COMPUTATIONAL MECHANICS 2021
36th conference with international participation
Srní
November 8 - 10, 2021

# Influence of an atmosphere at an airplane flutter velocity

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An airplane flutter is self-excited harmonic oscillation of a structure. It occurs without any warning and leads to destruction within a second. Flutter is cause by interaction of inertia, stiffness and aerodynamic forces. There have to be also considered a feedback between force and deformation of structure during mathematical analysis of a problem. A flutter analysis is an analytical process aimed at determination a velocity of flutter occurrence. A mathematical model for flutter analysis is based on airplane modal parameters obtained from ground vibration test of made prototype, mass and geometrical characteristic. A producer of airplane has to proof that each prototype of the airplane is free from flutter up to certain velocity given by airworthiness requirements. The minimal flutter velocity is usually related to a maximal airplane velocity referred as design velocity “$V_D$” multiplied by a safety coefficient, which is specified by airworthiness requirements of given category, it usually has the value of 1,2.

The flutter analysis is the most usually carried out for standardized atmosphere condition given by International Standard Atmosphere (next as ISA) model where model parameters such as a pressure, a temperature, a density, and a viscosity of the Earth's atmosphere change over a wide range of altitude. The ISA model works with a hypothetical standard day condition where all parameters represent averages of all over the planet location and all year seasons. It does not take in account actual meteorological situation or atmospheric conditions.

To determine variations in atmosphere parameters, the MIL-HDBK-310 is used. In this handbook is climatic data for use in engineering analyses. The atmospheric envelope model is chosen. This model consists climatic data of extremes at each altitude regardless of the location and time at which occurs. Therefore these envelopes are suitable for objects flying horizontally, see [1].

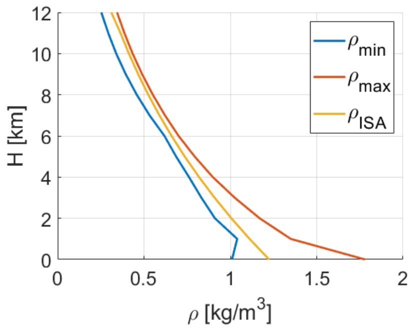


Fig. 1. Density at altitude

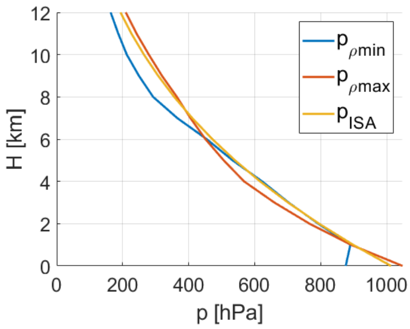


Fig. 2. Pressure at altitude

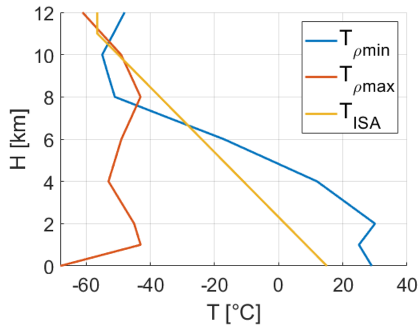


Fig. 3. Temperature at altitude

In used calculation model, the changing parameter of atmosphere is air density. Therefore, the extremes of density is used from handbook. Fig. 1 contains extremes of density at altitudes while Fig. 2 and Fig. 3 shows pressures and temperatures that occurs at this densities.

Three calculations method for determine a speed of flutter is used. 2D model uses unsteady aerodynamic load represented by Strip Theory and Theodorsen thin oscillation airfoil in ideal non-compressible flow. This model works with two-dimensional model. Therefore, the correction on finite span is made in 3D model. The third model is Double lattice method. This method uses thin oscillating surfaces in ideal compressible flow. The finite span is considered at this method, see [2].

The input data is taken from flutter analysis of airplanes which was performed at Department of Aerospace Engineering, Faculty of Mechanical Engineering, Czech technical university in Prague. The four cases of flutter are analysed as shown below.

Table 1. Analysed flutter cases

| ID | Airplane | Flutter type |
|---|---|---|
| ID1 | UFM-13 Lambada | tailplane, low-frequency mode |
| ID2 | VIA NG4 LSA | tailplane, high-frequency mode |
| ID3 | H55 | wing, low-frequency mode |
| ID4 | H55 | wing, high-frequency mode |

Calculations are performed for altitudes from zero to twelve km with one km step at true air speed (next as TAS). In Fig. 4 are shown v-d (velocity - negative logarithmic decrement) and v-f (velocity - frequency) diagrams for third case calculated by 2D method at 6 km. In v-d diagram we can find velocity at which flutter occurs. It is when negative logarithmic decrement reaches zero value. Then is read frequency for flutter velocity from v-f diagram. In this diagram is shown which modes interact with each other and causing flutter.

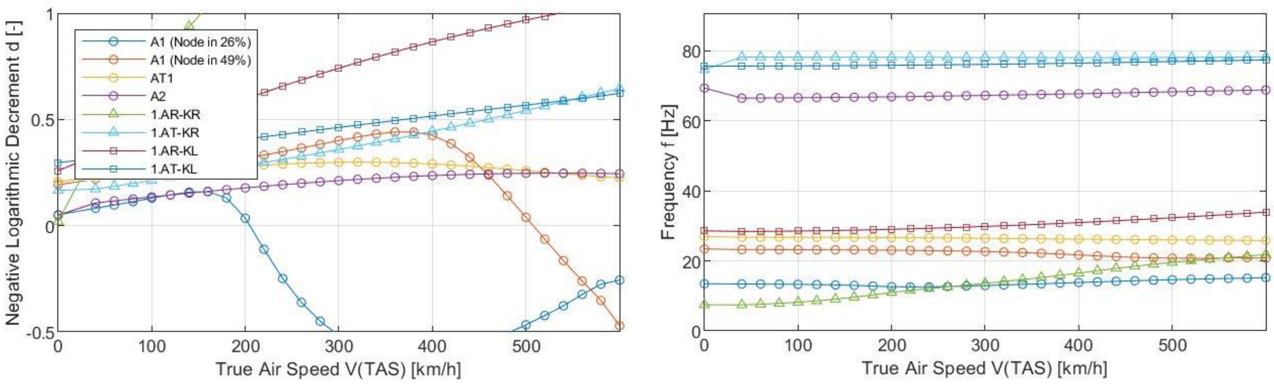


Fig. 4. ID3-MSA-2D, v-d v-f diagrams at 6km

From diagrams is read flutter velocities and frequencies for each altitude and from this values the graphs bellow is made.

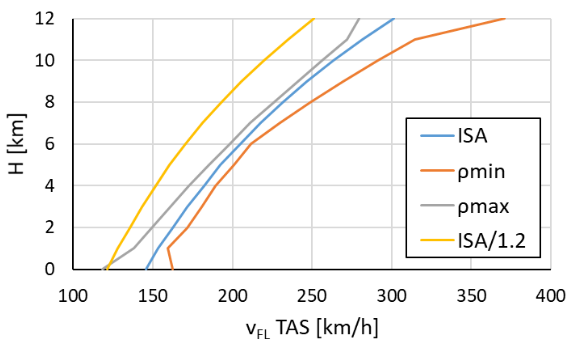


Fig. 5. ID3-2D, flutter velocity at altitude

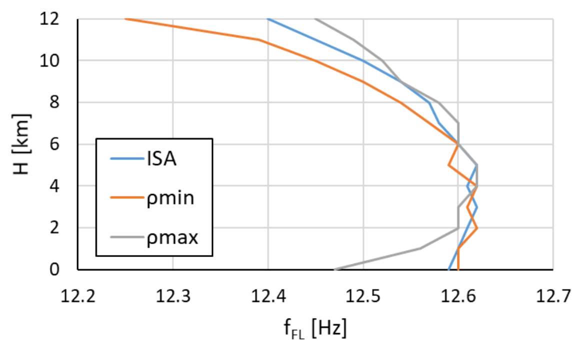


Fig. 6. ID3-2D, flutter frequency at altitude

Yellow curve in Fig. 5 shows limit values of flutter velocity for each altitude. This values is obtained by divining the ISA values by safety coefficient of 1,2. At the shown case is considerable reserve for higher altitudes, but for sea level the flutter velocity for maximal air density dropped below limit curve. This drop is not marginal and for DLM method, which should be more accurate, is this case ok. This is shown in the next figures. The curves of flutter frequency in Fig. 6 is different than in Fig. 8. This is given by differences in used computational models.

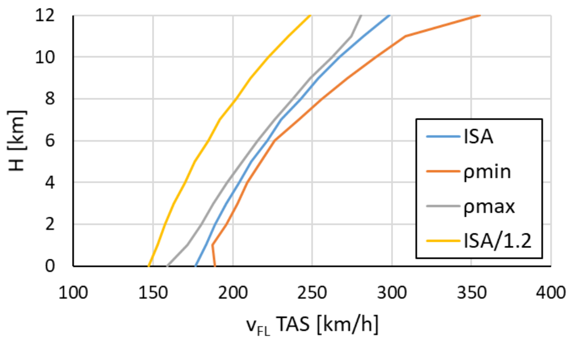


Fig. 7. ID3-DLM, flutter velocity at altitude

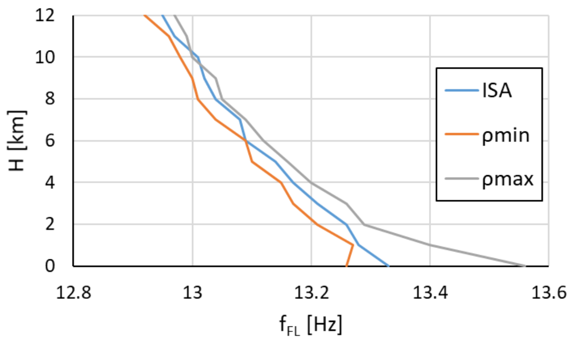


Fig. 8. ID3-DLM, flutter frequency at altitude

## Acknowledgements

The work has been supported by the grant project Aeroelastic optimization of aircraft composite structures (SGS20/162/OHK2/3T/12).

## References

[1] Global climatic data for developing military products, MIL-HDBK-310, United States Department of Defense, 1997.

[2] Slavík S., Weigl K., Flutter calculation model with isolated modal characteristics of control surfaces for small sport airplanes, Czech Aerospace Proceedings (Journal for Czech Aerospace Research), Czech Aerospace Manufacturers Association / ALV, Prague, No. 2, 2008.