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Engineering Notes

ENGINEERING NOTES are short manuscripts describing new developments or important results of a preliminary nature. These Notes should not exceed 2500 words (where a figure or table counts as 200 words). Following informal review by the Editors, they may be published within a few months of the date of receipt. Style requirements are the same as for regular contributions (see inside back cover).

Modified Aileron Tips Improve Lateral Stability

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Introduction

THE Aermacchi AM.3 Bosbok high-wing single-engine propeller aircraft of the National Test Pilot School has negative stick-free lateral stability for some speeds and flap settings. Considering the general configuration of the aircraft, this may seem surprising. The ailerons extend to the tips of the wing and the original aileron tips have pronounced dihedral (Figs. 1 and 2). During steady-heading side slips (SHSS), the dihedral of the aileron tips could tend to deflect the ailerons such that the stick force was reduced or even reversed from what is conventional. This conjecture was tested by designing and manufacturing new aileron tips without dihedral, mounting them to the aircraft, and performing manned flight tests. The test results show that the stick-free lateral stability was improved, although not fully cured.

In previous work, Grenestedt et al. [1] have shown that trailing-edge-mounted canted tabs could greatly improve the stick-free lateral stability of this aircraft.

Modified Aileron Tips

New aileron tips, as shown in Fig. 2, were CAD designed. They are essentially just small caps of the ailerons. The ailerons are very big and the modified tips reduced the planform area by only a few percent. Female molds were computer numerical control (CNC)-machined in a high-density polyurethane board. Right- and left-side aileron tips were manufactured by wet-laminating glass fiber and epoxy in these molds. After cure, the parts were demolded, freestanding post cured, trimmed, and mounted to the aircraft. The mounting brackets of the original aileron tips were used. The ailerons may require rebalancing. The left tip mounted on the aircraft is shown in Fig. 2.

Flight-Test Procedure

The effects of the modified aileron tips were evaluated by manned test flights with a pilot and a flight-test engineer. A restricted envelope was used (maximum 90 KIAS). Tape measures were attached to the right rudder pedal and to the stick. A handheld digital force gauge was used to measure stick force. Flight testing was performed by trimming the aircraft for level flight, then applying a certain rudder deflection and coordinating with ailerons to keep the aircraft in a steady-heading side slip. The rudder deflection, stick (aileron) deflection, and stick (aileron) force were measured and recorded by the flight-test engineer. Rudder deflections corresponding to approximately 25, 50, 75, and 100% of the maximum rudder pedal travel were applied both left and right. Tests were performed with no flaps and with two-thirds flap extension. The same tests were performed with both the original and with the modified aileron tips.

The accuracy of rudder and stick deflections was on the order of 5 mm. The stick force gauge is believed to have been very accurate, but due to the nature of the manned tests, there were some fluctuations in the applied stick force. The recorded forces are essentially averages and their standard deviations are believed to be no more than 1 N or 15%.

Flight-Test Results

Stick deflection and stick force (aileron) were measured for given rudder deflections during steady-heading side slips. The stick deflection required to maintain SHSS varied essentially linearly with rudder deflection with the original aileron tips. The modified tips did not alter this relation significantly.

The stick force changed significantly with the modified aileron tip. During SHSS of a laterally stable aircraft, the stick force should be negative for a positive rudder deflection, and vice versa. The sign

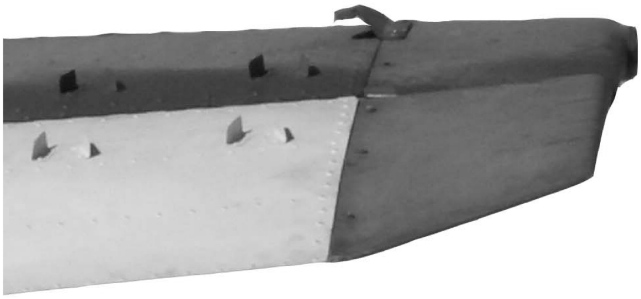

Fig. 1 Right wing tip of the Aermacchi AM.3 Bosbok seen from the rear. Note the dihedral of the aileron tip.

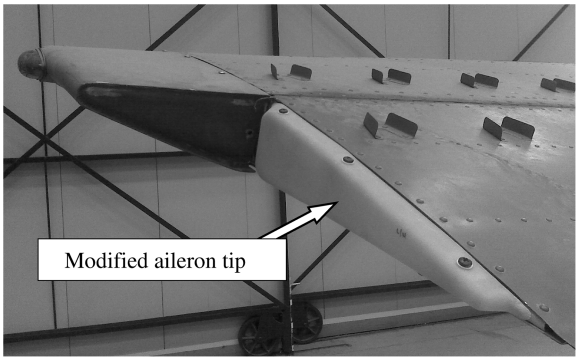

Fig. 2 Left wing tip showing the new modified aileron tip with no dihedral. The original aileron tip matched the extensive dihedral of the wing tip.

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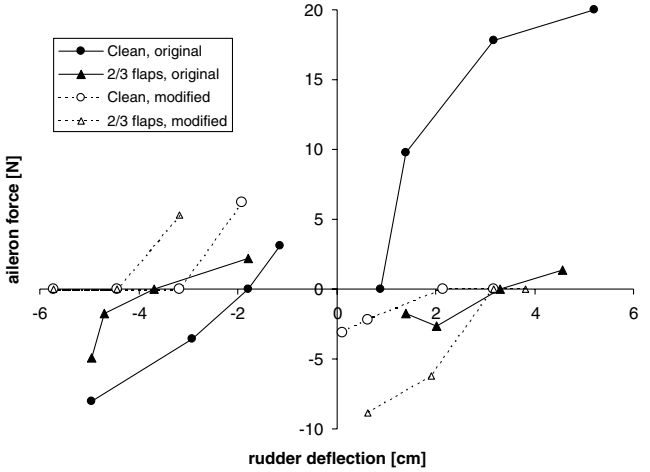

Fig. 3 Aileron stick force versus rudder deflection during steady-heading side slips.

convention used is that the aft elevator, right aileron, and right rudder deflections and forces are positive. As seen in Fig. 3, in the clean configuration (no flap deflection) with the original aileron tips, the stick force was zero or positive for all positive rudder deflections, indicating lateral instability. For negative rudder deflections, the stick force was initially positive, indicating lateral stability. For larger rudder deflections, the stick force became negative and the aircraft was laterally unstable. With flaps deployed, the aircraft was stable for smaller rudder deflections but unstable for larger deflections. Upon stick release while maintaining rudder input, the aircraft would roll in the proper direction (roll wings level and then into the turn) 25% of the time, roll in the wrong direction 55% of the time, and otherwise maintain its bank angle.

With the modified aileron tips, the stick force was in the proper direction for small positive and negative rudder deflections and the aircraft was laterally stable (Fig. 3, dashed lines). However, for larger rudder deflections, there was essentially no stick force required to maintain SHSS, indicating neutral stability. When the stick was released while maintaining rudder deflection, the aircraft would roll in the proper direction 65% of the time, roll in the wrong direction 20% of the time, and otherwise maintain its bank angle.

The neutral position of the rudder was measured on the ground and may differ from the neutral position in the air. This is believed to be the reason for the apparent offset of the axes in Fig. 3.

Conclusions

The modified aileron tips improved the stick-free lateral stability of the particular aircraft, although not sufficiently to make the aircraft fulfill Federal Aviation Regulation Part 23 requirements [2]. It may be speculated that aileron tips with anhedral could possibly cure the stick-free lateral stability deficiency, although this was not investigated. Needless to say, aileron tips with anhedral could affect the aircraft in undesirable or even dangerous ways.

Acknowledgments

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References

[1] Grenestedt, J. L., Ridder, S.-O., and Maroun, W. J., "Flight Testing a Simple Fix to Lateral Stability Deficiencies," *Journal of Aircraft*, Vol. 43, No. 5, 2006, pp. 1399–1404. doi:10.2514/1.20523

[2] "Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes," *Code of Federal Regulations*, Pt. 23, Federal Aviation Administration, U.S. Department of Transportation, Rept. 14CFR23.177, 2008.