FINAL REPORT

AAIU Report No: 2003-005
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Operator:	Private
Manufacturer:	Reims Aviation
Model:	FA-150 L
Nationality:	U.K.
Registration:	G-BAOP
Location:	Near Athboy, Co Meath.
Date/Time (UTC):	22 June, 2001 at 15:50 hrs

SYNOPSIS.

While flying from Dublin to Sligo, the engine failed. In the subsequent forced landing the aircraft was extensively damaged. Examination of the engine showed that the crankshaft had failed due to fatigue. An unapproved repair was found to have reduced the fatigue resistance of the crankshaft.

NOTIFICATION

The AAIU was notified of this accident at 17:30 hrs (local) on the day of the accident by Dublin ATC and the investigation commenced that day. The Chief Inspector of Accidents, Mr. Kevin Humphreys, directed that a Formal Investigation be conducted into this accident and appointed Mr. Graham Liddy as Inspector-in-Charge, assisted by himself as Operations Inspector. The investigation was subsequently assisted by Ms. Ann Evans, Inspector of Air Accidents, of the UK Air Accidents Investigation Branch (AAIB) in relation to details of the last engine repair.

Three Safety Recommendations are made in this report.

1. FACTUAL INFORMATION

1.1 History of the Flight.

The aircraft departed Weston Airfield (EIWT), Co Dublin, at 15:30 hrs UTC on 22 June 2001, on a Visual Flight Rules (VFR) flight to Sligo Airport (EISG). On board were the pilot and one passenger. Some 20 minutes into the flight, near Athboy, Co Meath, there was a sudden loud noise and the engine stopped. The pilot selected a field for a forced landing. As he approached the selected field, the aircraft passed over another field that was, in terms of the direction of flight, 250 metres long and nearly 1000 metres wide.

The pilot determined that he would be unable to clear the tall hedge on the far side of this field. He slowed the aircraft to minimise the impact with this hedge. As the aircraft neared this hedge, at an altitude of approximately 25 ft, it stalled. The aircraft struck the ground heavily, causing the nose undercarriage to fail. The pilot and passenger then vacated the aircraft. Local rescue services arrived on the scene shortly afterwards.

1.2 Injuries To Persons

The pilot suffered minor cuts. The passenger, who was the pilot's wife, was pregnant. She was removed to hospital for observation, but was found not to have suffered any ill effects.

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor	1	0	0
None	0	1	

1.3 Damage To Aircraft

The nose undercarriage was sheared off and one blade of the propeller was bent back underneath the nose of the aircraft. The aircraft suffered extensive distortion to the wings, fuselage and main undercarriage due to the heavy landing. There was considerable internal damage to the engine, including a failed crankshaft and camshaft.

1.4 Other Damage

There was no other damage caused by the aircraft. However, rescue service vehicles and others flattened a sizeable area of the grass crop in the landing field.

1.5 Personnel Information:

1.5.1 Pilot

Personal Details:	Male, 40 years of age
Licence:	PPL (U.K.)
Date of First Issue of PPL Licence:	12 January 2000
Medical Certificate :	Valid, issued 02/04/2000, Class 2

Flying Experience:

Total all types:	130	hours
Total all types PI:	63	hours
Total on type:	67	hours
Total on type PI:	33	hours
Last 90 days:	4	hours
Last 28 days:	2	hours
Last 24 hours:	½	hour

1.6 Aircraft Information

1.6.1 Leading Particulars:

Aircraft type:	FA-150 L
Manufacturer:	Reims Aviation
Constructor's number:	0190
Year of manufacture:	1973
Certificate of registration:	Issued 26 May 1999
Certificate of airworthiness:	Renewed 12 April 1999 (private category) for a period of 3 years, issued by the UK CAA
Total airframe hours:	5,280
Engine:	Rolls Royce Continental
Model:	0 -240 - A
Serial No.:	40R122
Engine Hours since overhaul:	1,096
Propeller:	McCauley 1A135BRM7150

1.6.2 General Information

The Reims Aviation FA-150 L is a license-built version of the Cessna 150 Aerobat. It is a single-engined, high wing, nose wheel aircraft. It is certified for aerobatics.

1.6.3 Maintenance History

1.6.3.1 While the aircraft was owned and largely operated in the Republic of Ireland, it was maintained under the UK Regulations because it was registered in the UK.

1.6.3.2 The Certificate of Airworthiness was last renewed in England on 12 April 1999. This Certificate of Airworthiness was valid for 3 years.

1.6.3.3 In April 2000, during a routine 50-hour inspection which was done in Northern Ireland, metal was found in the engine oil filter. The engine was removed from the airframe and was sent to a facility in England to be repaired. This facility was approved as an M3 organisation by the UK Civil Aviation Authority (CAA), in accordance with British Civil Aircraft Regulations (BCAR) Section A8-15. This facility in turn passed the engine to a "D" Licence Engineer, who performed the actual repair on the engine. The repair was carried out under the engineer's own Licence Approval. During the course of this repair, it was found that the crankshaft was damaged beyond repair, due to failure of the centre main bearing. The unserviceable crankshaft was replaced as detailed in Section 1.18 of this report. At the engine removal, the airframe had 5,140 hours total time and the engine had 953 hours since overhaul. This is a corrected figure for the engine, as an error of an extra 50 hours was made in the logbook for the entry of 6 April 2000.

1.6.3.4 The engine repair was duly certified for Release to Service by the M3 approved facility. The certification noted that:

- All engine components were inspected in accordance with manufacturer's overhaul manual to ensure compliance with service limits,

- Fluorescent magnetic particle inspection (MPI) carried out in accordance with BS 6072 on all steel parts. (This would include the replacement crankshaft).

1.6.3.5 The "D" Licence Engineer, who performed the repair on the engine, subsequently stated that the CAA regulations and the overhaul inspection procedures of the manufacturer concerning the crankshaft were followed precisely. He had held a "D" Licence for approximately 8 years when he worked on this engine.

1.6.3.6 The repaired engine was re-installed in the aircraft and an annual inspection was completed at this time. This work was carried out in Northern Ireland. The aircraft returned to service on 30 August 2000. The aircraft subsequently completed a 50-hour and 6 month inspection on 10 January 2001 at 5,190 airframe hours. Another annual inspection was carried out in Northern Ireland on 2 April 2001 at 5,240 hours and 1,053 engine hours (corrected hours). The next inspection due was a 50-hour inspection, which would have occurred at 5,290 hours (airframe).

1.7 Meteorological Information

Weather was not a factor.

1.8 Aids to Navigation

Aids to Navigation were not a factor in this accident.

1.9 Communications

Communications were not a factor in this accident.

1.10 Aerodrome Information

Not a factor in this accident.

1.11 Flight Recorders

No flight recorders were fitted to this aircraft, nor were they required to be fitted.

1.12 Wreckage and Impact Information

The ground marks indicated that the aircraft impacted initially left wing low and nose down. The nose wheel broke off at this initial impact. The aircraft then bounced and rolled right. The aircraft contacted the ground again with the right wing tip and right main wheel, and came quickly to a stop.

The total distance from the initial ground contact to the final stop was 40 feet. The aircraft came to rest in a nose down attitude, supported by the main undercarriage and the engine cowling. One blade of the propeller was bent backwards underneath the aircraft. The other blade was undamaged. The propeller could be rotated only with difficulty, due to internal engine damage.

1.13 Medical Information

Not a factor in this accident.

1.14 Fire

There was no fire.

1.15 Survival Aspects

Because the aircraft was certified for aerobatics, it was fitted with a 4-point harness on both the pilot's and passenger's seats. These harnesses were worn by both the pilot and the passenger, at the time of the accident.

1.16 Tests and Research

1.16.1 The engine was removed from the aircraft and dismantled. It was established that the crankshaft had failed on the crank between No. 2 cylinder big-end bearing and the central main bearing, at a point where the main bearing section meets the crank. Due to the orientation of the fracture, significant disruption of the innards of the engine occurred when the rear section stopped, and the forward section continued to briefly rotate under the fly-wheel effect of the propeller. The crankshaft failure is shown in Fig 1 of Appendix A.

1.16.2 The crankshaft was removed and subjected to metallurgical examination. This showed that the failure crack had initiated at the junction of the No 2 crank and the central main bearing. Examination also showed that the centre main bearing diameter had been reduced by machining and was then built up by applying flame spray. Flame spray (sometimes known as "Plasma Spray") is a process used to add metal to the surface of a component. The donor metal is fed through a spray gun, often in wire form. A mixture of compressed combustible gas, often oxygen and acetylene, is used to melt this material and it is then blown on to the surface of the component, in atomised form, by the compressed gas. The material is thus deposited on the component. During this process the temperature of the surface of the component can reach 6,500° C to 16,000° C, depending on the precise process used. In the case of a worn crankshaft bearing, this process would be used to build up the crankshaft to the required diameter.

1.16.3 Measurement showed that the final thickness of the metal applied by flame spray was approximately 1 mm (0.040 inches). A greater thickness would have been applied initially, and then the main bearing diameter would have been ground down to the correct diameter.

1.16.4 Examination of the applied metal on the centre main bearing also showed that it extended about 40% of the way up the blend-in radius between the main bearing surface and the crank. The applied surface material was found to be flaking off at this junction. It was also noted that applied material was made up of 2 layers. This is normal where flame sprayed material is applied in order to build up a wear resisting surface. The inner layer is a 'key' coat for attachment of the outer layer to the base material. It was also noted that the 'key' coat had not been applied far enough up the radius and that this was the reason for the flaking noted above. It is important to note that the coating ended in a critical region on the surface of the blend-in radius, i.e. where the maximum cyclic stresses occur in service.

1.16.5 The applied metal was analysed in a scanning electron microscope using an energy dispersive X-ray technique. This showed that the ‘key' coat was nickel containing aluminium, silicon, manganese and oxygen and that the outer layer was iron containing over 12% of chromium, some manganese and a relatively large amount of oxygen from the presence of oxides.

1.16.6 It is usual to prepare the surface prior to the addition of extra material, whether by flame spray or similar processes. It could not be determined what preparatory process had been used in the area of the failure. However it was determined that it was not a treatment such as shot-peening or case-hardening that would have introduced surface compression stresses in the component, thereby increasing fatigue resistance.

1.16.7 Examination of the crankshaft fracture surface showed approximately 150 markers. Each of these markers, which show up as wider bands on the fracture surface, indicates a power cycle, i.e. an increase of engine power from normal to a high setting.

1.16.8 The camshaft fracture showed the failure had resulted from a very low cycle reverse-bending fatigue mechanism.

1.16.9 The exhaust stub of No.1 cylinder was found to be badly cracked, and the crack had opened up considerably. This crack displayed the characteristics of high cycle fatigue. There was noticeable exhaust gas staining of the exterior of the stub and the securing studs and nuts. The cracked stub is shown in Fig. 2 and Fig. 3 of Appendix A.

1.17 Organizational and Management Information

This aircraft was owned and operated by a group at Sligo Airport. The pilot was a member of this group.

1.18 Additional Information

1.18.1 Before departure for Sligo Airport, the aircraft was examined on behalf of a potential buyer. During this examination, it was noted that the engine sounded very rough or noisy.

1.18.2 The group in Sligo purchased the aircraft about 2 years before the accident. The previous owner gave them a box of engine parts, which included a crankshaft, serial number DD 1647. This crankshaft came from an engine (serial No. 40R061) previously fitted to this aircraft.

1.18.3 When the owners were informed in April 2000 that the crankshaft in the engine required replacement, they requested the repairers to examine and test the spare crankshaft, DD 1647, which they had acquired with the aircraft. The owners stated that the repairers informed them that if this crankshaft passed the required inspection, it would be fitted to the engine. As they possessed no documentation, the owners were unable to provide any service history or other records, relating to this crankshaft, to the repairers. The Licensed Engineer did subject the crankshaft to Magnetic Particle Inspection (MPI), and stated that he did not detect any anomaly on the crankshaft. The crankshaft was identified as serial number DD 1647 by the serial number marked in the crankshaft propeller flange.

1.18.4 The engine was then re-assembled and returned to service in G-BAOP in August 2000. The repair did not constitute an overhaul of the engine.

1.18.5 All efforts to obtain logbooks or other details relating to engine serial No. 40R061 and its crankshaft DD 1647 during this investigation, were unsuccessful. Thus it could not be determined where or when the flame spray build-up on the crankshaft bearing had been carried out.

1.18.6 Teledyne Continental Motors, who designed the original version of this engine, were contacted to determine if flame spray was an acceptable method of restoring the main bearing diameter to specified diameter. They were categorical in stating that this was not an approved process and that crankshaft failure, within a relatively low number of engine hours, could be expected as a result of this repair.

1.18.7 The approved repair procedures for the crankshaft permit a maximum 0.010 inches (0.025 mm) build-up of main bearing diameter by means of re-nitriding. The engine manufacturer approves no other method of main bearing diameter rectification.

1.18.8 It should also be noted that the nitriding process generates compressive forces in the crankshaft surface, thereby enhancing its fatigue resistance. The repaired crankshaft had no nitriding.

1.18.9 In the course of this investigation the UK CAA was requested by the AAIB, on behalf of the AAIU, to clarify the regulations pertaining to fitting of used parts to engines when airworthiness and/or service history documentation is not available. They stated (direct quotations from the UK Air Navigation Order and a CAA Airworthiness Notice and are highlighted in bold below) :

"*CAA policy is that used parts cannot be fitted to engines when their airworthiness and/or service status has not been established. The policy is based upon: -*

- *The Air Navigation Order (ANO) Article 12 (7) (a) requires the engine be repaired* ***"... with material of a type approved by the CAA".***
- *The ANO Article 9 (7) (a) states that the Certificate of Airworthiness will be cease to be in force if parts are replaced* ***"……otherwise than in a manner and with material of a type approved by the CAA ".***
- *CAA policy is stated in Airworthiness Notice (AN) 14, Paragraph 6.4* ***"The person issuing the certificate of release to service for the fitting of a component to an aircraft on the UK register, is responsible for ensuring that the records of that component are sufficient to enable its maintenance and operating history to be established, including the embodiment of modifications and mandatory ADs, service life used etc."***"

1.18.10 The following is not related to the causes of this accident, but is noteworthy. A prospective buyer of the salvage of G-BAOP, who works in the aviation business in the UK, viewed the aircraft after the accident. He stated to the investigation that he believed the propeller was repairable and saw no problem in straightening it and returning it to service. A photo of the damaged propeller is in Fig 4 of Appendix A. The propeller is bent back approx 85° at the tip. The maximum permissible cold rolling repair limit is 20°. This is laid down by the propeller manufacturer, McCauley, in Figure 4-2 of their overhaul manual, document 730720.

2. ANALYSIS

2.1 The main bearing surface, in the area of the failure, had received some form of treatment prior to application of the flame spray, presumably to provide a good key for the metal deposited in the flame spray process.

2.2 While the precise nature of this treatment could not be determined, analysis showed that it was not a treatment that would enhance fatigue resistance.

2.3 The flame spray build–up on the crankshaft was 1 mm (0.040 inches), which is 8 times the thickness of the maximum permissible build-up using the approved nitriding process.

2.4 The high temperatures involved in the flame spray application process can induce thermal stress cracks in the surface of the parent metal of the crankshaft. Such cracks act as initiation sites for fatigue cracks. For this reason the practise of flame spraying is not approved, for crankshaft repairs, by the engine manufacturer. Consequently, it was totally inappropriate to use this process for the repair of the crankshaft.

2.5 The use of flame spray may be appropriate for the repair of crankshafts in other non-aviation applications. However given the high specific power-to-weight outputs of aircraft engines, and other design considerations, this process is totally inappropriate for the repair of aircraft engine crankshafts.

2.6 The absence of a nitrided surface significantly reduced the fatigue resistance of the crankshaft in the critical area of the centre main bearing.

2.7 It has been impossible to positively establish where or when this flame spray repair was carried out on the crankshaft, due to the absence of any documentation, maintenance or service records regarding this crankshaft or engine No. 40R061. However, based on the life expectancy comments of the engine manufacturer, it is unlikely that the repaired crankshaft had carried out many, if any, service hours in the previous engine. Furthermore, the evidence of the fatigue markers suggests that the crankshaft crack initiated some 150 power cycles prior to failure. The aircraft logbook indicates that the number of power cycles since the installation of the crankshaft in the engine was of this order of magnitude (at the time of the failure, the aircraft had completed 143 hours since the engine repair). This would indicate that the crankshaft underwent the flame spray process after it was removed from the previous engine. It also indicates that the flame spray process had been carried out on the crankshaft prior to its installation in the engine during the documented engine repair.

2.8 The owners of the aircraft provided the repairers with the replacement crankshaft DD 1647. They were aware that they were unable to provide any service history, service records or airworthiness documentation in relation to this crankshaft. They stated that they understood that it would only be fitted if it passed the required inspection tests. However, it was inappropriate that this crankshaft should have been provided for fitting to the engine, as it could not meet the provisions of the UK ANO, due to the absence of any service history.

2.9 The repairers accepted a crankshaft for fitting to the engine, without any documentation or knowledge of the service and maintenance history of the crankshaft. This was contrary to UK CAA policy, as noted in paragraph 1.18.9 above.

2.10 The crankshaft was thus fitted to the engine having successfully evaded three safeguards of good aviation practise:

- Unapproved repair procedures must not be applied to components.
- Owners of aircraft must be aware of their responsibilities, and should desist from actions such as requesting repair facilities to fit used components without any service records and airworthiness documentation.
- The policy of the local airworthiness authority, as laid down in the UK ANO and AN 14, was not observed during the repair of the engine.

2.11 The crankshaft was subjected to MPI Non Destructive Testing (NDT) by the repairer. NDT tests for a given component are designed (often as a result of hard experience) to detect defects of a type that might arise in normal or abnormal service, or during an approved repair process, of a given component. Such tests are not generally designed to detect unapproved repair techniques. It is not safe to assume that just because a component has passed a specific test that it is serviceable. Other factors, including its service history, visual inspection etc., must also be considered when assessing the serviceability of a component.

2.12 The crankshaft passed the magnetic particle test immediately before it was put in this engine. This could indicate that the fatigue crack had not initiated during service in the previous engine, and would support the deduction that the crankshaft was flame sprayed after it was removed from the previous engine.

2.13 The pilot had relatively low experience, having gained his PPL only 18 months prior to the accident. He had completed engine failure practise as part of his training. However, the combination of low experience and the suddenness of a real engine failure made a safe landing problematical. An effective protection against such situations is the reduction of the possibility of engine failure by good maintenance practise.

2.14 The high cycle nature of the fatigue crack of the exhaust stub of No.1 cylinder, and the extent of external staining, indicated that the stub had been cracked for a considerable time. The exhaust noise emanating from this crack would have rendered the engine considerably noisier than normal.

It would also have made it more difficult to detect rough running or vibration in the engine caused by the progressive nature of the growing crack in the crankshaft. Consequently, a possible opportunity to detect the incipient crankshaft failure was missed.

2.15 The crack in the exhaust stub could have been detected by careful examination of the engine. This can be seen in Fig 3 of Appendix A.

2.16 The damaged propeller blade was bent in excess of 4 times the maximum cold-rolling repair limit, as a result of this accident. It is a concern that an individual in the aviation maintenance business perceived no difficulty in having the propeller straightened and returned to service. This would indicate that the inappropriate repair of the crankshaft is not an isolated event.

2.17 The nature of the failure of the camshaft is consistent with overload resulting from the crankshaft failure. The camshaft failure was therefore a result, rather than cause, of the engine failure.

2.18 The use of 4-point harnesses prevented serious injury during the rapid deceleration of the aircraft in this accident. It should be noted that such harnesses are not a requirement in non-aerobatic light aircraft.

3. CONCLUSIONS

3.1 Findings

3.1.1 The engine was fitted with a crankshaft on which unapproved, and inappropriate, repairs had been carried out.

3.1.2 The time, place and other details of the crankshaft repair could not be established due to the total absence of any documentation relating to this component.

3.1.3 The fracture analysis indicates that the unapproved and inappropriate repairs were performed after the crankshaft was removed from the previous engine and before it was fitted to this engine. This finding is supported by the successful result of the MPI test and the fatigue markers of the fracture.

3.1.4 The action of the aircraft owners in providing the engine repairers with this crankshaft, while aware of the absence of any service records or airworthiness documentation, was inappropriate.

3.1.5 The acceptance of this crankshaft without any service records or airworthiness documentation, for fitting to the engine, by the repairers, was contrary to UK CAA policy and the UK ANO.

3.1.6 The availability and use of 4-point harnesses resulted in the absence of serious injury in this accident.

3.2 **Causes**

3.2.1 The in-flight engine stoppage was caused by the failure of the crankshaft.

3.2.2 The failure of the crankshaft was due to the use of unapproved repair procedures, i.e. the use of inappropriate surface preparation, and the application of metal build-up on the main bearing by flame spray. Additionally, the fatigue resistance was compromised due to the absence of a nitriding coating. The crankshaft ultimately failed in fatigue.

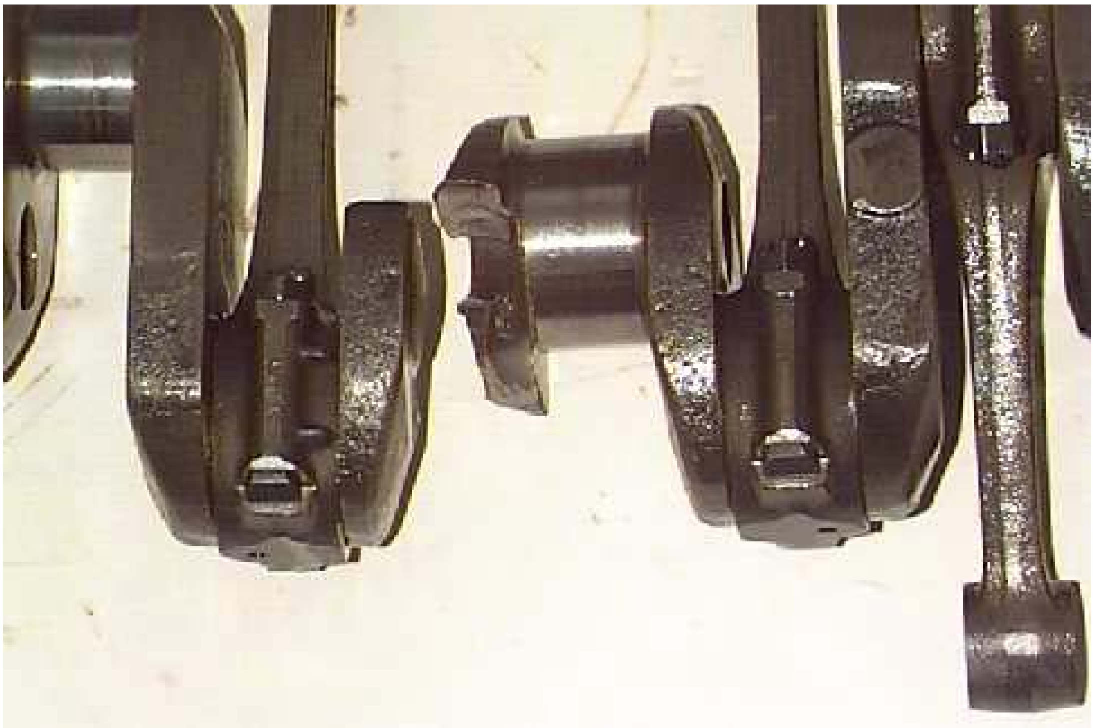
4. SAFETY RECOMMENDATIONS

4.1 The UK CAA should review the regulations with regard to permitting the fitting of used parts, which do not have airworthiness and service record documentation, to Private Category aircraft, in order to ensure that the aircraft maintenance industry are fully aware of the CAA policy. (**SR 13 of 2003**)

4.2 The UK CAA should monitor the repair facility and others involved in the repair of this engine, and should monitor the service history of other engines repaired or overhauled therein, in order to confirm that flame spray is not being used in the repair of crankshafts. (**SR 14 of 2003**)

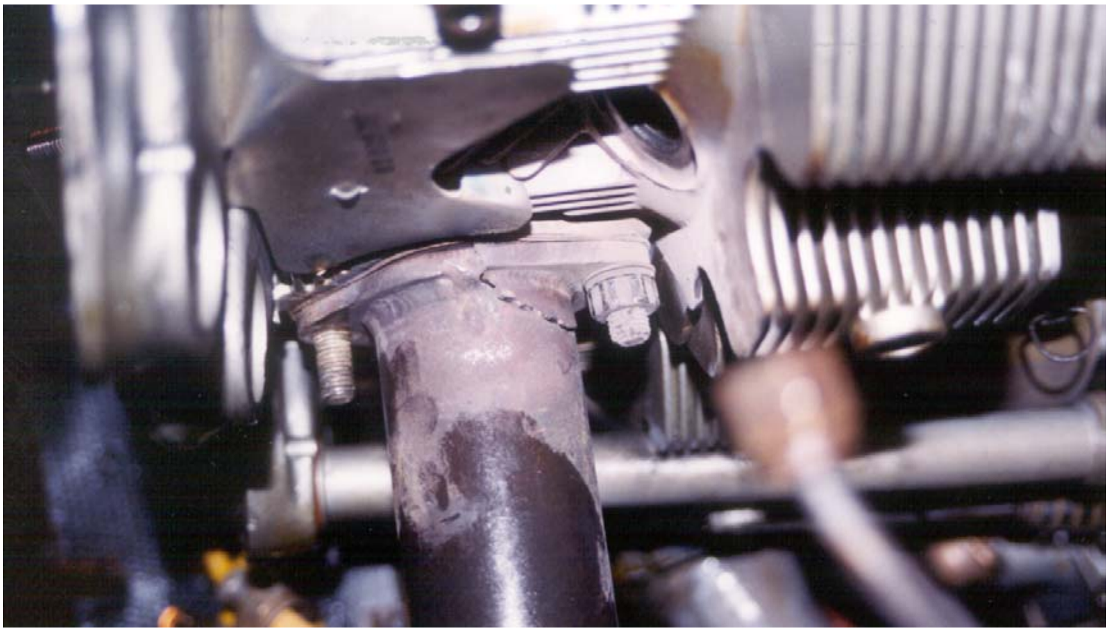
4.3 The UK CAA should consider a program to educate the general aviation maintenance industry and aircraft operators of the dangers of fitting used parts to aircraft without proper service records and airworthiness documentation. (**SR 15 of 2003**)

Appendix A



Failed Crankshaft
Fig. 1

Cracked Exhaust Stub
Fig. 2



Cracked Exhaust Stub
(as found on the engine – the missing nut was removed during the investigation)
Fig. 3

Bent Propeller
Fig. 4