Treatment for gap and step nonconformity of slat on tail-hang civil aircraft

Weibin Zhu1a, Suxiao Wang1b, Jian Lan1c

1Production Support Engineering Department, Shanghai Aircraft Design and Research Institute, Shanghai, 200436, China
aemail: zhuweibin@comac.cc, bemail: wangsuxiao@comac.cc, cemail: lanjian@comac.cc

Abstract. Slat aerodynamic contour nonconformity often occurs during the manufacture of civil aircraft, which can cause appearance influence, drag increase and even manoeuvrability & stability problem. This article introduces 4 types of gaps and 3 types of step nonconformity and reason for them. Then the article studies treatment principle for wing slat contour nonconformity. In the end, the article figures out acceptable criteria and 5 types of standard repair methods for slat gap and step nonconformity.

1. Introduction
Normally there are 6 slats on the front of the wing leading for tail-hang civil aircraft, which increases aerodynamic lift during the take-off and landing flight period together with flaps. Aluminium slats are consisted of skin, front spar, rib, angle and trailing edge. Slats gap and step are influenced by part fabrication and assembly, during which tolerances of slat, leading-edge, slide and drive mechanism accumulate [1]. If part tolerance distribution is not planned in design engineering or assembly engineering, the nonconformity is more prone to happen [2].

Slats gap and step nonconformity may cause appearance influence, drag increase and even manoeuvrability & stability problem [3]. Low work efficiency or even technique risk may occur when engineers cope with this problem, especially when they lack experience and standard treatment criteria. Therefore, proper repair is necessary and crucial.

The purpose of the article is to study standard treatment methods and procedures for slat nonconformity and decrease technology risk.

2. Treatment principle

2.1 Position of slat nonconformity
The gap and step of slats can be summarized as 4 types of gap and 3 types of step as follows:
- Gap between slat and wing root or wing tip fairing, signed as $\Delta_1$, according to figure 1;
- Gap between slat and slat, signed as $\Delta_2$, according to figure 1;
- Gap between slat and fixed leading-edge, signed as $\Delta_3$, according to figure 2;
- Gap between slat lower boundary and fixed leading-edge, signed as $\Delta_4$, according to figure 2;
- Step of slat and wing root fairing or wing tip fairing, signed as $\Delta_5$, according to figure 1;
- Step of slat and slat, signed as $\Delta_6$, according to figure 1;
- Step of slat lower boundary and fixed leading-edge, signed as $\Delta_7$, according to figure 2;
2.2 Treatment principle

The following principles should be complied when coping with gap and step nonconformity:

- Gap and step should be restored to the drawing requirements as far as possible to avoid clash between slats or between slat and fixed structure, harmful influence on flight control system or other assembly problems.

- Slat contour, gap, step and gap at lowest position should be assessed as a whole to estimate the influence on aircraft aerodynamics, property, manoeuvrability and stability.

- Shape correction on aluminum structure at room temperature should be used only once and fluorescence infiltration inspection or other non-destruction inspection should be done before and after shape correction [4].

- Treatment method should not influence interchangeability of slat.
3. Treatment method

3.1 Determinant criteria for methods

The nonconformity is acceptable if the maximum and minimum gap or step is during the limits in table 1. If the nonconformity exceeds the limits, the slat should be repaired or reworked according to table 1, in which 5 repair methods fit for different kind of nonconformity.

Table 1 Acceptable, repair or rework criteria for slat gap and step nonconformity (unit: mm)

| Nonconformity item | Should be | Acceptable when | Repair according to 3.X | Rework |
|--------------------|-----------|----------------|--------------------------|--------|
| Δ₁                 | Δ₁min ~ Δ₁max | Δ₁min−1.5 ~ Δ₁max+0.5 | ✓ | ✓ | ✓ | ✓ |
| Δ₂                 | Δ₂min ~ Δ₂max | Δ₂min−1 ~ Δ₂max+0.5 | ✓ | ✓ | ✓ | ✓ |
| Δ₃                 | Δ₃min ~ Δ₃max | Δ₃min−1.5 ~ Δ₃max+0.5 | ✓ | ✓ | ✓ | ✓ |
| Δ₄                 | Δ₄min ~ Δ₄max | Δ₄min−Δ₄max+1 | ✓ | ✓ | ✓ | ✓ |
| Δ₅                 | ±Δ₅       | ±(Δ₅+1.5)           | ✓ | ✓ | ✓ | ✓ |
| Δ₆                 | ±Δ₆       | ±(Δ₆+1.5)           | ✓ | ✓ | ✓ | ✓ |
| Δ₆                 | ±Δ₆       | ±(Δ₆+1)            | ✓ | ✓ | ✓ | ✓ |

3.2 Trim and file method

3.2.1 Suitable circumstance

The trim or file method is suitable for the following circumstances:
- Gap between slat and wing root fairing or wing tip fairing is too small owing to the fact that slat is longer than required.
- Gap between slat and slat is too small owing to the fact that slat is longer than required.
- Gap between lower boundary and fixed leading-edge is too small.

3.2.2 Operation procedure

Trim or file the superfluous material on both ends and lower boundary of slat and restore the gap to the design requirements. The surface roughness should be smoother than Ra3.2 and anodize the trimmed or filed area and cover primer and topcoat.

3.3 Shape correction method

3.3.1 Suitable circumstance

Gap between slat trailing edge and fixed leading-edge skin is unqualified and the nonconformity is caused by slat contour deviation. The slat trailing edge is made of 2024 aluminum and nonconformity is 3 millimeters at the most more than the limits in table 1.

3.3.2 Operation procedure

Operation procedure of shape correction method is as follows:
- Straighten the slat trailing edge at room temperature to restore the contour to the required position and make the gap between slat trailing edge and fixed leading-edge skin right.
- Remove the paint on the shape correction area. Check whether crack exists using fluorescence infiltration or eddy current inspection. If crack does not exist, anodize the unprimed area and refurnish this area.
- If crevice occurs on the edge of the fastener countersink head, remove the fastener and check the hole quality using detailed visual inspection. Check the material around the fastener using eddy current inspection [4]. If the condition is qualified, reinstall the fastener.
3.4 Filler method

3.4.1 Suitable circumstance
If the inverse step of the slat lower boundary and fixed leading-edge exceeds the limits in diagram 1 and the nonconformity is caused by slat contour deviation, the method could be used. But the step should not be 2 mm more than the limits in diagram 1.

3.4.2 Operation procedure
Operation procedure of filler installation method is as follows:
- Drill the fasteners connecting slat outer skin and angle.
- Make fillers using 2000 or 7000 serial aluminum and trim or file it to the required thickness and length. The width should be the same with the angle. Anodize the filler and furnish it with primer. If the thickness of the filler is not even or the filler length is too short, fluid filler made of resin should is appropriate[6].
- Put the filler between outer skin and angle and reinstall the fasteners with appropriate length.

3.5 Sliding rail reinstall method

3.5.1 Suitable circumstance
Sliding rail replace method is suitable for the following circumstances:
- When gap between slat trailing edge and fixed leading-edge skin is unqualified and the nonconformity is caused by misplacement of sliding rail and slat. Besides, the relative position of sliding rail and slat can't be adjusted.
- When step of slat and wing root fairing or wing tip fairing is unqualified and the nonconformity is caused by misplacement of sliding rail and slat. Besides, the relative position of sliding rail and slat can't be adjusted.
- When step of slat and slat is unqualified and the nonconformity is caused by misplacement of sliding rail and slat. Besides, the relative position of sliding rail and slat can't be adjusted.
- When step of slat lower boundary and fixed leading-edge is unqualified and the nonconformity is caused by misplacement of sliding rail and slat. Besides, the relative position of sliding rail and slat can't be adjusted.

3.5.2 Operation procedure
Operation procedure of sliding rail reinstall method is as follows:
- Dismantle bolts and nuts connecting slat and sliding rail.
- Manufacture new sliding rails without pilot holes of one slat assembly.
- Relocate the new sliding rails and slat to make the relative position is qualified and drill the sliding rail from the existing hole on the flange of the slat stiffening rib.
- Reinstall the bolts and nuts connecting slat and sliding rails.

3.6 Rib assembly relocate method

3.6.1 Suitable circumstance
When gap between the slat and wing root fairing or wing tip fairing is too big and the nonconformity is caused by displacement of rib assembly of fixed leading-edge.

3.6.2 Operation procedure
The rib assembly relocate method is suitable for the following circumstance:
- Drill fasteners connecting wing front spar, rib and fixed leading-edge skin.
- Remove rib assembly and wing root or wing tip fairing skin.
- Manufacture special rib assembly and special skin, and the two uniquely made parts should be widened on the same side while other manufacture information is the same with the original part.
- Relocate the special rib assembly and special skin.
- Drill holes and install fasteners according to the drawing.

3.7 Rework method

3.7.1 Suitable circumstance
The rework method is suitable for the following circumstance:
- Gap between the wing root fairing or wing tip fairing is too big and exceeds the limits in diagram 1 and the nonconformity is caused by the fact that slat is shorter than required.
- Gap between slats is too big and the nonconformity is caused by slat short dimension.
- Gap between slat trailing edge and fixed leading-edge is caused by slat contour deviation and the deviation is 3mm more than the limits in diagram 1.
- Crack occurs when forming slat trailing edge at room temperature.
- Gap between slat lower boundary and fixed leading-edge is too big.
- Step of slat and wing root fairing or wing tip fairing is too big and the nonconformity is caused by slat contour deviation.
- Step between slats is too big and is caused by slat contour deviation.
- Downstream step of slat lower boundary and fixed leading-edge is too big, or upstream step is 2mm more than the limits in diagram 1, and the nonconformity is caused by slat contour deviation.

3.7.2 Operation procedure
The rework method is suitable for the following circumstance:
- Dismantle the slat with contour deviation or short dimension and protect the aircraft meanwhile from foreign object damage.
- Manufacture a new slat according to the drawing.
- Reinstall the new slat according to the drawing.

4. Conclusion
This article firstly introduces slat structure, neighboring structure and main reason for contour nonconformity. Then the article classifies and illustrates gap and step nonconformity of slats of tail-hang aircraft. In the end, the article figures out acceptable, repair and rework criteria and treatment procedures for 7 types of gap and step nonconformities based on principle analysis, aerodynamic evaluation and engineer practice.

These treatment methods of the article can guide nonconformity treatment on aircraft production, increase work efficiency and decrease technology risk. Besides, the research thinking can also be used on flap, aileron, spoiler, rudder and elevator of civil aircraft. Furthermore, structure part and assembly tolerance distribution should be planned and used to avoid contour nonconformity.

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