Parker

M & P

MATERIAL ANALYSIS REPORT

TO: Bob Heath cc: Distribution
FROM: Bob Cashman
DATE: November 18, 2002
SUBJECT: LR 207400

SUMMARY

A 747-400 lower rudder manifold suffered a complete break in the area of the retaining cap for the yaw damper modulating piston (mod) and sleeve assembly. An analysis of the fracture found that it was the result of multiple origin fatigue. The cracks initiated in the first full thread root radius without any physical defect or evidence of corrosion at that location. The primary crack propagated completely in fatigue from the ID thread root radius through the wall.

The manifold was the correct 7075 material and it had adequate mechanical properties. The conclusion was that the manifold had reached the end of its fatigue life at this thread root radius for the actual load spectrum that the part experienced during service. Another contributing factor may have been insufficient pre-torque at installation. This could not be confirmed since the manner of separation during failure precluded measuring the torque.

BACKGROUND

A portion of the 747-400 lower rudder manifold had broken completely off the main unit in the area of the retaining cap for the yaw damper modulating piston (mod) and sleeve assembly. The lock wire on the upper cap had a seal that did not have the Parker markings on it, indicating that this had been opened at some time in the past. The two seals are illustrated in Figure I.

The manifold is made from a 7075 T411 forging that had been heat treated to the T73 condition. A review of the 333200-1003 assembly traveler for the manifold (SN 137) found that it was of the -1 configuration (machined completely from a rectangular forged billet). The traveler showed that the heat treatment had been done at the forging blank level. For this manifold, good mechanical properties were obtained.

ANALYSIS

NDT

The manifold was penetrant inspected per ASTM E1417 and BMF 5203 using level 2 penetrant. No indications were found in the yaw damper cavity of the manifold. Also, there were no indications on the outside surface of this area. The threaded end that had broken off was also inspected. No indications were found in this piece.

Material Properties

The chemistry of the manifold met the requirements of AMS-A-22771 (Stork MMA certification PO 8111-51101-000/716). The hardness and conductivity were measured from a portion of the manifold in the vicinity of the fracture. The hardness was measured at 80.5 HRB, within requirements. The IACS conductivity was 39.6%, just below the minimum conductivity of 40.0%. A longitudinal tensile specimen was excised from the yaw damper cavity wall and a short transverse specimen was excised from another area of the forging. The longitudinal tensile was 69,300 PSI, with a yield strength of 60,100 PSI and an elongation of 8.0%. The short transverse tensile strength was 68,100, with yield strength of 61,100 PSI and an elongation of 7.0 % (Ref: Stork MMA certification 225454). As the thickness of the billet at the time of heat treatment was outside the ranges described in Table 4 of Mil-A-22771D, these values are for comparative information. The values show that good properties had been obtained by the heat treatment.

Fractography

An overall view of the fracture surface is illustrated in Figure 2. Examination of this surface on the Scanning Electron Microscope (SEM) identified three separate crack initiation sites. No mechanical damage or other part defect was visible at these sites. In particular, there was no evidence of corrosion cracking and no evidence of stress corrosion cracking. One of these three areas exhibited clamshell markings that are characteristic of fatigue (Figure 3).

Each of these crack sites had fatigue striations at a number of locations, including the origin. The examination identified that each crack initiation site was located along the first full thread root radius. The primary crack (the crack that extended from the inner wall of the yaw damper cavity to the outer surface) had propagated entirely across the wall in fatigue. The wall thickness at this location was .226 inches. A fatigue striation count estimated the number of cycles to failure as 7760.

After the crack had penetrated the wall, the remainder of the surface had dimple rupture features that are characteristic of overload.

Dimensional and visual inspection:

Several other components from the unit were dimensionally inspected or tested.

A mold was made of the threads on the yaw damper cavity. These were found to be J threads conforming to Mil-S-8879 B except for slight out of round condition. The thread root radius at the first full thread was measured at .006 - .008".

The threads on the cap conformed to J threads per Mil-S-8879B except for the thread root radius and deformation at some threads.

The cap had a witness mark from contact with the piston. This is illustrated in Figure 7 and Figure 8. The witness mark was up to .0005" deep, indicating that substantial contact had been made.

Other marks were present on the ID wall of the cavity. These were attributed to contact of the aluminum wall with steel parts during the final stages of the failure.

Metallography

A cross section was made through the fracture origin. No defects were identified at the origin in the cross section. The anodize thickness was measured at .000080" near the fracture origin. This indicates that Type I anodize had been applied as required by the drawing. Type I anodize has favorable fatigue characteristics compared to other anodize coatings.

CONCLUSIONS

1. The manifold was made of 7075, the drawing specified material.

2. Good mechanical properties had been obtained by the heat treatment.

3. The manifold had been made of the 241752B -1 configuration, a forged billet blank. Other manifolds in service may be made directly from 241752F forgings (-1 or -3 configuration) or may also have been made from a -1 forging blank. As the grain flow in the two forgings is different, some difference in fatigue properties may result. All configurations would be expected to meet the same design fatigue requirements for the manifold.

4. The fatigue cracks initiated in the first full thread root radius without any physical defect or evidence of corrosion at that location. The primary crack started from the ID thread root radius and propagated in fatigue completely through the wall.

5. At the thread root radius, the manifold had reached the end of its fatigue life for the actual load spectrum that the part experienced during service. Another contributing factor may have been insufficient torque at installation. This could not be confirmed since the manner of separation during the failure precluded measuring the torque.

Robert Cashman
Technical Support Engineer
Materials and Processes

Parker

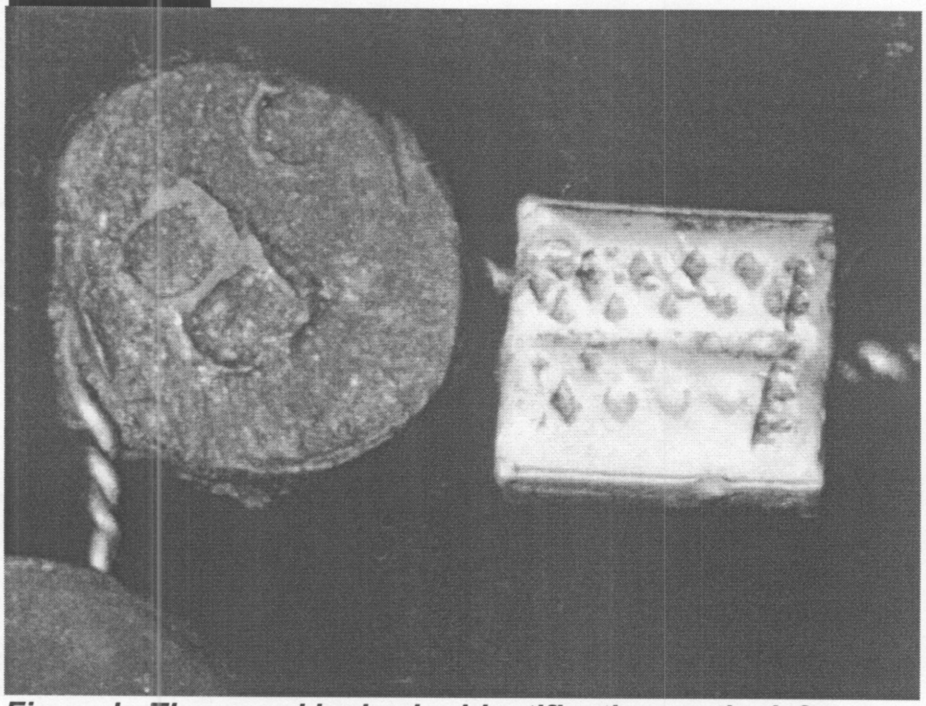

Figure I: The round lock wire identification on the left was connected to the broken end of the manifold. All other lock wires on the remainder of the manifold were rectangular as noted on the right side of the photo.

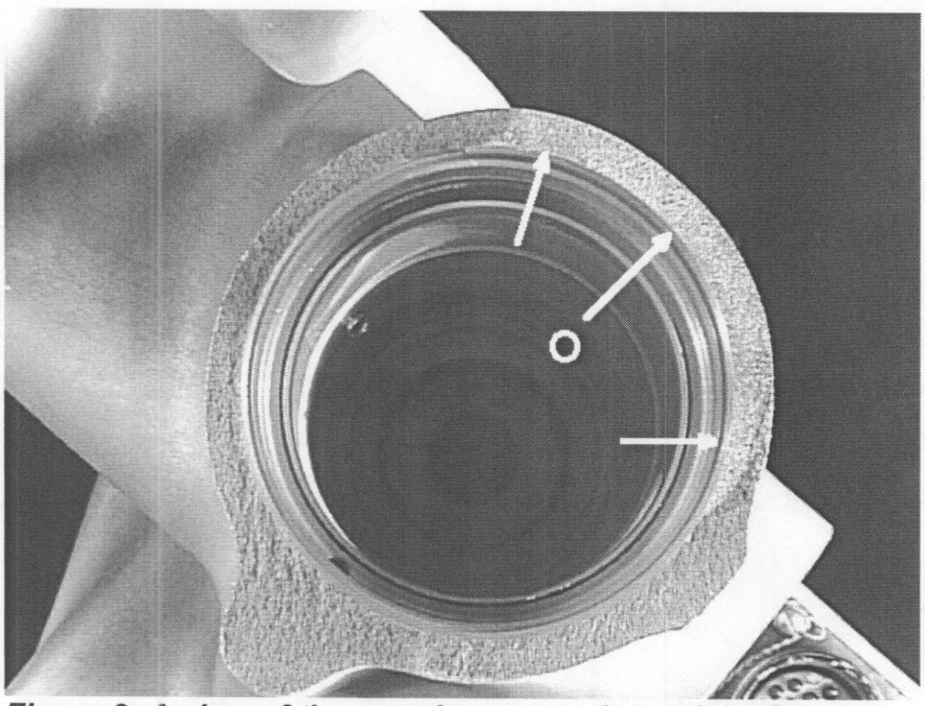

Figure 2: A view of the yaw damper cavity and the fracture surface of the broken end. The origin is located at O. The dull area outside of the arrows is the area of overload.