Australian Government
Civil Aviation Safety Authority

Airworthiness Bulletin

AWB 85-023 Issue 3 – 10 June 2021

Piston Engine Spark Plug Insulator Cracking

An Airworthiness Bulletin is an advisory document that alerts, educates and makes recommendations about airworthiness matters. Recommendations in this bulletin are not mandatory.

1. Effectivity

All spark ignited aviation gasoline reciprocating engines.

2. Purpose

To advise owners, registered operators, maintenance organisations and Licensed Aircraft Maintenance Engineers to consider undertaking specific interrogative maintenance to detect and give warning of possible adverse internal engine wear.

3. Background

During 2018 CASA was made aware of some operators experiencing an increase in incidents of spark plugs exhibiting physical damage with corresponding combustion chamber deterioration.

There are many different types of spark plug malfunctions with various causes and effects. It is recognised that detonation can crack spark plug insulators and the spark plug may be the first victim in a series of damaging events. It is also acknowledged that the ceramic insulator can become packed with abrasive cleaning media and/or the biproducts of combustion leading to insulator cracking and pre-ignition.

The durability of a spark plug and its resilience to the onset of such deterioration may also be influenced by.

- the techniques used in engine handling for the type of flying being undertaken inducing prolonged detonation (particularly in turbocharged engines)
- the result of mechanical damage from being dropped or mishandled
- the quality and type of fuel being used, magneto timing and/or poor engine cooling.

Failure to adequately verify spark plug condition or ignoring adverse indications or unusual behaviour of the engine, can lead to catastrophic engine failure.

Issue 3 of this AWB summarises the analysis outcomes from detonation and pre-ignition testing conducted to ascertain whether commercially available Avgas was a potential contributing factor in reported events.

Some industry participants have expressed the view that this condition is related to the change in grade of aviation gasoline (AVGAS), in particular the perceived introduction of higher levels of aromatics and reduction in lead.

To test this theory detonation and pre-ignition analysis was conducted concurrently with a broader investigation program to compare the operating characteristics of a naturally aspirated spark ignition engine running on commercially available Avgas from Australia and the United States of America. The test program was conducted at various operating points and environmental conditions including hot conditions at cylinder head, oil temperature and induction air limits. This testing was conducted by engine manufacturer Lycoming at their engineering facility with independent oversite provided by the US Federal Aviation Administration (FAA), and included remote witnessing from the FAA, Robinson Helicopter Company and CASA.

The Referee Method described in ASTM D6424 was used for cylinder pressure-based detonation detection. For each operating condition tested, no counts of detonation were measured. The maximum knock number recorded was over 3 times lower than the limit required to be considered detonation. Negligible changes in average knock number were also noted, indicating normal combustion events on each fuel.

Additionally, no significant changes were noted in the location (crank angle) and value for highest maximum cylinder pressures recorded. Therefore, there were no indications of pre-ignition occurring at any operating condition on any of the fuels tested.

Based on available information there is no evidence to support a claim that a change in the grade of commercially available Avgas created a condition which has given rise to spark plug insulator cracking.

4. References

FAA Advisory Circular (AC) No: 43.13-1B, Chapter 8, Section 1, Para. 8-15 Spark Plugs

Champion Aerospace – Spark Plug Maintenance, AV6-R Tech Manual (latest revision)

Tempest – Spark Plug Cleaning the Right Way

CASA - AWB 20-1 – Spark Plug Care (latest revision)

5. Recommendations

The service life of a spark plug can vary greatly with operating conditions, engine models, ignition systems and spark plug types. Adherence to the scheduled servicing interval is essential for optimum performance. Spark plug gaps and deposit conditions should be closely monitored with reconditioning and replacement intervals being followed or supplemented by past experience with a particular engine model.

An engine's spark plugs can reveal a lot of information about how the engine is running. Close examination of used spark plugs can be useful in diagnosing the cause of engine rough running or other erratic engine operating conditions. The type of wear the plugs exhibit can also reveal the cause of adverse cylinder piston conditions.

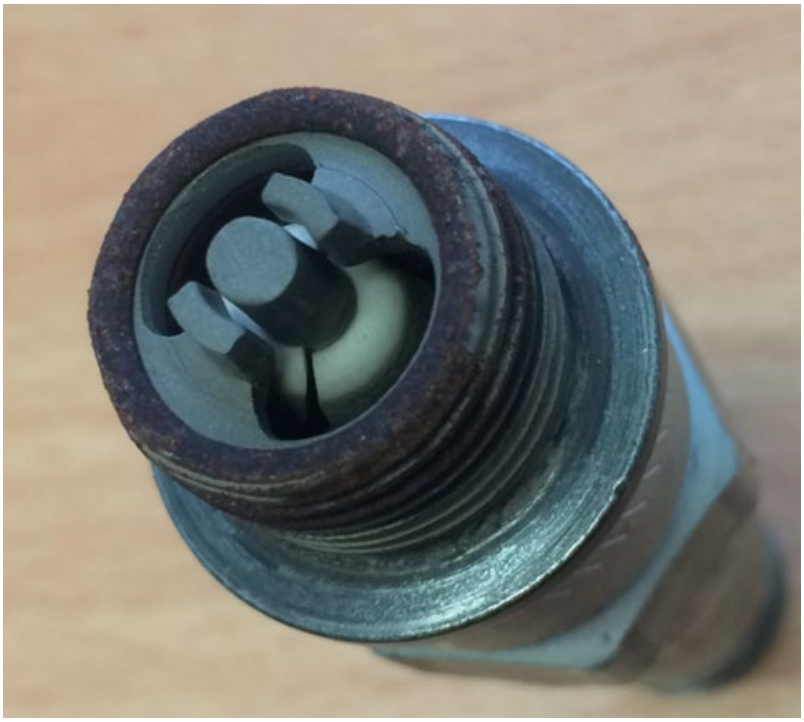

Figure 1 – Spark Plug Insulator Cracking, (Massive Electrode)

(Source: DRS No: 611851378)

The primary contributing factors for spark plug insulator (electrode insulator) cracking are considered to be.

- Pressure shockwaves from detonation
- Mishandling (dropping), improper cleaning or gapping
- Shockwaves and heat from crossfire induced pre-ignition.

Note: The majority of cracked ceramics are from mechanical impact in shipping handling and maintenance. The causes of detonation and pre-ignition are too many and varied to be discussed in detail in this bulletin. The following information provides an overview of the conditions and leading indicators.

Detonation

Detonation subjects the combustion chamber to adverse mechanical shock pressures. The effect of this mechanical shock can damage spark plug electrodes or crack the insulator core. Detonation in an air-cooled aircraft engine will not be audible in flight and can only be detected by steadily climbing CHT's typically beyond 420°F (216°C).

When an engine has experienced light to medium detonation, there can be little or no additional evidence. Prolonged heavy detonation which can lead to spark plug damage becomes apparent upon cylinder removal or via borescope inspection. Detonation damage usually shows in the edges of pistons and on the cylinder head between the spark plug ports and valves. The cylinder head and piston should be inspected for a "sand-blasted" look. A lack of deposits or a clean head and piston face can also indicate that detonation has occurred, (see Figure 2a & 2b).

If you suspect that an engine has been experiencing detonation, remove the spark plugs for inspection as soon as possible and follow the engine manufacturer's recommendations for cause and correction.

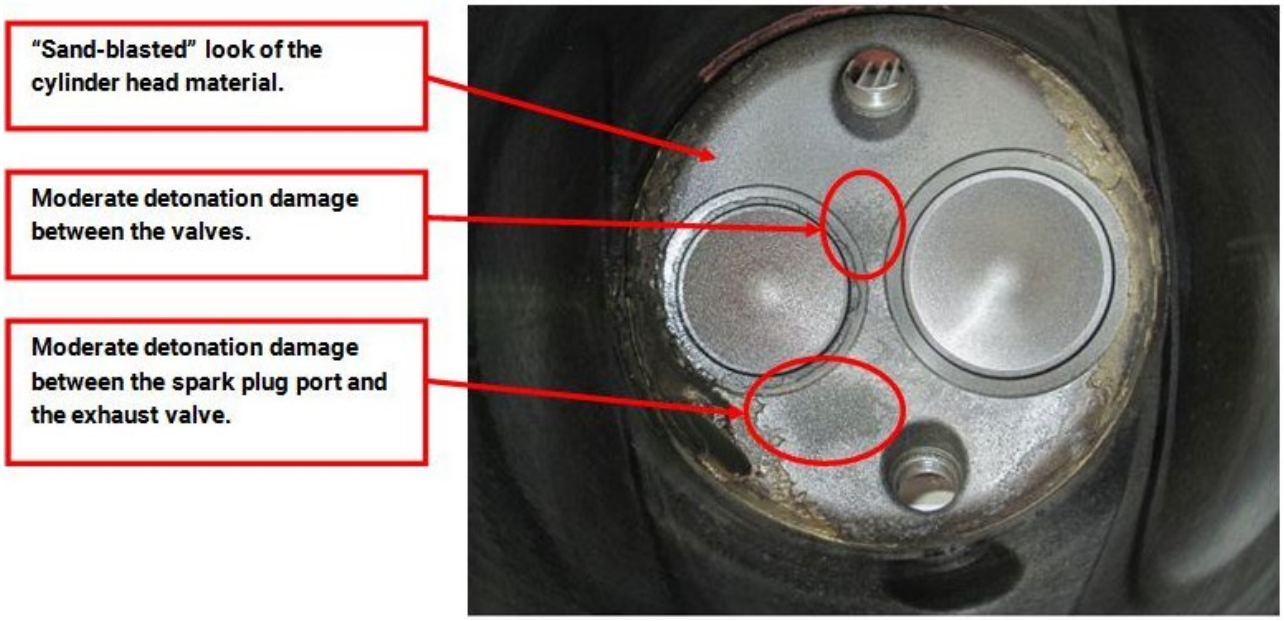

Figure 2a – Combustion Chamber Detonation

(Source: www.lycoming.com/contact/knowledge-base/tips)

Figure 2b – Combustion Chamber Detonation Testing*

* IO470N cylinder at TBO, tested with light detonation for 20 hours, medium detonation 2-3 hours and 30min of heavy detonation. Note it is completely clean, yet no physical damage occurred

(Source: Advanced Pilot Seminars and General Aviation Modifications Inc)

Spark Plug Maintenance and Handling

Regular, meticulous spark plug maintenance is essential for optimum performance. Refer to the engine and spark plug manufacturer's maintenance data to ensure that the spark plugs are being removed, cleaned, inspected, gapped and position rotated at the appropriate intervals.

Clean and inspect the spark plugs in accordance with the manufacturer's recommendations, observing all cautions and warnings. Determine spark plug serviceability in-line with the manufacturer's inspection criteria. Spark plugs that fail to meet the "normal electrode condition" characteristics" should be discarded.

Tools and methods used for setting the spark plug gap vary with electrode configuration. Observe the manufacturer's gap setting procedure. NEVER bend or apply pressure to the centre electrode as this can fracture the ceramic insulator.

Refer to the spark plug rotation chart and install the spark plugs in accordance with the engine manufacturer's data to help equalise wear.

Always install a new spark plug gasket when servicing spark plugs or installing new spark plugs. Failure to install a new spark plug gasket may result in incomplete sealing of the combustion chamber, loss of heat transfer with spark plug overheating leading to possible pre-ignition.

Whilst the spark plug insulator material is hard it is also very brittle. If a plug is ever dropped from any height or has any mechanical damage it should be discarded. A cracked or damaged spark plug insulator can induce pre-ignition. Cracks start so small they need to be seen with magnification. If in doubt, throw it out.

Pre-Ignition

Pre-ignition is caused when the combustion charge is ignited prior to the normal, timed spark. This may be caused by a cross firing magneto or harness, but most often a hot spot due to an overheated spark plug. Indicators include a rapid rise in the cylinder head temperature, and a small drop in exhaust gas temperature or TIT, there may be some engine roughness.

Pre-ignition can cause severe engine damage in a matter of minutes if not detected and arrested immediately It may be difficult at times to discern the difference in detonation and pre-ignition once a very high CHT is observed as the rate of change for pre-ignition is much greater, an example would be 385°F (196°C) to 485°F (252°C) in 60 seconds. Appropriate CHT alarm thresholds assist in early detection and inflight correction before damage is done.

Typically, pre-ignition results in localised overheating of the piston material and fusing of the piston crown. Failure of the cylinder is usually within 1-3 minutes of reaching approximately 500°F (260°C). A properly configured engine monitor is the best method of detection and intervention. Intervention requires full rich operation and any possible power reduction while maintaining flight to a suitable landing.

If you suspect that an engine has operated in pre-ignition, remove all spark plugs from the affected cylinder, discard them and inspect the cylinder with a borescope for possible damage. Follow the engine manufacturer's recommendations for inspection, damage correction and operational protective procedures.

Figure 3. Pre-Ignition Piston Crown Damage

(Source: DRS No: 611851388)

Contributing Factors - Other

Ignition System - Proper magneto-to-engine timing is an important factor. The timing is affected by wear and therefore should be checked and reset at intervals specified per the engine manufacturer's instructions. Regular, meticulous magneto maintenance and ignition harness inspection will help to avoid undesirable effects.

Fuel Management - Mixtures that are Rich of Peak EGT, in the range of Δ35-50°F (Δ20-28°C) promote detonation when other parameters like high CHT, high Oil Temperature, and high Inlet Air Temperature are present. Low Octane rating and advanced spark timing are also contributors. Turbocharged engines with insufficiently rich enough mixtures can more readily operate in detonation.

Normally aspirated engines that are conforming to the manufacturers design operating on conforming fuel will not readily detonate. However, departure from conforming parameters combined with some of the above-mentioned contributors can. Operation with mixtures on the lean side of peak EGT cannot support detonation. Operate lean enough or rich enough to avoid detonation.

6. Reporting

Report all instances of spark plug failures to CASA via the DRS system available on the CASA website. Details of the maintenance history for the engine ignition system and spark plugs should be provided in addition to information concerning the method of failure detection, the location and condition of the defective plug(s) and any other information on possible triggers for the reported event. This information will facilitate a detailed review of potential failure causes and contributing factors.

7. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link email address:

AirworthinessBulletin@casa.gov.au

or in writing, to:

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Standards Division
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