditions were identical. During testing, we found that cylinder number one reached a value of 6.1 ATM, cylinder number two reached a value of 6.2 ATM. Considering that the engine uses 1/3 fewer compression piston rings, it is surprising that the pressures in the cylinders increased. We observed approximately 5% lower consumption when using the engine than during test runs before the modifications. The head temperatures were kept at the same temperatures as before testing. Considering the location of the temperature sensor, it is unlikely that the temperature reduction on the cylinder walls had an adequate effect on the head temperature around the spark plug. Also temperature sensor in exhaust system will be used as described in (Koša, Čerňan, 2023) to improve air/fuel mixture and get lower carbon monoxide and hydrocarbon content in exhaust gasses. Policy of carbon neutrality will lead our effort to use also new types of fuel, as stated in (Valášek, Čerňan, 2023). Here the optimal function of piston rings will be crucial for good performance of the engine.

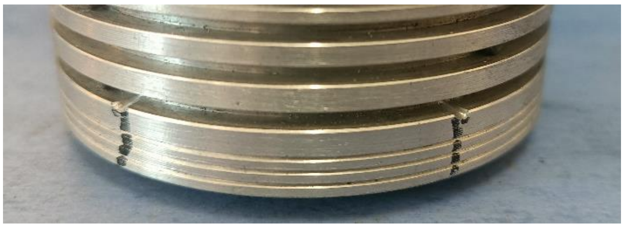

Figure 4. P65 engine piston after the mentioned modifications

5. Conclusion

Our experiment shown that it is possible to boost the efficiency of older engines by utilizing modern technologies. We can save resources during routine maintenance because of these fairly straightforward changes.

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