18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012

pp. 44–45
Paper #15

AEROELASTIC CERTIFICATION OF LIGHT SPORT AIRCRAFT ACCORDING "LTF" REGULATION

J. Čečrdle[*], V. Hlavatý[**]

Abstract: *Submitted paper deals with the aeroelastic certification of a light sport aircraft according the German regulation standard "LTF-UL". The procedure is simple, fast and low-cost, however it keeps the high standard regarding the quality and reliability of the obtained results. The procedure is based on the ground vibration test of the aircraft and flutter analyses based on the measured mode shapes. Whole process is demonstrated on the example of the FM-250 "Vampire II" light sport aircraft certification*

Keywords: ***aeroelasticity, ground vibration testing, light sport aircraft, LTF regulation***

1. Introduction

In the Czech Republic, there have been a considerable growth in development and production of the light sport aircraft recently. New generation aircraft are lighter, aerodynamically refined and equipped by more powerful engines. It allows installation of advanced equipment, also flight performances are increasing. However the design is ordinarily made with no regard to the aeroelasticity and certification is based only on the formal flight flutter tests. However the additional requirements regarding aeroelasticity have appeared in some regulation standards in the recent times. The typical example is the German national regulation standard "LTF-UL". It requires the ground vibration test and flutter analyses prior the flight flutter test for the aircraft with the design velocity over ***200 km.h**$^{-1}$*. This paper describes the certification procedure used at the VZLU. It is based on the ground vibration and the flutter analysis using the measured modal characteristics. The procedure is demonstrated on the ***FM-250*** **"Vampire II"** aircraft example.

2. Ground Vibration Test

The purpose of the ground vibration test (***GVT***) is to get the modal parameters which are the input parameters for the follow-on flutter analyses. The ***FM-250*** aircraft test was performed on the completely equipped and weighted aircraft. The empty weight was ***280.5 kg***, plus ***2*** pilots of ***75 kg*** each and ***26 lt.*** of fuel. The aircraft total mass was ***450 kg***. The control system was free, there was used only soft rubber spring to fix a stick with no significant influence to the measured system. Due to the unstable vibrations, the elevator tab was fixed excluding the measurement of the tab flapping mode. The aircraft was suspended in the flight position by means of the rubber springs. The front belt was placed on the front fuselage and the rear belt was behind the wing. The measurements were performed by means of the ***PRODERA 2008*** test system.

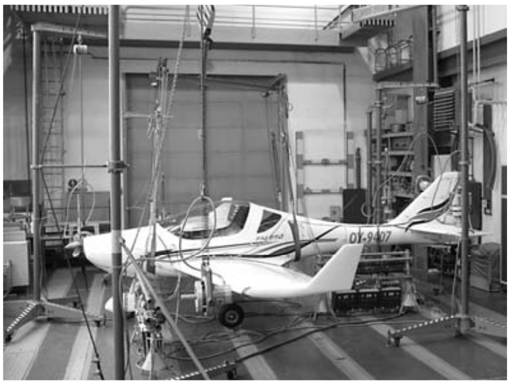

Fig. 1: GVT test arrangement

* Ing. Jiří Čečrdle, Ph.D.: Výzkumný a zkušební letecký ústav a.s., Beranových 130; 199 05 Praha - Letňany; tel.: +420.225 115 123, fax: +420 283 920 018; e-mail: cecrdle@vzlu.cz
** Ing. Václav Hlavatý: Výzkumný a zkušební letecký ústav a.s., Beranových 130; 199 05 Praha - Letňany; tel.: +420 225 115 178, fax: +420 283 920 018; e-mail: hlavaty@vzlu.cz

There were used ***50 N*** exciters, the elevator tab flapping mode was excited by means of ***4 N*** exciter. The acquisition points grid contained ***139*** uni-axial accelerometers with the mass of ***0.001 kg*** each. The rough estimation of the natural modes distribution was measured by means of the swept sine excitation. Then the particular modes were investigated by means of the phase resonance method. The modal masses and damping ratios were obtained by means of the complex power method and by supplied energy method respectively. The exception was the elevator tab flapping mode for which the modal mass was set analytically due to the large play inside the actuation mechanism. Quality of the measured parameters were assessed by criteria functions (*Δ* and ***MIF***) characterizing the quality of the particular mode excitation. Natural frequencies and modal masses were corrected with respect to the additional mass and stiffness of the test device.

3. Flutter Analysis

The analyses were based on the experimental modal model given by the ***GVT***. For the purpose of analyses, the measured modal deformations were recalculated to the grid of points with 3-directional deformation. Also, the points were moved to the leading and trailing edge respectively in order to avoid the errors due to splining extrapolation. For the aeroelastic flutter analysis, the ***ZAERO*** system was used. The aerodynamic unsteady loads were given by the ***ZONA6*** Subsonic Unsteady Aerodynamic Theory. This theory solves the respective unsteady three dimensional linearized small disturbance potential equations of the subsonic aerodynamics. The ***FM-250*** aircraft aerodynamic model included the lifting surfaces only, influence of the fuselage body was neglected. The aerodynamic mesh consists of ***2405*** aerodynamic elements in total. Aerodynamic matrices were calculated for the selected values of reduced frequency ranging from $k = 0.02$ to $k = 2.0$. Considering the velocity range of interest (up to $1.2*V_D$), the Mach number was considered $M = 0.0$. For the interpolation between structural grid and aerodynamic model, the "Infinite Plate splines" were used. For the flutter stability solution, the g-method was employed. Calculations were performed for a several altitudes ranging from $H = 0$ to $H = 3000$ [m]. The velocities were ranging from $V = 10\ m.s^{-1}$ to $V = 200\ m.s^{-1}$. The Mach number was considered $M = 0.0$ for the whole range of velocities. Thus, the results for high velocities (over $100\ m.s^{-1}$) must be considered as artificial due to incompressible flow aerodynamics used. This is ordinary practice in the aeroelastic analysis, also called non-matched analysis. The artificial results are used to evaluate the rate of reserve in terms of the flutter stability with respect to the certification velocity ($1.2*V_D$). The structural damping was included via viscous model. There were found the flutter of the main lifting surfaces, controls and tabs. The most important ones are rudder, wing aileron and elevator flutter. The main contributing factors are low rudder flapping frequency and the aileron static under-balancing as well as the flapping frequency.

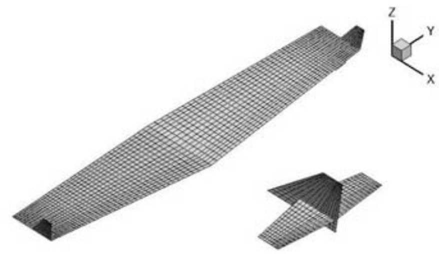

Fig. 2: Aerodynamic model for flutter analysis

4. Conclusion

The paper demonstrates the simple and fast procedure of aeroelastic certification suitable for light sport aircraft category based on the ***GVT*** of the aircraft and flutter analysis. The solution is demonstrated on the ***FM-250*** **"Vampire II"** light sport aircraft certification according German national airworthiness regulations **LTF-UL-2003, section 629**. There was evidenced no flutter issue within the aircraft flight envelope.

References

Čečrdle, J. (2011) Assessment of Aileron Tab Installation Influence to Aircraft Flutter Characteristics, *52nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference (SDM)*, April, 4 - 7, 2011, Denver, CO, USA, AIAA-2011-1849

Hlavatý, V. (2010) Mobile Modal Test Laboratory at VZLU, *Czech Aerospace Proceedings*, Vol.4/2010, pp.37-41, ISSN 1211-877X

(2003) Lufttüchtigkeitsforderungen für aerodynamisch gesteuerte Ultraleichtflugzeuge, LTF-UL, 30.1.2003