6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

# ON ALLOWABLE STEP HEIGHTS: LESSONS LEARNED FROM THE ATTAS AND F100 FLIGHT TESTS

**Geza Schrauf**[1]

[1] DLR, Lilienthalplatz 7, 38108 Braunschweig, Germany, geza.schrauf@dlr.de

**Key Words:** *Laminar-turbulent boundary layer transition, surface imperfections, steps.*

In 1987 and 1992, two important flight tests to demonstrate the application of natural laminar flow (NLF) for regional transport aircraft were performed. First, the DLR research aircraft VFW614 ATTAS was equipped with an NLF glove on the upper side of the starboard wing within the German national TLF project [1], [2]. The flight tests showed that laminarity can be achieved for Reynolds numbers up to 23 million and Mach numbers up to 0.67 [5].

**Figure 1: VFW614 ATTAS aircraft with NLF glove.**

Driven by the success of this flight test, a second NLF flight test was performed in 1992 within the European ELFIN project. For this test, an NLF glove for both the upper and lower side of the starboard wing was mounted on a Fokker 100 aircraft [3], [4]. This test extended


**Figure 2: Fokker 100 aircraft with NLF glove.**

the region for which natural laminarity was studied to Reynolds numbers up to 30 million and Mach numbers up to 0.80. An evaluation with different linear stability theories was later

performed within the European follow-on project ELFIN II [5]. The conclusion of both tests was that natural laminar flow is possible for

- leading edge sweep angles below $23^0$,
- Mach numbers up to 0.75, and
- Reynolds numbers up to 25 Million.

After the F100 tests, no further large-scale NLF flight test was performed in Europe, so that these results form the basis for today's design of NLF wings in Europe [6, Fig. 2].

During the two flight test campaigns, forward and backward facing steps were simulated with

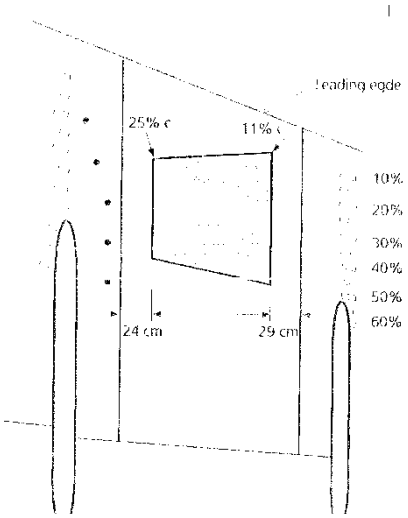


**Figure 3: Arrangement on a foil on the upper side of the F100 glove.**

the help of foils attached to the gloves, as, for example, shown for a forward facing step in Figure 3. In this paper, we will present results of both flight tests on forward and backward facing steps. Furthermore, we will propose a new criterion for allowable step sizes.

## REFERENCES

[1] G. Redeker, K.H. Horstmann, H. Köster, P. Thiede, J. Szodruch, Design of a natural laminar flow glove for a transport aircraft. *AIAA 90-3043*, 1990.

[2] K. Horstmann, G. Redeker, A. Quast, U. Dreßler, H. Bieler, Flight tests with a natural laminar flow glove on a transport aircraft. *AIAA Paper* 90-3044, 1990.

[3] K.H. Horstmann, C.H. Rohardt, C.H. Wichmann, U. Dreßler, H. Hansen, S.Rill, Auslegung eines Laminarhansschuhes für die Fokker 100. 8. DGLR Fach-Symposium 10.-12. November 1992, Köln-Porz, DGLR-Bericht 92-07, 1992.

[4] Voogt, N., "Flight Testing of a Fokker 100 Aircraft with Laminar Flow Glove, *Proceedings of the Second European Forum on Lamina Flow Technology*, AAAF Report, 2-3–2-14, 1996.

[5] G. Schrauf, Large-scale laminar-flow tests evaluated with linear stability theory, *AIAA Journal of Aircraft*. Vol. **41**, No. 2, 224 – 230, 2004.

[6] G. Schrauf, Status and perspectives of laminar flow. *The Aeronautical Journal*, Volume 109, Number 1102, 639-644, 2005.