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Defect Investigation as a Tool for Quality Improvement

B. Gurumurthy, Y.N. Nagaraja, C.N. Nagesh, and G.S. Ravindra
Aeronautical Development Establishment, Bangalore – 560 075

ABSTRACT

Defect investigation is an important tool for quality improvement as it identifies the root cause of errors and steps to be taken to eliminate these. In this paper, four cases of defect investigation are presented. The case studies cover link elevator, wing-fuselage attachment bolt, and stiff nut for *Lakshya* unmanned aerial vehicle. It was observed that the link elevator was discolourised even though the material used was the stainless steel. Investigations revealed that the stainless steel was heat-treated. In the case of leading edge, it was found that there was no provision for the location of a component in the tool, resulting in mismatch. Thread damage was noticed in wing-fuselage attachment bolts because of over tightening. All these studies resulted in improvement in the raw material bonding, inspection procedures, and fabrication methods, thus resulting in quality improvement.

Keywords: Defect investigation, quality improvement, unmanned aerial vehicle, link elevator, wing-fuselage attachment bolt, stiff nut, failure analysis, inspection, fabrication

1. INTRODUCTION

The unmanned arial vehicle (UAV) *Lakshya* designed and developed by Aeronautical Development Establishment, Bangalore, has been inducted into the Indian Air Force after extensive user trials. After the development phase was over, ADE was responsible for making five aircraft under limited series production. For the mission of an unmanned aircraft to be successful, quality components are to be used as there is no human interface onboard to correct any malfunction. This was a new task for an R&D organisation to adopt a production-oriented approach. During the limited series production, a large number of problems were encountered, from the usage of raw materials to the assembly of aircraft, as there was no set of guidelines to follow. This resulted in some defects occurring during manufacture/assembly. This paper presents the four case studies at ADE to find how and why the defects occurred and the remedial action taken for their prevention. This failure analysis has helped the system to adopt new procedures in inspection and fabrication, that led to the improvement of product quality.

1.1 Case Studies

1.1.1 *Case study on Blackening of Stainless Steel Components*

As the limited series production was under progress to manufacture *Lakshya* unmanned aerial vehicle, some vendors were identified to manufacture the components. The link elevator (Fig. 1) was the one among many to have blackened. The raw material for the component used was stainless steel 6S-80 having a diameter of 38 mm and a bonding Qno. of 108B.The hardness recorded at the time of bonding was HRC 28-29. A sample of the raw material, which had a shiny appearance was cut

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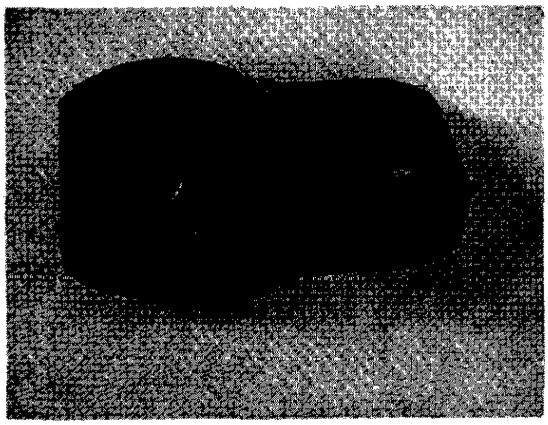
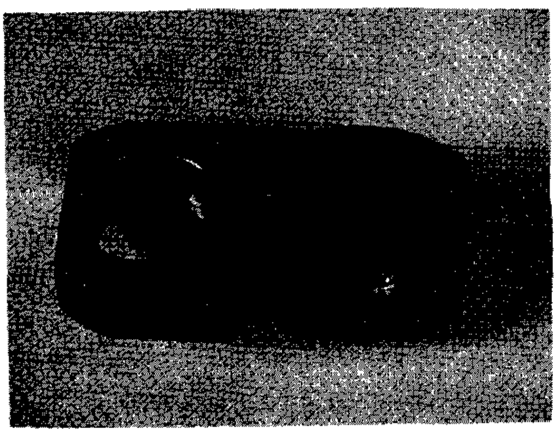


(a)



(b)

Figure 1. (a) Blackened link elevator and (b) link elevator

and immersed in plating baths with different etching solutions. It was found that there was no reaction in the material. This sample was subjected to heat treatment at HT shop, where it was observed that the colour of the raw material had changed to black, which resembled the one on the component. Hardness for the sample was checked, and it was found that the hardness has increased to HRC 39-40. This clearly establishes that the vendor had resorted to heat treatment. As the final observation, the material was subjected to microscopic examination. It was found that the grain structure had changed from 5-6 ASTM on the bar stock to 7-8 ASTM on the component, and was also indicating higher hardness value. Based on this study, the vendor was advised not to heat-treat the stainless steel. It was also suggested to incorporate the material condition on drawings. Subsequently, the next batch of components did not show any discolourisation.

1.1.2 *Case Study on Wing Profile Mismatch*

The *Lakshya* had a sweptback symmetric airfoil wing of 3 m span. The smooth profile of this wing is one of the parameters that affect the aerodynamic characteristics. A mismatch at the leading edge interface of wing profile was noticed in the wings fabricated at the ADE. The mismatch was found to be uniform throughout the length of the leading edge. The leading edge is shown in Fig. 2. The leading edge is made up of polyurethane foam and glass fiber-reinforced composites, with metallic channel embedded for fastening the leading edge to the wing structure. On visual examination it was suspected that the metallic channel was opening out during riveting, leading to mismatch. Staff of the assembly team, who was fabricating the wing, supported this view. They had also found it difficult to insert the leading edge before riveting, and it was possible that the channel was opening out at the time of insertion. To verify this, measurements of thickness at 20 per cent chord (leading edge interface) were carried out on the leading edge (before assembly) and assembled onto the wing, separately. The readings are tabulated (Table 1). As observed from measurements, the thickness at 20 per cent chord had increased by 2 mm as compared to non-assembled leading edges. This may be due to either opening out of metallic channel in the leading edge, or additional thickness due to painting, or due to sealing compound.

An increase of about 0.5 mm is attributed to the thickness of painting and sealing compound. For further investigation, the mould for the fabrication

Table 1. Reading before correction

Distance from root (mm)	Thickness after assembly (mm)		Thickness before assembly (mm)
	LE1	LE2	
200	79.00	79.50	75.3
400	70.00	70.50	68.10
600	60.60	61.26	59.00
800	54.24	53.50	51.30
1000	43.94	42.96	43.10
1200	36.00	34.70	33.60
1385	26.60	27.00	26.40

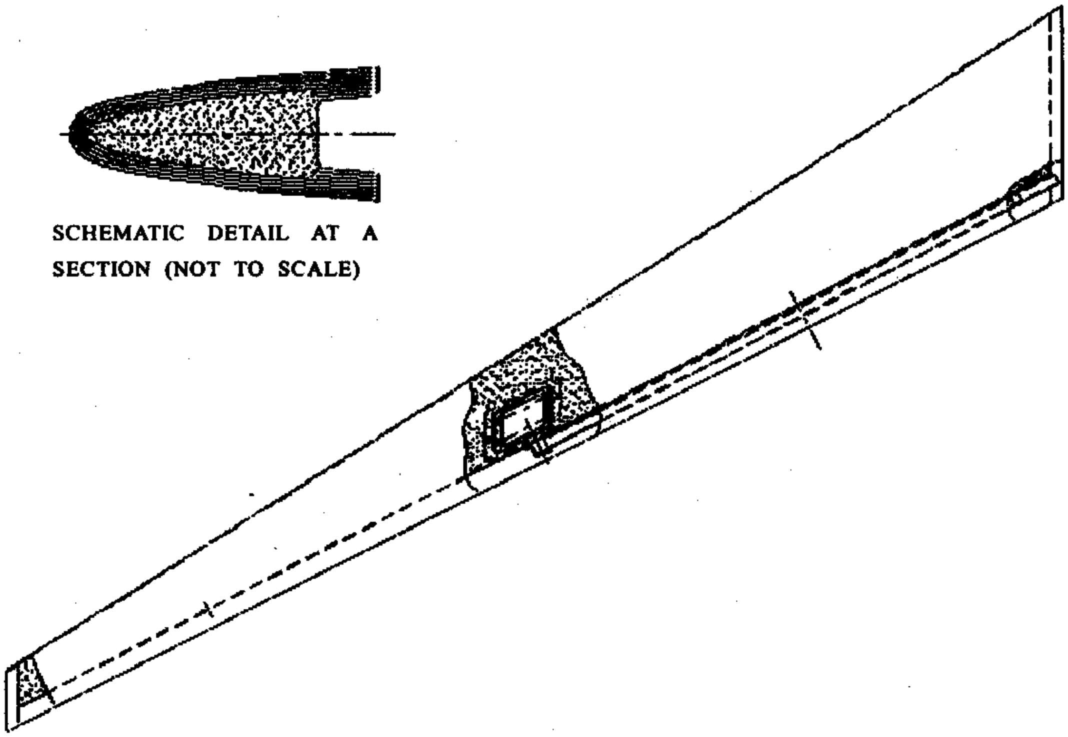


Figure 2(a). Leading edge interface of wing profile

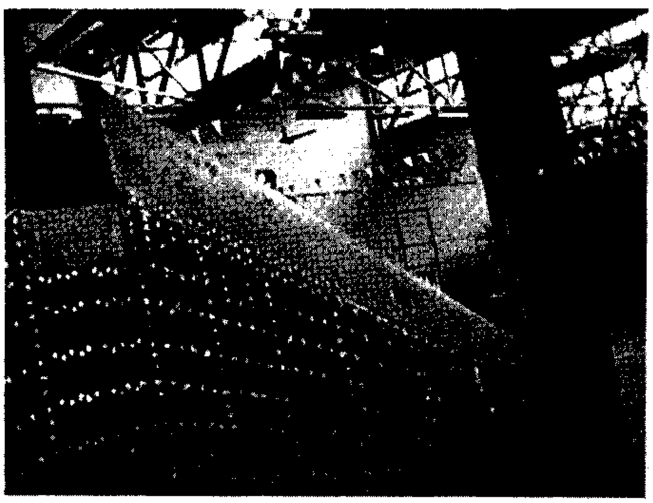


Figure 2(b). Wing leading edge during assembly

of the leading edge was inspected and it was found that there was no locator in the mould for locating the metallic channel. These metallic channels are fabricated with extra length to cater for trimming during assembly, and also the channel has a compound taper. Because of these reasons, improper trimming can lead to decrease in thickness of channels, creating problems during assembly. The mould was then corrected by giving a locator for the channel. The next wing was subsequently fabricated and thickness measurements showed no mismatch at the leading edge. The readings are given in Table 2. It was also found that some local undulations during fabrication (riveting) cannot be eliminated but can be corrected during putty and painting work. It was suggested that the putty work and subsequent emerying be carried out along the wing profile to get smooth wing contour.

Table 2. Reading after correction

Distance from root (mm)	Thickness after assembly (mm)		Thickness before assembly (mm)
	LE1	LE2	
200	75.50	75.00	75.3
400	69.00	67.50	68.10
600	59.54	58.84	59.00
800	51.40	51.78	51.30
1000	42.82	42.00	43.10
1200	33.60	33.90	33.60
1385	25.70	25.90	26.40

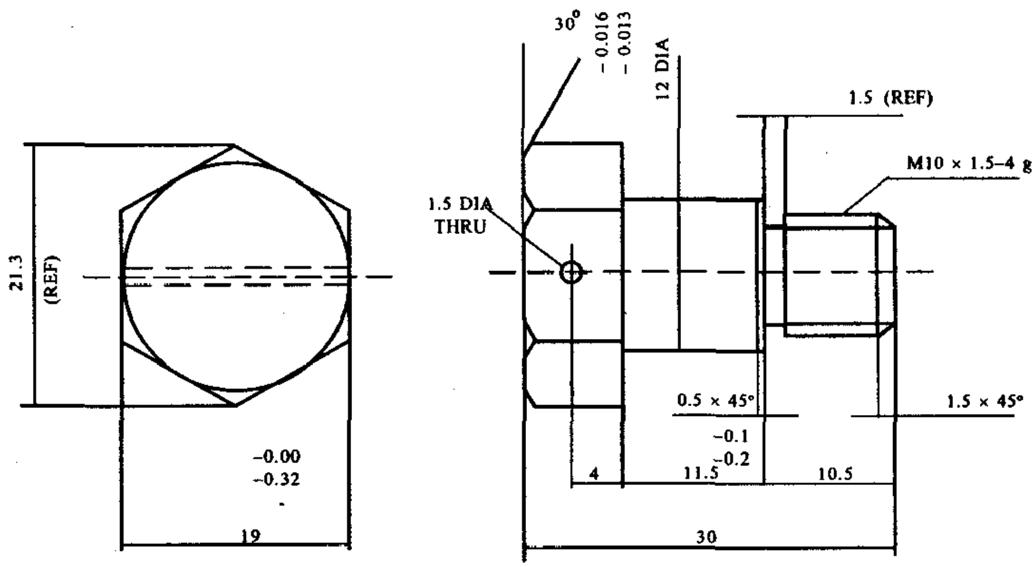


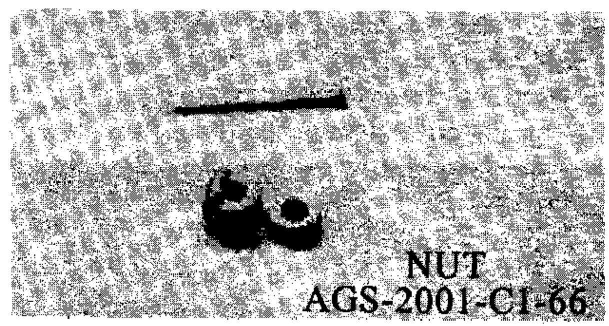
Figure 3. Wing-fuselage attachment bolt

1.1.3 *Case Study on Wing-Fuselage Attachment Bolt*

The wing fuselage attachment bolt is a critical component on the UAV *Lakshya*. On investigation, it was found that some bolts were defective, and the threads were damaged on all the bolts. Also, the visual examination of the bolts and the attachment bracket revealed that the helicoil insert was wrongly installed by insufficient drill depth, leading to the damage on the threads. The bolt heads revealed extensive marks of deformed shape at the head portions. This was attributed to improper torquing of the bolts. The bolt is shown in Fig. 3. After process, specification for the installation of helicoil inserts was specified in the drawings. As a result of this study the thread damage in subsequent assemblies was reduced.

1.1.4 *Case Study on Failure of Stiff Nut*

The unmanned aircraft *Lakshya* uses some of the aircraft general stores which are available on catalogue numbers. The stiff nut connects the tail plane to the rear fuselage and is critical one from the flight point of view. The part was AGS-2001-C1-66 as shown in Fig. 4 and was found defective. On visual observations it was found that the item used did not have the marketing of the manufacturer, and the nut had failed due to overtorquing as can be observed seeing the damages at the ends of the nut.



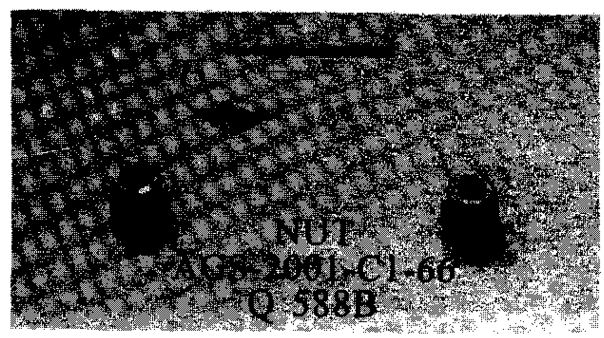


Figure 4. Stiff nut connecting the tail plane to the rear fuselage.

2. CONCLUSIONS

Based on the study, the following corrective measures in the system for quality improvement has been taken

- Material condition was specified on the drawings.

- Bonding procedure was modified and implemented.
- Calibration of instruments and gages was undertaken.
- Interchangeability and traceability criteria were established.
- Storage and handling conditions with protective treatment were implemented.
- Fabrication methods were improved.
- Stage inspection was introduced.
- Design improvement was introduced.

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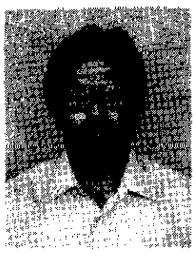
Contributors



Mr G Gurumurthy obtained his diploma in Metallurgy and is working as Technical Officer B at the Aeronautical Development Establishment (ADE), Bangalore. He has been engaged in the field of x-ray radiography of castings, and weldments of unmanned aircraft since 1977.

Mr YN Nagaraja obtained his dioploma (Mech Engg) and is working as Technical Officer C at the ADE, Bangalore. He has been engaged in the field of quality assurance of mechanical components for airborne applications since 1973. His field of specialisation includes: Process and procedures standardisation, metrology, quality assurance and management. He has published two technical papers in the areas of quality improvement.