Automatized alignment control of wing mechanization in aerodynamic contour of aircraft

K A Odnokurtsev

Irkutsk National Research Technical University, 83, Lermontova St., Irkutsk, 664074, Russia

E-mail: kodn82@gmail.com

Abstract. The method of automatized control of accuracy of an aircraft aerodynamic contour when mounting wing mechanization elements is described in the article. A control device in the stand of the wing assembling, equipped with the distance sensors, is suggested to be used. The measurement of control points’ inaccuracies is made automatically in a special computer program. Two kinds of sensor calibration are made in advance in order to increase the accuracy of measurements. As a result, the duration of control and adjustment of mechanization elements is reduced.

1. Introduction
When mounting an aircraft wing, the adjustment of wing mechanization elements is demanded so that they fit with the aerodynamic contour of an aircraft. Usually the control is made by equidistant templates. The templates are made according to the planned section of the wing. The templates have the contour equidistant to the aerodynamic contour of a wing in a given plane. The template is set on a wing box in a manual way either on a special control device or assembly jig. The control is made by manual measuring instruments, for example, a measuring probe. The adjustment of mechanization elements is also made manually. That is why the whole process of controlling and adjustment is so time-consuming and takes an indefinite number of iterations.

2. Automatized Instruments of Coordinate Measurements
Except for control of assembly tooling, automatized instruments of coordinate geometrical control are applied in an aircraft construction, such as a laser tracker [1–4], a laser radar [5], iGPS [6], a 3D scanner [7, 8]. These tools allow comparing the geometric pattern of an object with the 3D model. Thus, the process of measurement is automatized. The application of such measuring instruments is limited by the following:

- Free access to the measuring surfaces.
- Stable external conditions (absence of vibration and temperature change).
- The process should be controlled by the high level qualification operator.
- High cost of instruments of coordinate measurements.

In the workshop of the aircraft factory, when the wing is set in the assembly jig, the access to the measured surfaces is limited; vibrations, temperature changes and accidental external effects are possible. Applying automatized instruments of coordinate measurements is difficult under such circumstances.
3. Distance Sensors
When using the control devices or control templates, it is possible to shorten labor intensity of measurements if we set distance sensors on them. The control of a wing aerodynamic contour requires sensors that can measure the distance at least up to 30 mm with the accuracy not less than ±0.1 mm. Various types of distance sensors correspond to such requirements: contact, laser. Non-contact laser sensors [9–11] are the most comfortable in use. The sensors can be set either on a control device or control templates at target points. Laser distance sensors let us determine inaccuracies of a wing aerodynamic contour, gather and process the results of measurements in electronic format. The labor intensity of measurements is lower significantly in comparison with the manual measurements, because the measurements are made in all control points simultaneously.

4. Structural System of the Control Stand
The device for controlling wing mechanization alignment in an aircraft aerodynamic contour is a part of the wing assembly stand. In this stand, the elements of wing mechanization are set; control and adjustment of their position on the wing are made. The control device can be a rigid frame with equidistant control templates on it. The frame is set in the wing assembly stand on special mount seats. Distance sensors, set on a control device, measure the distance to the wing surface. Measured points are set on both wing mechanization elements and a wing box (Fig.1). These points presents a kind of discrete model of the wing surface. This model can be automatically designed from the 3D model of the wing [12, 13] and it can be used in developing the assembly process and assembly tooling for the wing [14–16].

![Control Stand Diagram](image)

**Figure 1.** The pattern of control device with laser distance sensors

Required accuracy of the frame position and control templates are provided when mounting this control device. Modern mounting technology is made in accordance with the data of the 3D model using the laser tracker for coordinate measurements [17]. Such technology is applied nowadays for the majority of assembly jigs in aircraft construction and provides the accuracy up to ±0.1 mm.

5. Providing of Control Accuracy
Sensors control is performed with the help of a special program, which provides taking the readings of the data of the sensors and processing of measurement results according to a specific algorithm.
To determine inaccuracies from the wing aerodynamic contour at each control point with high accuracy, the distance sensors should be calibrated. The initial and working calibrations are offered to be used.

The initial calibration is performed once after mounting the control device using a laser tracker. For this purpose, the aircraft wing is set into the assembly stand and inaccuracies of the wing aerodynamic contour from its 3D model at each control point are determined with the laser tracker. Then the sensors measure the distance to each control point. The data of inaccuracies are transmitted to the program that control the sensors to calculate the nominal distance for each sensor according to the formula:

$$ D_0 = D + \delta_D $$

where $D_0$ – nominal distance,
$D$ – measured distance,
$\delta_D$ – inaccuracy rate, measured by the laser tracker.

Working calibration of distance sensors is performed every time when mounting the wing. The laser tracker is not used during this process. The wing is set in the assembly stand and then the sensors measure inaccuracies at the points of the wing box only. After that, the controlling sensor program updates the nominal distance for each sensor at control points on the wing mechanization elements according to the formula:

$$ D_i = D_0 + \left[ \frac{\delta_1 \cos \varphi_2 - \delta_2}{L_2} \cdot L_i + \delta_1 \cos \varphi_i \right] $$

where $D_i$ – updated nominal distance for the sensor at the control point on the wing mechanization elements.
element,

\( D_0 \) – nominal distance for the sensor, which is calculated as a result of the initial calibration,
\( \delta_1, \delta_2 \) – inaccuracies according to the sensors on the wing box,
\( \varphi_i \) – angle between the normals to aerodynamic contour at control points \( i \) and \( 1 \),
\( \varphi_3 \) – angle between the normals to aerodynamic contour at control points \( 1 \) and \( 2 \),
\( L_2 \) – the distance among the control points on the wing box,
\( L_1 \) – the distance from the control point on the element of wing mechanization to the nearest control point on the wing box (from point \( i \) to point \( 1 \) in this case).

The values of angles \( \varphi_i, \varphi_2 \) and distances \( L_i, L_2 \) are taken from the 3D model of the wing, as Figure 3 shows.

**Figure 3.** The parameters for the calibrating process of distance sensors

After the working calibration, the inaccuracies of the sensors at the control points on the wing mechanization elements are measured. In addition, both nominal distances of the sensors given in the controlling program as a result of the initial calibration and the corrections, received as a result of working calibration of distance sensors for the wing box, are taken into consideration.

The suggested method allows providing the high accuracy of measurements, inasmuch as after the initial calibration and working calibration some of the inaccuracies influencing the accuracy of the control are excluded (Table 1).

| Inaccuracy type                                      | Estimated inaccuracy rate [mm] | Method of elimination of the inaccuracy |
|-----------------------------------------------------|--------------------------------|----------------------------------------|
| Inaccuracy of manufacturing control templates       | \( \pm 0.1 \)                  | Initial calibration of distance sensors |
| Inaccuracy of mounting control stand                | \( \pm 0.1…0.2 \)              | Initial calibration of distance sensors |
| Static deformation of control device or control templates | up to 0.5                      | Initial calibration of distance sensors |
| Inaccuracy of setting wing into assembly stand      | \( \pm 0.5…1.0 \)              | Working calibration of distance sensors |
| Measuring error of laser tracker (for example, API Radian [3]) | \( \pm 0.02…0.06 \)            | Not eliminated                        |
| Measuring error of distance sensor (for example, Baumer OADM 12 [11]) | \( \pm 0.032…0.078 \)          | Not eliminated                        |

To keep the given accuracy of measurements, periodical checking of the control device by the laser
tracker and iteration of the initial calibration of distance sensors are required (for example, after every 10 items assembled).

6. Conclusion

The suggested method of control allows keeping the existing construction of control devices. It does not require constant application of high cost and complex in usage instruments of coordinate measurements, such as a laser tracker, a laser radar, iGPS or a 3D scanner. The efficiency of the control process is increasing significantly due to the distance sensors, set in the control device. The sensors allow making objective measurements at all control points simultaneously, and processing the results of measurements on a computer in the controlling program. The laser sensors make measurements without any contact with the wing surface. Based on the results of control in the sensors controlling program, the magnitude of adjustment of each wing mechanization element for a certain plane can be calculated.

Thus, the suggested method of control can be efficient under the conditions of serial production of the majority of modern passenger and cargo planes.

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