

LOW COMPRESSION IN THE CYLINDER OF AIRCRAFT PISTON ENGINE DUE TO GAS LEAKAGE

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Abstract: Piston-prop aircraft are typically used in general aviation and consist of an internal combustion engine paired with a propeller. The combustion chamber in the cylinder must remain leak-proof during the compression and power strokes to maximize power output. Leakage in the combustion chamber is one of the factors that cause failure to reach peak pressure during the compression stroke. This study focuses on low compression in the cylinder of the aircraft piston engine due to gas leakage, failing to reach peak pressure. Three experienced aircraft maintenance engineer license holders were involved in the interview for this study. Most frequently occur in valves, particularly in exhaust valves due to carbon deposits accumulating around the valve face. Second, piston leaks are indicated by too large side clearance of compression piston rings or in-line compression piston ring gaps, and finally, although leaks are rarely found in the spark plug area, it is still recommended to check this area when performing a compression check. Further research can be conducted using quantitative research to determine the frequency of occurrence. It can also be done with intensive research involving laboratories to find out the cause.

Keywords: Aircraft Piston Engine, Carbon Deposit, Compression Check, Combustion Gas Leakage, Low Compression, Qualitative Study

Introduction

Aviation is classified into three major categories: general, commercial, and military (Altuntas, 2021). explains this more clearly that military aviation encompasses all activities related to defense operations in the air; general aviation includes various functions such as training, firefighting, private flying, air taxi services, and medical assistance operations; and commercial aviation refers to activities involving passenger and cargo transport, both scheduled and unscheduled air transportation. Two types of engines are used in aviation as a powerplant for aircraft: piston engines or reciprocating engines and gas turbine engines. The reciprocating engine is the oldest practical type of heat engine used as a powerplant for aircraft (Crane, 2018). Piston-prop aircraft are typically used in general aviation and consist of an internal combustion engine paired with a propeller (Altuntas et al., 2015). While the internal combustion engine in this system generates power by burning fuel and air inside a combustion chamber, the propeller is used to manage the amount of thrust (Crane, 2018). As of today, piston engines are still commonly used in aviation, particularly recreational aircraft, taxi planes, agricultural planes, and small transport planes (Czarnigowski et al., 2010), in other applications, piston engines are utilized as powerplants for training aircraft. This preference is due to the inexpensive engines and lower maintenance costs than turbine engines (Czarnigowski et al., 2010). The high population in aviation and the frequency of engine piston failures have become concerns about aviation safety.

It has been determined that piston engines on general aircraft are the second largest contributors to aviation incidents, significantly affecting aviation safety (Glowacki, 2018), this is caused by negligence in maintenance and poor detection of powerplant failures during routine maintenance. Aviation maintenance operations are crucial for successful aviation activities. Proper maintenance of aircraft ensures safe and reliable air transportation. Without an adequate maintenance environment, the aviation industry may suffer negatively (Şöhret et al., 2019). Maintenance is carried out under two subheadings: scheduled or routine and unscheduled. Unscheduled maintenance is performed following any emergency problem with the aircraft. Scheduled or routine maintenance proceeds according to a plan and program under normal operating procedures (Şöhret et al., 2019). During routine maintenance activities, aircraft conditions often do not meet the airworthiness standards determined by the manufacturer. If such conditions are identified, it becomes additional work for routine maintenance to rectify the findings. The combustion chamber in the cylinder must remain leak-proof during the compression and power strokes to maximize power output. When a highly compressed fuel-air mixture is ignited, it rapidly releases energy, resulting in maximum cylinder pressure and the greatest push on the piston (Crane, 2018). If the peak pressure required during the compression stroke fails to be achieved, then the maximum push on the piston during the power stroke will also fail achieved. Leakage in the combustion chamber is one of the factors that causes failure to reach peak pressure during the compression stroke. This study focuses on low compression in the cylinder of the aircraft piston engine due to gas leakage, failing to reach peak pressure.

Method

This study employed qualitative methods, specifically semi-structured interviews, to collect data. Qualitative research aims to gather a range of expressions and interpretations of people's perceptions (Nergård, 2014; Nergard et al., 2011). Semi-structured interviews are designed to capture participants' perspectives (Kioulepoglou & Makris, 2023). Three experienced aircraft maintenance engineer license holders were involved in this study. Their aircraft maintenance experience spans 10 to 19 years with piston-engine-powered general aircraft, including the Piper Warrior, Piper Archer, Piper Dakota, Piper Seneca, and Socata TB-10. Interview guidelines were developed to gather qualitative data regarding the engine performance issues caused by low compression. Triangulation was conducted on the qualitative data obtained from interviews with the three experienced aircraft maintenance engineer license holders.

Result

Based on interviews, one of the most experienced engineers said the issue began when the aircraft piston engine ground run failed to reach the standard revolution per minute (RPM), and the engine felt rough. Each typical aircraft has a standard RPM when the engine operates at certain conditions. The ground run is performed when the aircraft warms up in the morning after remaining overnight or just before the flight along with checking other parameters. All of them stated that from the many troubleshooting attempts, one of all troubleshooting actions led to performing to know the root cause of the engine failure to achieve the standard performance is a compression check.

During the compression check, based on his experience, an engineer with 19 years of experience said that the first thing to check is the possibility of a leak in the valves, especially exhaust valves. If there is no leak, check the spark plug or sparkplug bushing, and the piston and piston ring sequentially. As a general aviation engineer, he frequently discovered leaks in all three, with the most common leaks occurring in the exhaust valve. Somewhat different, 10 and 12 years

of experience engineers said that the possibility of leakage after knowing low pressure during compression check is in the valves and piston rings.

Although a little different, they recognized that leaks most frequently occur in valves, particularly in exhaust valves. Regarding leaks in the exhaust valve, all three stated that the cause was the same: carbon deposits accumulating around the valve face. During the compression check, low compression on the cylinder required them to remove the cylinder from the crankcase and inspect it. During the inspection, they found carbon deposits on the face of the exhaust valves. Carbon deposits on the exhaust valve face can prevent the exhaust valve from closing properly against the valve seat. This improper closing creates a gap between the valve and the seat when the exhaust valve is in the closed position. As a result, gases can leak out during the operation of the piston engine. This gas leak is the cause of low compression pressure.

As for the cause of the carbon deposit on the exhaust valve, neither 19, 12, nor 10 years of experience as a general aviation engineer can confirm it because, according to them, in-depth analysis and laboratory testing are required to determine it. Likewise, regarding when it occurred, they cannot be sure because even though it was found during routine maintenance, not all routine maintenance activities found this issue.

If leakage occurs in the piston ring, a visual inspection after removing the cylinder from the crankcase will reveal certain issues. A most experienced engineer found wear on the cylinder wall characterized by a rough surface or the piston ring gap in abnormal condition. This was also confirmed by engineers who have fewer years of experience. However, this case is found less frequently than carbon deposits on the exhaust valve. Furthermore, although it is rare to find leaks in spark plugs and spark plug bushings, engineers with the highest working years still recommend checking this area when doing a compression check. This is because its position is outside so it is easy to check and still potentially leakage.

Discussion

During the ground run of an aircraft piston engine, engineers must check several engine parameters, including magneto check, engine response during acceleration and deceleration, and a full-throttle power engine check (Pilot's Operating Handbook Cessna Model 172N, 1977; Pilot's Operating Handbook Cherokee Archer II, 1979). During the ground run a rough running engine can be caused by uneven compression, so it is necessary to check the compression, also when the engine fails to reach the idle position properly (Airplane Maintenance Manual PA-28-181 Archer III, 2014). Uneven compression causes the power generated by each piston to rotate the crankshaft unevenly. Especially cylinder/s that suffer low compression will produce lower power than other cylinders with normal compression. This condition causes the engine to become unbalanced, leading to destructive vibrations and rough engine operation.

The cylinder compression test evaluates whether the valves, piston rings, and pistons are sealing the combustion chamber properly. Excessive pressure leakage can hinder engine power. This test helps determine if cylinder replacement is needed, preventing complete engine failure. Periodic testing is essential, as low compression is often caused by leaky valves (Aviation Maintenance Technician Handbook–Powerplant Volume 1, 2012).

The exhaust valve is an important element of the piston engine. It seals the cylinder during compression stroke, providing maximum combustion chamber pressure for achieving engine performance (Miljković, 2019). The valve face is designed to form a seal against the valve seat in the cylinder head when the valve is closed (Aviation Maintenance Technician Handbook–Powerplant Volume 1, 2012). The torque and RPM of a piston engine are directly proportional to the brake mean effective pressure (BMEP) value; a higher BMEP results in higher torque and RPM (Grabowski et al., 2019). Carbon deposits were also observed on these components

(Glowacki et al., 2020) because emissions in the exhaust gas of a piston engine consist of soot or particles of carbon oxides (carbon dioxide and monoxide), hydrocarbons (Woś & Michalski, 2011), nitrogen oxides, and other volatile organic compounds (Xu et al., 2025). The deposits were composed of several matters, mainly sourced from fuel, lubricating oil, and body materials (Zhang et al., 2025). The main factors contributing to carbon deposition in a piston engine are: the amount of lubricating oil introduced into the combustion chamber, which is the most significant factor; the type of oil used; the temperature within the combustion chamber; and the duration for which the preceding factors have been in effect (Orelup & Lee, 1925). What the engineer observed may not have been the carbon deposit on the valve, but rather erosion of the valve seat or valve caused by hard carbon particles exiting with exhaust gas at high speeds. According to Orelup & Lee (1925) the detrimental effects of carbon formation lead to increased pitting of the valve seats by hard carbon particles, preventing the valves from closing properly and resulting in a loss of power. Carbon deposits can accumulate not only on exhaust valves but also on fuel injectors, intake valves, ports, and within the combustion chamber in gasoline piston engines (Altin & Eser, 2004). Another potential cause of leakage in the valve area is the valve guides. The manufacturer recommends checking the valve guide holes using a replacement flat plug rejection gage. Diameter and roundness are checked in at least two positions at 90 degrees measurement during piston engine overhaul activities (Overhaul Manual for TSIO-520 Series Aircraft Engine, 1979). Valve guide clearance that is too large beyond tolerance and a shape that is not perfectly round can potentially cause the valves to not close perfectly on the valve seat.

When assembling the piston into the cylinder make sure the piston ring gaps should be positioned 180 degrees apart with the first or top toward the top of the piston (Overhaul Manual for TSIO-520 Series Aircraft Engine, 1979). The in-line piston ring gap position has the potential to cause gas leaks in the engine piston combustion chamber. Too large a side clearance between the piston ring and the piston ring groove also has the potential to cause gas leaks. Side clearance must not exceed the tolerance limit. To measure side clearance, follow the instructions of the engine piston manufacturer. Examining the side clearance of piston rings (compression rings) is mandatory when overhauling the engine (Overhaul Manual for TSIO-520 Series Aircraft Engine, 1979).

Combustion gases can also leak out through the gaps in the spark plug threads. It is important to check the helical coil installed in the spark plug hole. the outer ends of the helical coil should lie in the first full thread of the tapped hole in which they were installed.

Regardless of the cause of failure in the main power-producing component of a piston engine, the consequences can be fatal. Cylinder head (CH) failures in aircraft piston engines can have serious or fatal consequences for the crew and aircraft safety. When such failures occur repeatedly and critically, leading to the loss of aircraft, property damage, and, most importantly, loss of human lives, it is essential to investigate the cause of these failures using a scientific approach (Krstic et al., 2013). Most of the events of piston engine failure are connected with powertrain and cylinder systems, so the majority of failures concern the power section and cylinder section.

Conclusion

This study focuses on low compression in the cylinder of the aircraft piston engine due to gas leakage, failing to reach peak pressure. Uneven compression causes the power generated by each piston to rotate the crankshaft unevenly. Especially cylinder/s that suffer low compression will produce lower power than other cylinders with normal compression. This condition causes the engine to become unbalanced, leading to destructive vibrations and rough engine operation. The cylinder compression test evaluates whether the valves, piston rings, and pistons are sealing the combustion chamber properly. Excessive pressure leakage can hinder engine power. Most

frequently occur in valves, particularly in exhaust valves due to carbon deposits accumulating around the valve face. Carbon deposits on the exhaust valve face can prevent the exhaust valve from closing properly. The gap between the valve and the seat, when the exhaust valve is in the closed position, occurred. As a result, gases can leak out during the operation of the piston engine. The deposits were composed of several matters, mainly sourced from fuel, lubricating oil, and body materials. Second, piston leaks are indicated by too large side clearance of compression piston rings or in-line compression piston rings ring gaps, and finally, although leaks are rarely found in the spark plug area, it is still recommended to check this area when performing a compression check. Further research can be conducted using quantitative research to determine the frequency of occurrence. It can also be done with intensive research involving laboratories to find out the cause.

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