AAIU Report No.2001-011
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Aircraft Type and Registration:	**Rallye Club MS 880, EI-AYA**
No. and Type of Engines:	**Continental 0-200A**
Aircraft Serial Number:	**2256**
Year of Manufacture:	**1973**
Date and Time (UTC):	**19 December 1999 14.55**
Location:	**Luska Pier, Co. Tipperary**
Type of Flight:	**Training**
Persons on Board:	**One**
Injuries:	**None**
Nature of Damage:	**Damage to nose undercarriage, engine and tail**
Commanders Licence:	**Student Pilots Licence**
Commanders Age:	**40 Years**
Commanders Flying Experience:	**77.30 hours, 65.20 on type**
Information Source:	**CFI Limerick Flying Club** **AAIU Field Investigation**

SYNOPSIS

The aircraft took off from Coonagh Airfield at 14.25 on 19 December 1999. A solo navigation exercise was planned and the pilot intended to fly to Portumna, 31 N.M. away and back to Coonagh. On the return leg and at 1600 ft AMSL the engine and propeller stopped suddenly. The pilot identified a suitable field on which to execute an emergency landing. During the landing the nose undercarriage was damaged and the tail struck the hedge bordering the field. The pilot exited the aircraft uninjured.

1. FACTUAL INFORMATION

1. 1 History of the Flight

The aircraft took off from RWY 10 at Coonagh Airfield at 14.25 hours on 19 December 1999. The pilot planned a solo navigation exercise and intended to fly to Portumna and back to Coonagh via Killaloe. The flight was approved by the CFI prior to take-off. The pilot said he did not file a flight plan as he would not be entering into controlled airspace. The planned flight duration was 48 minutes and the aircraft's endurance at take off was 3 hours 30 minutes. The pilot took off with the fuel selector on the right hand tank.

The aircraft turned over Portumna 24 minutes after take-off and was returning to the airfield via the east bank of Lough Derg. Approximately 4 minutes later the pilot switched to the left-hand fuel tank. Very shortly afterwards the engine cut completely. The pilot said that the engine failure was sudden, without warning and that the propeller stopped very quickly. At the time of the incident the aircraft was at an altitude of about 1600 ft AMSL, the mixture control was set fully rich flying at 85 kts with the engine speed set between 2600 and 2700 RPM. (The engine had recently been reworked and a high power setting is recommended by the manufactures during the engine "run-in" phase.)

The pilot eased the nose of the aircraft down, reduced airspeed to about 60 kts and selected first stage flaps. The pilot said that he alternated between fuel tanks but that the engine would not restart. He attempted to crank the engine but the propeller did not turn at all and remained in the horizontal position at all times.

The pilot identified a suitable field to execute an emergency landing. The tail of the aircraft hit a hedge on the approach to the field as the pilot attempted to land. On landing, the nose gear collapsed and the aircraft slid to a stop in the field. The pilot switched off the battery master switch, removed the keys and got out of the aircraft. He returned later to remove personal belongings and to ensure that the aircraft was safe.

1.2 Injuries to Persons

There were no injuries to persons.

1.3 Damage ot the Aircraft

The nose gear collapsed. There was damage to the engine cowling and lower fuselage structure supporting the nose gear. The firewall was damaged and pushed back. There was a dent on the slat on the R/H wing and a dent on the L/H flap. The step on L/H side was broken at its mounting. The elevator was damaged with dents on the elevator balances.

1.4 Other Damage

There was no other damage apart from a 2 ft gap in the hedge caused by the tail of the aircraft striking the hedge on landing.

1.5 Personnel Information

The pilot had flown dual on other light aircraft for a total of 12 hours flying time. He had completed 40 hours dual and 25 hours solo flying on this aircraft.

1.6 Aircraft Information

On the day following the accident, the aircraft was inspected by the Investigators. The engine oil filter was removed and some sludge found in the oil. The aircraft was then removed to the AAIU facility at Gormanston.

The Socata Rallye Club MS880b is a 3 /4 seat aircraft with a 100 HP Continental engine and a fixed pitch propeller. Wing tanks hold a total of 96 litres of fuel. Cruising speed is about 93 kt at 75% power at 5000ft. Stalling speed with the flaps down is 41kts and the landing speed is 38 kt.

The O-200A engine has externally-finned aluminium alloy head castings, screwed and shrunk permanently on externally-finned steel barrels. The pistons are cam ground aluminium castings with three compression rings above the piston pin. The top ring is chrome faced with an oil control ring below the piston pin. The piston pins are full floating ground steel tubes with ground aluminium end plugs. The crankshaft is made from a steel alloy forging with nitrided journals and crankpins. The camshaft is a steel alloy forging. The aircraft was not fitted with an optional cylinder head temperature gauge.

1.6.1 Aircraft and Engine history

The engine of this aircraft had been installed on another aircraft up to a total time since previous overhaul of 2008 hours flying time. The engine was then removed from that aircraft and overhauled in the USA. The engine was then installed on EI-AYA during an annual inspection of the aircraft in May 1996. The engine cooling baffles were repaired and painted at that time. The airframe flight time was then at 4008 hours total and the aircraft was signed, off following the work, on 27 May'96.

On15 May 1997 at 4359 hours the starboard undercarriage collapsed following a taxi incident. The aircraft wing was removed during repairs. The aircraft was released to service on 5 Sept.1997, following an annual inspection.

At 4601 hours, the aircraft underwent an annual inspection on 29 May'98. The engine exhaust was removed, cleaned and all nuts, bolts, gaskets and air ducting replaced. The aircraft again flew on 16 July'98. By the 11 July 1999, the airframe hours had reached a total of 5048 hrs and the engine 1039 hrs since overhaul.

The airframe and engine then underwent an annual inspection at a maintenance organisation.

1.6.2 Engine Rebuild

During the annual inspection of July 1999 the engine was removed and bulk stripped for replacement of camshaft and its bearings, engine seals, gaskets and piston rings. This engine work was carried out by a separate licensed contractor. The engine had been handed over to him with the cylinders removed from the engine. These had been removed by the same crew who removed the engine from the aircraft. The engine contractor said that he stripped the engine as per the manufacturers overhaul manual and inspected all parts for wear or damage prior to reinstallation. All four cylinders had glaze removed by application of a flex hone tool. (see below)

New piston rings were then fitted. The camshaft was replaced complete with bearings, gaskets and "O"rings. The build-up of the engine took place in an area at the rear of the general hangar work area which was unsuitable for such work. A job card and an engine strip report were furnished for this work but a detailed technical survey and rectification worksheet was not available. This was not considered necessary by the contractor as the engine was not being overhauled. On stripping the engine, the crankcase was also cleaned by a member of the staff of the maintenance organisation and inspected by the contractor. All other work on the engine was carried out and inspected by the contractor himself. At hand over of the finished engine, all ports were blanked and the cylinders inhibited. The engine was not filled with oil at this stage. The engine was returned to the maintenance organisation as a "bare" engine without air filter, air ducting or exhaust flanges. The engine was then installed on the aircraft, these components added, and the engine filled with oil. A duplicate inspection was then carried out on all aircraft engine controls. On 7 Dec.1999 a test flight was carried out and the aircraft and engine considered satisfactory. . An oil leak check, carried out after the first test flight, was found satisfactory.

The aircraft was flown again for 15 min. on the 8 Dec 1999 and the released for service on the 9 Dec. 1999. Its final flight, whilst the aircraft was under the control of the maintenance organisation, was for 30 min. on the10 Dec. 1999.

1.6.3 Flights following acceptance

A pre-acceptance test flight, lasting 40 min. was carried out and the aircraft was returned to its base on the15 Dec. 1999 after a 1 hour 10 min. ferry flight. Nothing unusual was reported.

Three flights took place on the 19 Dec.1999. No adverse reports or defects were reported following the first two flights of the day. The CFI of the flying club who was aboard the aircraft on the second flight said that all instrument indications were normal and that the engine sound and vibration indicated nothing unusual. He said that "the engine was in run-in phase, using high power i.e. varying up to a maximum continuous RPM of 2600 to 2650 as instructed." The total flight time for these two flights was 1 hr 35 min.

Prior to the final flight of EI-AYA, the pilot carried out a pre-flight inspection and afterwards remembered that the oil was blacker than he would have expected after only 4 hrs 35min. engine running. This flight lasted 35 min. The pilot said that during the flight, all engine temperature and pressure indications were "in the green". He looked at these indications during the outward leg at Killaloe and scanned them from then on. He did not remember reading the indicators as such. No rapid decent or climb was undertaken during the flight. The mixture control was set "fully rich" and the RPM was set between 2600 and 2700.

1.6.4 Examination of engine

The engine was removed from the aircraft. The engine air filter, apart from the clay picked up at impact, appeared clean. The engine was fully stripped down. The oil in the crankcase showed streaks of darker coloured oil mixed with the lighter mineral oil, particularly in the vicinity of the No.1 and No. 2 cylinders.

1.6.5 Crankcase and con rod bearings

The mating surfaces of these bearings were rough and scored in the direction of rotation. The dimensions of the bearings were measured and found to be satisfactory for a 10 thou undersize crankshaft, which was that fitted to the engine. They did not, however, show a surface representing a short period of a total of 5 hours of operation since replacement

All oil galleries within the crankcase were checked and found free of visible contaminant.

1.6.6 Fuel pump

The spring which puts pressure on the lever to engage the cam of the fuel pump on the camshaft was found broken. This caused the lever arm to have excessive lateral play and to exhibit evidence of bounce on the cam.

The cam was marked at this particular point. The cam had not been replaced during the re-build of the engine.

1.6.7 Cylinder barrels

All four barrels exhibited scoring of the cylinder internal surfaces. This scoring took place in the 5 hours of operation considering the internals had been honed prior to engine re-build. In particular No.2 and No.3 cylinders showed burring marks caused by the piston pin caps impinging on the internal walls of the cylinders. Additionally, No.2 cylinder exhibited longitudinal marks all along the internal walls caused by the piston rings in successive rotation.

1.6.8 Piston and piston pins

In No.2 and No.3 cylinders the gudgeon pin caps showed signs of wear where these had impinged on the walls of the cylinders. In addition, the No.2 pin showed signs of severe overheating with a distinct discolouration of the metal surface. The piston body itself showed wear where it had come in contact with the cylinder wall. The piston rings in No. 2 cylinder also exhibited scraping in a longitudinal cylinder direction where they came in contact with the cylinder wall. There was also some evidence of previous corrosion of the cylinders, which, it is expected, would have been removed during honing.

1.7 Meteorological Information

A slack east-northeast flow affected the area, which was under the influence of a large anticyclone with north-south axis over the midlands, at the time of the incident.

Wind: At surface, VRB/03-05kt.
At 2000ft, 030-060/10kt.

Note; Wind estimated from surface analysis charts at 1200 UTC and 1800 UTC on the day in question.

Weather:	Nil.
Visibility:	10+ kilometres
Cloud:	FEW 2000ft SCT 3000ft
Temp/Dewpoint:	03/00 Celsius
Pressure:	1028 hPa MSL

1.8 Aids to Navigation

Not Applicable

1.9 Communications

Not Applicable

1.10 Aerodrome information

Not Applicable

1.11 Flight Recorders

There were no recorders on board and these were not required.

1.12 Wreckage and impact information

There was very little damage to the surrounding area at the impact site apart from a gap in the hedge caused by the tail of the aircraft. The nose wheel of the aircraft broke off on impact and was found some distance away. All other components remained attached to the aircraft.

1.13 Medical information

Not Applicable

1.14 Fire

There was no fire.

1.15 Survival Aspects

A full four point harness was used and exit was made by sliding the canopy.

1.16 Tests and Research

Straight 100 engine mineral oil was being used during the first 25 hours of flying as the engine was being run in following reworking.

A sample of this engine oil was sent to a laboratory for analysis. Visual inspection of the oil sample showed that there was little residue in the oil sample taken from the aircraft after the landing. The metallic species were not visible to the unaided eye. The oil was significantly discoloured, being opaque and black, suggesting that the oil had been in use for some time. However, it was known that the engine had just completed a service, the oil replenished, and this oil had only been in service for 5 hours and 10 minutes

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X-Ray analysis was conducted on the residue using a PGT-Energy Dispersive Analyser (EDS) attached to a scanning electronic microscope. EDS spectrum analysis of the black residue from the oil revealed levels of iron, with lower levels of copper, manganese, chromium, lead, phosphorous, silicon, bromine and carbon. Individual particles within the black residue were identified as consisting predominantly of lead, bromine and iron.

The oil manufacturer stated that it was normal to get iron in the oil, along with other substances, and this would give the oil a black appearance. The iron content should be about 100 to 120 ppm (parts per million). The iron comes from the action of the steel piston rings rubbing on the internal surface of the cylinder bore. During the "break in" period following engine build-up, the hot gases blow past the piston rings and increase the oil temperature.

When matching of the rings and bore occur then this ceases. It is therefore necessary during this time to manage the engine correctly so that the mixture is not leaned too much which would cause the engine to further overheat.

A further sample of the oil was sent to the oil manufacturer in the U.K. for quantitative analysis. Spectrometry results show that the oil contained large amounts of iron and silicon. The iron reading during these tests showed 806 parts per million, or eight times more than would be expected.

The following is an extract from the report compared to what could be expected from an engine oil in service:-

Constituent (ppm)	Normal	Severe	EI-AYA
Fe (Iron)	100 - 120	200	806
Al (Aluminium)	Less than 25	Greater than 45	81
Si (Silicon)	15 - 20	50	175

Their report concluded:-

"The analysis results show alarming contamination with abrasive silicon, with direct effect on wear of the whole engine. Recommend that this engine is completely checked and probably overhauled."

1.18 <u>Additional Information</u>

1.18.1 Cylinder Honing

The hone marks in factory or workshop finished cylinders are produced by a specific machine and have a definite cross pattern, with an appreciable flat between grooves. This finish allows enough depression to hold oil during the break-in period. The crossed pattern is achieved by honing in a figure of 8 motion with rapid reciprocation of the carbide honing head in proportion to its rotation speed.

The flex hone tool (or spring-loaded hone), on the other hand, is recommended by some engine manufacturers for use in cylinder bore reconditioning "in the field" and has rounded tips made from silicon carbide grit. The tool is rotated by an unguided drill into the cylinder in order to remove the glaze from the cylinder wall. The cylinder internals should then be washed down thoroughly. This hone removes the cylinder wall glaze but produces an irregular pattern on the cylinder wall and an unreliable surface finish. Any taper or irregularities in the cylinder will not be reduced.

For this reason, it is believed that some engine manufacturers do not recommend the use of the flex hone. The flex hone used on this engine is no longer made by the original manufacturer and has been out of production for five years.

1.18.2 Cylinder Cleaning

The engine manufacturer's Overhaul Manual states;- *"Every effort should be made to keep engines free from external accumulations of foreign matter and to prevent the entrance of abrasive particles."* The manufacturer states that the cleaning associated with honing is part of general engine maintenance practice and should consist of cleaning with a stiff brush and repeated washing out of the cylinder with warm water.

Another engine manufacturer publishes a more detailed publication in the form of a Servicing Instruction and the essential details of this are in *Appendix A* to this report.

1.18.3 Running–in of Engine

It is recommended by engine manufacturers that care should be taken when operating an engine following such servicing. Operators are advised to pay particular attention to any signs of high oil and cylinder head temperatures. The airspeed should be maintained so as to increase the quantity of cooling air over the engine in order to achieve low temperatures. Shallow climb out angles should be considered.

2. ANALYSIS

A small quantity of sludge was removed from the engine oil filter at the landing site. This would not be considered abnormal as the engine had just come off a rebuild and a small amount of "bedding-in" debris can be expected.

However, the quantities of iron, silicon and aluminium found in a clean sample of the oil were excessively high. Taking into consideration that the oil was black in colour after only 4.5 hours indicates that a high level of iron had built up in the oil. The iron comes from the action of the piston rings rubbing on the internal surface of the cylinder bore. During the "run-in" period the hot gases blow past the piston rings and increase the oil temperature. (After bedding in between the rings and cylinder walls this action ceases). During this phase, the increased friction also increases the temperature and the engine may run very hot. It is therefore necessary to manage the engine so that the fuel/air mixture is not leaned too much which would cause the engine to further overheat.

The presence of abrasive silicon would increase the friction in the cylinder thus raising the temperature.

Due to the difference in temperature coefficients between aluminium and steel, the aluminium pistons, complete with steel rings, will score the cylinder walls. The gudgeon pin caps, being also of aluminium, will score the walls.

There was evidence of such scoring on both No.2 and No.3 cylinders. The high concentrations of aluminium in the oil is consistent with this action. Since the crankshaft and pistons were free to move upon engine cooling, it is concluded that the engine stoppage was due to the excessive expansion of the No. 2 (and possibly No.3) cylinder piston caused by very high frictional heat. Excessive localised heating may not show up in the standard aircraft oil temperature and pressure gauges in sufficient time to alert the pilot.

The pilot said that he maintained the engine RPM between 2600 and 2700, whilst the instructor who flew on the previous flight indicated that the RPM should be maintained between 2600 and 2650. Both of these sets of figures are within the indicator green arc (normal area) and as 50RPM reads one-half graduation, the difference is considered of little consequence in this case.

3 CONCLUSIONS

3.1 The internal components of the engine were allowed to become contaminated with abrasive silicon during the build-up of the engine.

3.2 The quantity of silicon indicates that it most likely came from the flex hone tips, which are manufactured from silicon carbide grit.

3.3 The engine was built-up over several weeks in a section of a hangar in which general aircraft maintenance was being carried out. The correct cleanliness standard and required engine workshop practices, including heat and light recommended by the manufacturer, were not adhered to.

4. RECOMMENDATIONS

4.1 The contractor should assemble an engine only in the clean environment of an engine workshop facility**.(SR 20 of 2001)**

4.2 The IAA should ensure that engine rebuild/overhaul should only take place in an area specifically designed and built for this type of detailed work**. (SR 21 of 2001)**

4.3 The engine manufacturer should consider issuing a service bulletin pointing to the dangers of abrasive contamination and include a detailed cleaning procedure. **(SR 22 of 2001)**

Appendix A

(a) Use kerosene or light engine oil for lubrication while honing.

(b) Clean hone and abrasive thoroughly before honing another cylinder.

(c) When de-glazing procedure has been accomplished, wipe as much as possible of the abrasive build-up from cylinder walls and recesses. Pay particular attention to the recess formed by top of cylinder barrel and bottom of cylinder head. Fabricate a hooked tool from soft wire and run the tool around in the recess to loosen build up of abrasive. This operation must be performed each time the cylinder is flushed. No abrasive must remain in this area. Proceed to clean cylinder as follows:

(d) Flush cylinder thoroughly with a hydro-carbon solvent. Use solvent under air pressure. The use of a soft bristle brush is recommended in conjunction with flushing, to remove abrasive build-up in difficult to reach areas. Do not use a wire brush. At the conclusion of first flushing operation, wipe out cylinder with a clean white cloth, dipped in SAE 10 engine oil. Examine cloth carefully under a light for evidence of abrasive remaining in cylinder. If abrasive is found on the cloth repeat flushing operation.

(e) After cleaning, oil the cylinder thoroughly with SAE 50 engine oil or rust preventive oil conforming with specification MIL-C- 6529.