VISUAL EXAMINATION OF A BROKEN ROCKER ARM

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Report No:	PHT/MET /08/10-2
Date:	August 2010
Client:	Fredrick Moreno
Item:	Engine rocker arm
Application:	Continental IO-550N, opposed 6 cylinder, 310 HP, light aircraft internal combustion engine.
Service Life:	Total time on the rocker arm was 90 hours at failure

1.0 INTRODUCTION

A broken rocker arm which broke in service was submitted for visual examination.

Metallographic sectioning was not permitted because the arm will be supplied to CASA and Continental Engines for a more detailed fracture investigation.

The following therefore can be regarded only as a preliminary to the main investigation and the preliminary conclusions require verification or otherwise by metallographic sectioning.

The following brief was supplied by Frederick Moreno:

Key questions:

- *Why did the rocker arm fail*
- *Are the remaining rocker arms on the engine trustworthy?*
- *How many defective rocker arms might there be in the fleet, and how can they be detected?*

This last question is one for CASA and the engine manufacturer.

2.0 VISUAL EXAMINATION

Figure 1 shows a general view of the broken rocker arm with the fracture position indicated by an arrow. The embossed casting identification was 628530 K ADI. The colour indicated that the rocker arm was electroplated with copper during manufacture.

Figure 2 shows the fracture surfaces on the detached rocker tip and main arm. The curved rocker tip surface was bright and free from copper. Original grinding scores from manufacture were evident on the rocker tip.

Figure 3 shows an oblique view of features evident on the main arm fracture surface. Arrow 1 indicates a dark area in an axial plane. Arrow 2 indicates smearing metal on the fracture surface. Arrow 3 indicates the main fracture surface. Arrow 4 indicates a shear lip.

Figure 4 shows the main arm fracture surface viewed inverted and in the axial direction. Arrow 1 indicates an axial groove along one side of a mould joint line. Arrow 2 indicates the region of smeared metal. Arrow 3 indicates a lightly tarnished area containing fatigue crack growth striations. Arrow 4 indicates the transition between lightly tarnished and brighter fracture surface. Arrow 5 indicates the shear lip. Arrow 6 indicates another axial groove along the other side of the mould joint line.

Figure 5 shows the underside or service tension side of the broken rocker arm. Arrow 1 and arrow 2 indicate the grooves to either side of the mould joint line. Arrow 3 indicates a flow lip associated with the area of smeared metal on the fracture surface.

Figure 6 shows the fracture surface on the detached piece of rocker tip. Arrow 1 indicates a set of gouges. Arrow 2 indicates an area of polishing on the fracture surface. Arrow 3 and arrow 4 indicate surfaces which correspond to extensions of the two grooves shown in figure 5.

Figure 7 shows gouges (arrow 1) and wear on the rocker tip surface (arrow 2).

Figure 8 shows polishing wear of the bearing bushes.

Figure 9 shows a close up view inside the push rod cup.

Figure 10 shows indentations (1) on the top surface of the push rod cup housing. Arrow 2 indicates an area of polishing wear on the outside surface of the cup housing.

Figure 11 shows a magnified view of part of the fracture surface on the detached piece of rocker arm tip. Arrow 1 indicates an origin of fatigue at a seam in the casting. Arrow 2 indicates multiple origins of fatigue on a second seam in the casting. This region appears to have been a secondary origin of fatigue. Arrow 3 indicates one of the more distinct fatigue crack arrest striations. Arrow 4 indicates fainter and more widely spaced fatigue crack arrest striations.

Figure 12 shows a magnified view of the multiple secondary origins of fatigue. Arrow 1 indicates a dark area of casting seam. Arrow 2, arrow 3 and arrow 4 indicate jogs which are a characteristic feature of multiple origin fatigue. The jogs are long thin triangular steps formed where fatigue cracks on slightly different planes approach each other and the ligament of metal breaks between the two fatigue cracks.

3.0 DISCUSSION & PRELIMINARY CONCLUSIONS

The rocker arm appears to have been manufactured as a precision shell moulded casting in spheroidal graphite cast iron, also known as ductile iron. Copper electroplating commonly is used as a stop-off to prevent surfaces from becoming carburized whilst bare surfaces such as the rocker tip are being carburized for improved wear resistance.

Two longitudinal seams or cold laps were accidentally formed during casting and these have acted as planar defects and initiation sites for fatigue crack growth in service.

Later metallographic sectioning should reveal oxidation and part penetration of the defects by the copper electroplating.

Further destructive examination will be required to determine whether or not the fault is likely to be widespread amongst rocker arms made during the same period.

Testing of the rocker arms for similar manufacturing defects is relatively quick and easy provided that the arms are not already installed in an engine. Magnetic particle testing would readily reveal similar defects and the equipment is portable and can be used in any workshop with a 240 V AC outlet.

In situ testing of rocker arms is not recommended.

Figure 1 General view of the broken rocker arm with the fracture position indicated by an arrow. The embossed casting identification is 628530 K ADI. The colour indicates that the rocker arm was electroplated with copper during manufacture.

Figure 2	Fracture surfaces on the detached rocker tip and main arm. The curved rocker tip surface is bright and free from copper. Original grinding scores from manufacture can be seen on the rocker tip

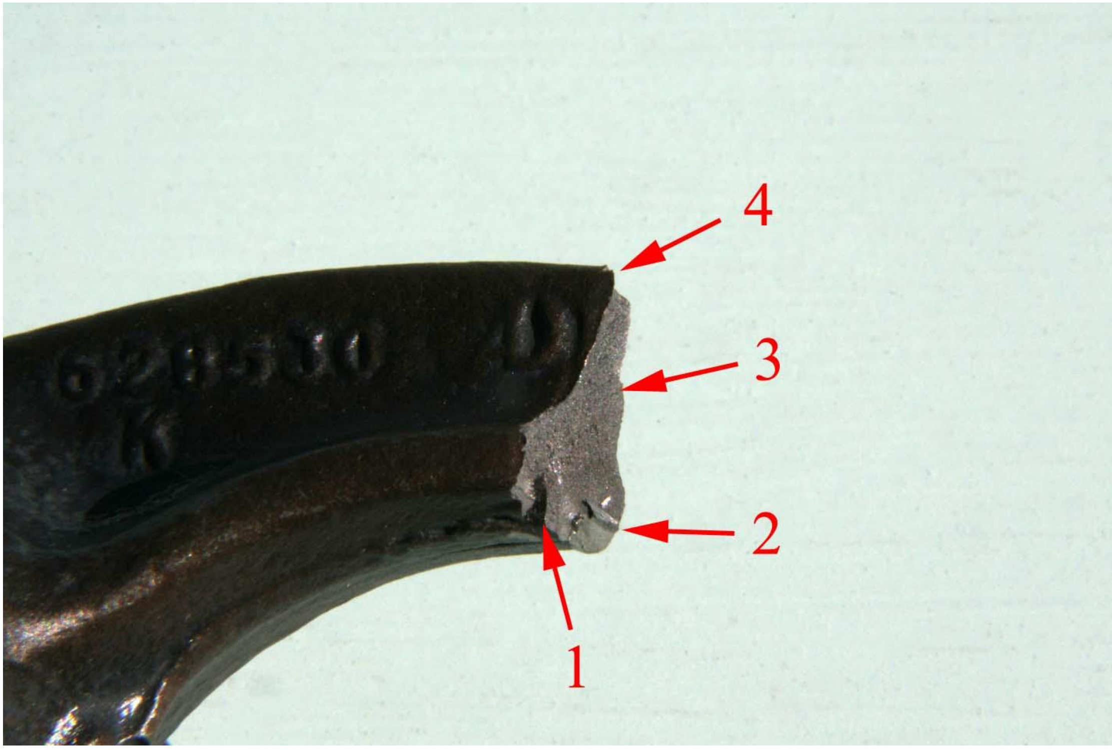

Figure 3 Oblique view of features evident on the main arm fracture surface. Arrow 1 indicates a dark area in an axial plane. Arrow 2 indicates smearing metal on the fracture surface. Arrow 3 indicates the main fracture surface. Arrow 4 indicates a shear lip.

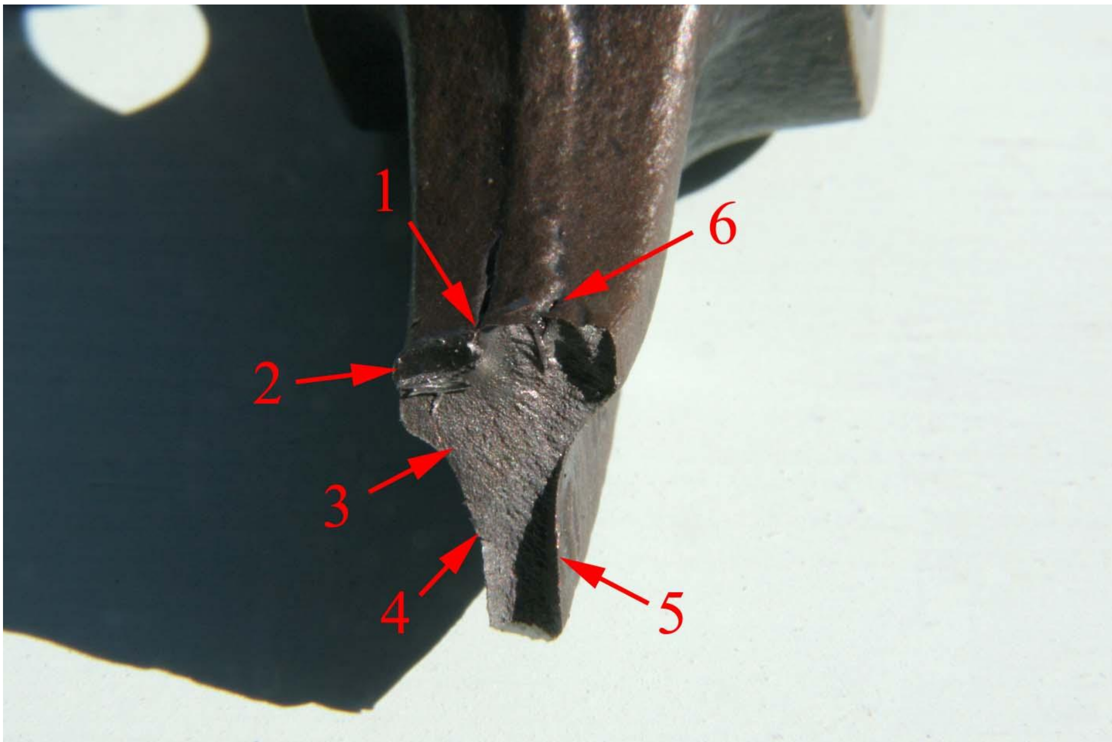

Figure 4 Main arm fracture surface viewed inverted and in the axial direction. Arrow 1 indicates an axial groove along one side of a mould joint line. Arrow 2 indicates the region of smeared metal. Arrow 3 indicates a lightly tarnished area containing fatigue crack growth striations. Arrow 4 indicates the transition between lightly tarnished and brighter fracture surface. Arrow 5 indicates the shear lip. Arrow 6 indicates another axial groove along the other side of the mould joint line.

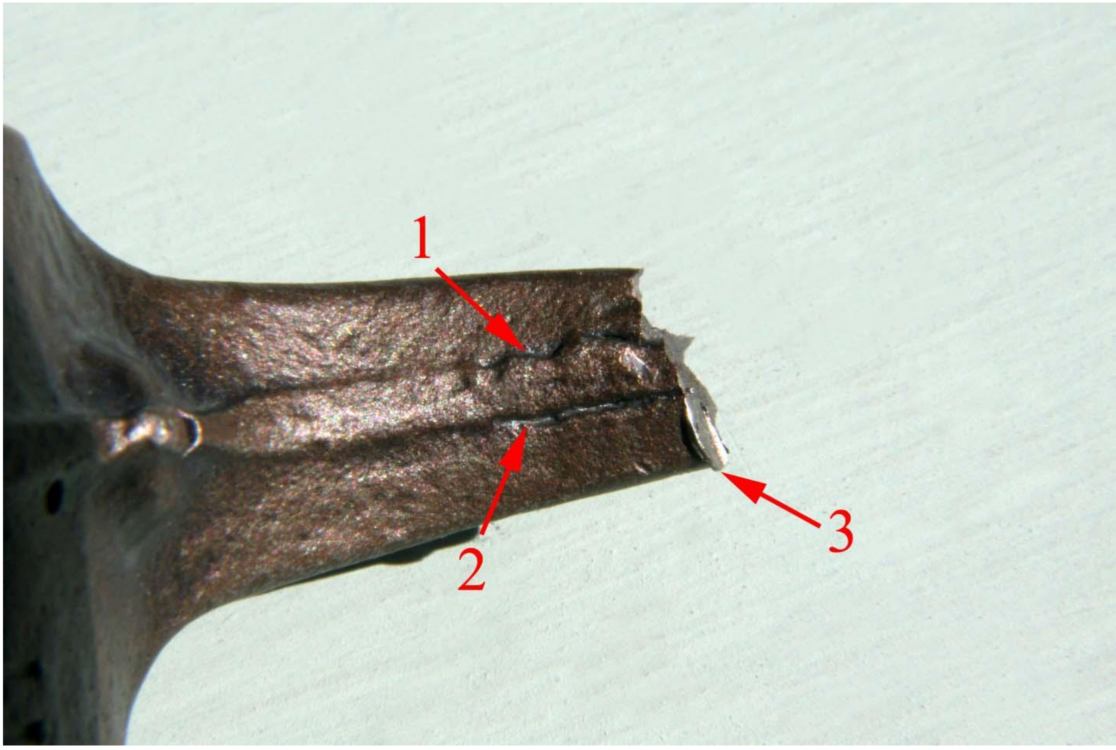

Figure 5 Underside of the broken rocker arm. Arrow 1 and arrow 2 indicate the grooves to either side of the mould joint line. Arrow 3 indicates a flow lip associated with the area of smeared metal on the fracture surface.

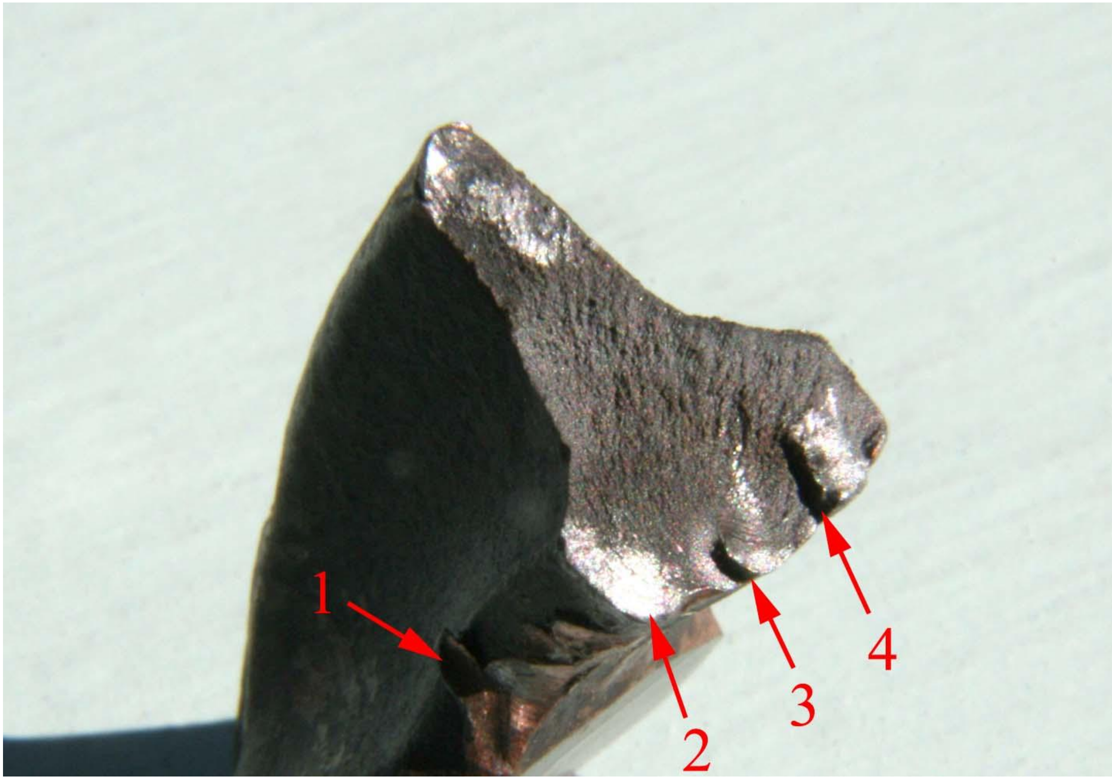

Figure 6 Fracture surface on the detached piece of rocker tip. Arrow 1 indicates a set of gouges. Arrow 2 indicates an area of polishing on the fracture surface. Arrow 3 and arrow 4 indicate surfaces which correspond to extensions of the two grooves shown in figure 5.

Figure 7 Gouges (arrow 1) and wear on the rocker tip surface (arrow 2).

Figure 8 Polishing wear of the bearing bushes.

Figure 9 Close up view inside the push rod cup.

Figure 10 Indentations (1) on the top surface of the push rod cup housing. Arrow 2 indicates an area of polishing wear on the outside surface of the cup housing.

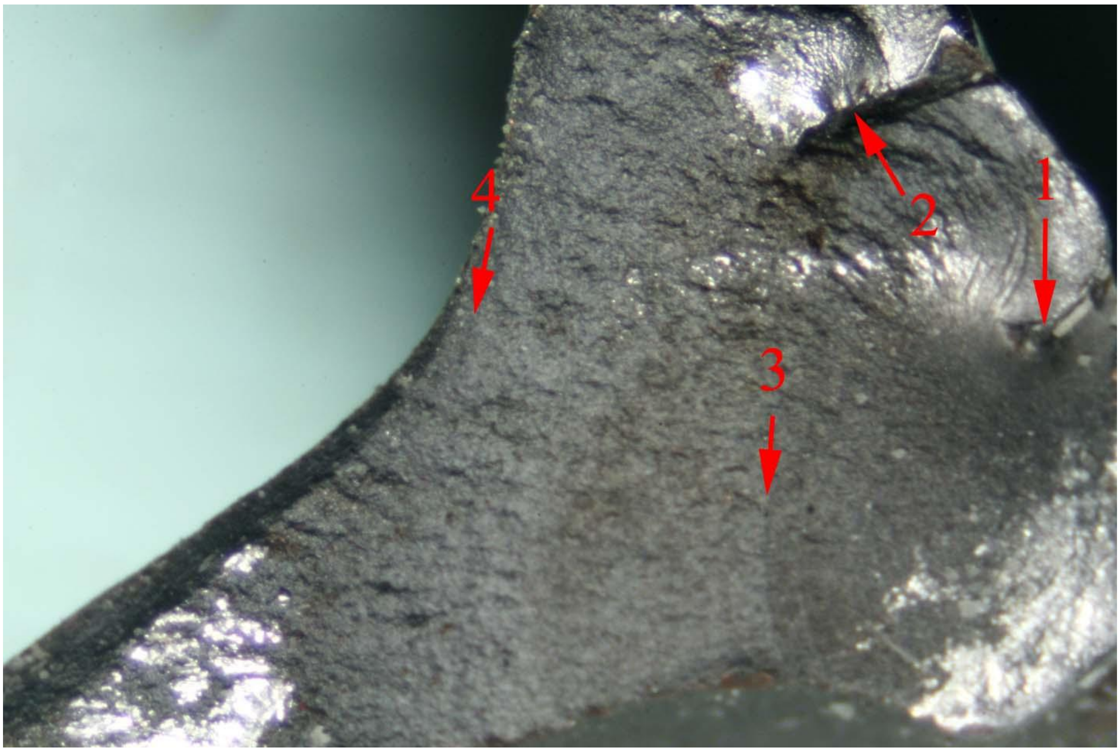

Figure 11 Magnified view of part of the fracture surface on the detached piece of rocker arm tip. Arrow 1 indicates an origin of fatigue at a seam in the casting. Arrow 2 indicates multiple origins of fatigue on a second seam in the casting. This region appears to have been a secondary origin of fatigue. Arrow 3 indicates one of the more distinct fatigue crack arrest striations. Arrow 4 indicates fainter and more widely spaced fatigue crack arrest striations.

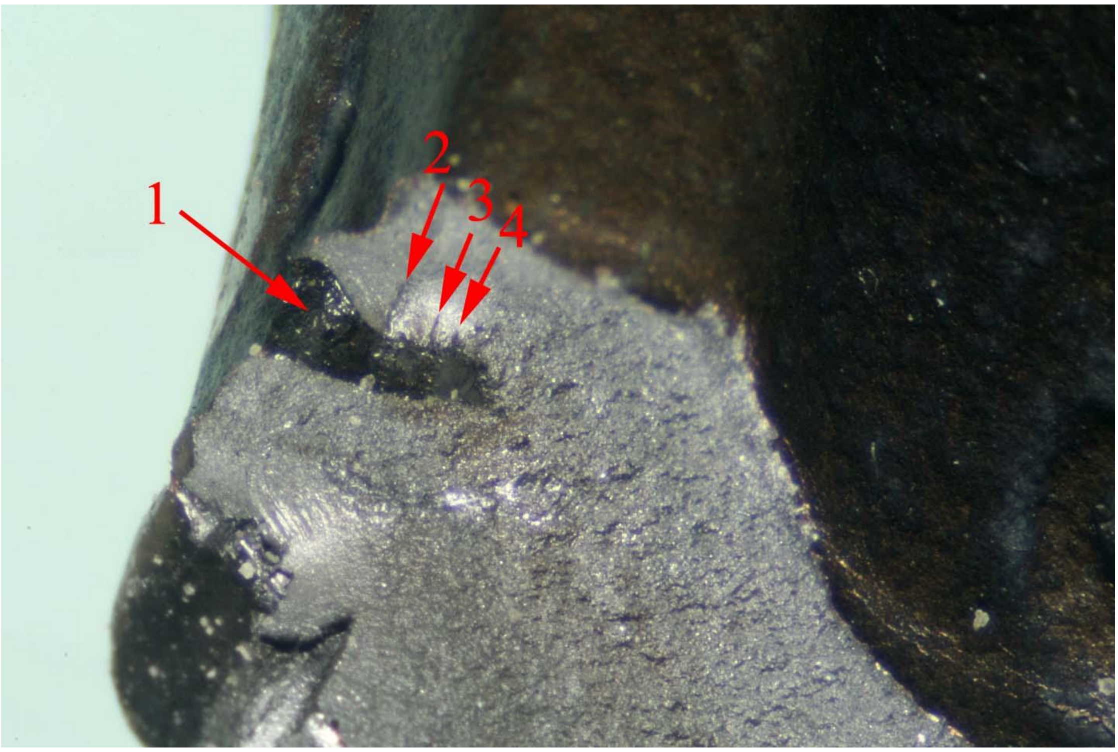

Figure 12 Magnified view of the multiple secondary origins of fatigue. Arrow 1 indicates a dark area of casting seam. Arrow 2, arrow 3 and arrow 4 indicate jogs which are a characteristic feature of multiple origin fatigue. The jogs are long thin triangular steps formed where fatigue cracks on slightly different planes approach each other and the ligament of metal breaks between the two fatigue cracks.