Failure Analysis of One Main Landing Gear (MLG) Sliding Tube of A320 Aircraft

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Abstract. Landing gear system is one of the critical systems of an aircraft and is configured along with the aircraft structure because of its substantial influence on the aircraft structural configuration itself. Landing gear and its attachments are one of the principal structural elements and are useful for aircraft during taxiing, take-off and landing. In this research, A MLG sliding tube from one airline operated A320 aircraft, was returned by user, after a crack indication was discovered at one end of the axle arm. The part had completed about 25,000 cycles since new and 8,000 cycles since overhaul. The mode of crack propagation was intergranular, the crack surface was heavily corroded. A region on the outer diameter encompassing the crack had been blended prior to the receipt. No specific initiation site could be found, it was suspected based on the shape of the crack that initiation occurred from the outer diameter. Deformation was observed on the unblended inner diameter, suggesting that this location suffered a significant impact which imparted residual stress into the component. The Barkhausen noise inspection results support this.

1. Introduction
Landing gear system is one of the critical systems of an aircraft and is configured along with the aircraft structure because of its substantial influence on the aircraft structural configuration itself [1]. Landing gear and its attachments are one of the principal structural elements and are useful for aircraft during taxiing, take-off and landing. Principal structural element’s failure results in catastrophic failure. The main failure mechanisms in landing gear are fatigue, corrosion-related problems and overload failures. Fatigue failure is brittle-like (relatively little plastic deformation) [2] —even in normally ductile materials and hence, it is sudden and catastrophic.

Catastrophic metal fatigue can lead to aircraft tearing apart in mid-flight. Estimation of fatigue life for the landing gear system is mandatory in order to certify the landing gear and frame the schedule for maintenance [3].

Many military transports use multiple wheel assemblies to distribute the load over a large footprint. These features allow the planes to be used on unimproved surfaces and still dispatch their loads[4]. The large C-5 cargo plane (the largest plane in the USAF) uses 24 main wheels supporting four struts, while also using a four wheel nose setup. The more recent C-17 uses fourteen wheels, distributed between two nose wheels, and twelve main wheels that support two main landing gear struts. The long serving C-130 (turboprop) uses two nose wheels, and four main wheels, with two main landing gear struts (Fig. 1) [5][6].
In this research, a MLG sliding tube from one airline operated A320 aircraft, was returned by user, after a crack indication was discovered at one end of the axle arm. The part had completed about 25,000 cycles since new and 8,000 cycles since overhaul.

Figure 1. Retracting landing gear used by commercial transport aircraft

2. Test and Examination

2.1 Initial Examination
Figure 2 shows the part in the as received condition. The part was observed to have a crack in the axial direction at one end of the axle arm. Figure 3 shows the location of the crack on the outer diameter, the crack extended into the first thread. The crack location has been blended on the OD and some material has been removed. Figure 4 shows the location of the crack on the inner diameter, the crack has gone through the entire wall section but it does not extend as far on the inner diameter. Figure 5 shows the part number and serial number.

2.2. Dimensional Inspection
A CMM scan of the outer and inner diameter was performed with intervals of 1 degree (Table 1). The crack location can be found at 110°. The maximum inwards deformation observed was 0.444mm and 0.213mm, on the outer and inner diameter respectively (Figure 5). The deformation was also recorded at 110° at the same location as the crack. The outer diameter was blended in this region but the inner diameter was not.

Table 1. Results if the CMM scan of the inner and outer diameter

| Dimension      | Drawing requirement | Measured Value | Unit |
|----------------|---------------------|----------------|------|
| Outer Diameter | 111.8-112.0         | 111.75         | mm   |
| Inner Diameter | 105.572-105.625     | 105.625        | mm   |

For the OD and ID of the wheel axle-φ112; φ105.5; perform a CMM measurement at least every 1 degree around the face
2.3. NDT Inspection
The part was sent to NDT for acid etch inspection, magnetic particle inspection and Barkhausen noise inspection. The acid etch inspection revealed no indications. The magnetic particle inspection confirmed the location and length of the crack. The Barkhausen noise inspection showed high readings of up to 330mp compared to the base reading of 35mp and 45mp. The NDT report can be found in NDT report.

![Figure 2. Overview of the sliding tube as received](image)

2.4. Fractography
The crack had propagated to the first thread on the axle arm with a length of approximately 11mm (Figure 6). The crack surface was heavily corroded. The shape of the crack suggests that it had initiated from the outer diameter of the axle. No initiation region could be confirmed, possibly due to the removal of material from the outer diameter.

The crack surface was examined in the scanning electron microscope. The mode of crack propagation was found to be intergranular across the whole surface. The surface was also heavily corroded which can be seen in Figure 7.
2.5. Material Examination

2.5.1. Hardness Three Brinell hardness indentations were performed on the part utilising a 1mm ball indenter and a 30kg load. The average hardness result was 569HB30 this conforms to the specification requirement of 555≤HB≤590 for 300M in the fully heat treated condition.

![CMM scan of the inner diameter and outer diameter](image1)

*Figure 5. CMM scan of the inner diameter and outer diameter*

![Overview of the crack surface](image2)

*Figure 6. Overview of the crack surface*

![Electron microscope image of the fracture surface](image3)

*Figure 7. Electron microscope image of the fracture surface*
Table 2. Brinell hardness results

| Test     | 1   | 2   | 3   | average | Specification MTL |
|----------|-----|-----|-----|---------|------------------|
| Brinell Hardness | 569 | 573 | 564 | 569     | 555≤HB≤590       |

2.5.2. Microstructure A microsection was taken, progressively polished and acid etched using a 2% nital solution. The microstructure consisted of tempered martensite (Figure 7). This is typical of 300M in the fully heat treated condition.

![Image of microstructure](image)

Figure 8. Microstructure consisting of tempered martensite

3. Conclusion
- The mode of crack propagation was intergranular, the crack surface was heavily corroded.
- A region on the outer diameter encompassing the crack had been blended prior to the receipt.
- No specific initiation site could be found, it was suspected based on the shape of the crack that initiation occurred from the outer diameter.
- Deformation was observed on the unblended inner diameter, suggesting that this location suffered a significant impact which imparted residual stress into the component. The Barkhausen noise inspection results would further support this.
- The hardness results conform to the specification requirements of MTL-1201.
- The microstructure is typical of 300M in the fully heat treated condition.

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