Towards a consideration of the uncertainties in flight loads

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Abstract

For certification requirements, structural loads of aircraft has to be demonstrated with required margins. These structural loads can be predicted by the design office thanks to calculations on a load model of the aircraft. Estimations of these loads can only be checked and confirmed with the real flight measurements. But these measurements are subjected to uncertainties. So the loads have to be known with accuracy to reduce these margins to the minimum.

A current flight load determination relies on a method developed by NASA (ex-NACA) in 1954 [1]. This method, known as the "Skopinski" method from the name of its main author, includes two steps: a ground load calibration and flight test applications.

The flight loads cannot be directly measured. The most common method consists in measuring the effects of the flight loads on the structure, which means the strains. These local strains are measured. The formulation of the direct problem is the following one:

$$F'^{flight} = (\mu_k)^T(\beta_k) \tag{1}$$

where F' is the load, μ_k is the measurement of the strain at location k and β_k is the parameter associated to the strain at location k representing the response of the structure. It is also necessary to know the response of the structure to determine flight loads.

A ground load calibration allows characterizing the behaviour of the structure which is calibrated. Chosen loads are applied on the structure. Local strains are measured. Knowing loads and strains, the structural response is thus characterized by the resolution of the inverse problem:

$$(\beta_k) = ([\mu_k]^T[\mu_k])^{-1}[\mu_k]^T(F'^{ground}) \tag{2}$$

The system representing the problem is over determined. First, a criterion has been implemented to make a systematic and reliable choice of the strain measurement [2] for the identification of the structural behaviour. Results (Figure 1) show a good fit between the currently used criteria and this new criterion.

Then, flight loads are determined by flight test applications. Local strains are measured in flight. Knowing the behaviour of the structure thanks to the ground load calibration, the flight loads can be estimated by the direct problem (1).

The general objectives of the works on this topic are the determination, the quantification and the propagation of uncertainties through the load determination method. The originality of the present paper is to take into account sources of uncertainty in the complete load determination method, whether in the ground load calibration or in the flight test application. The structures which are studied in this paper are the wings.

The current work concerns the ground load calibration. The main sources of uncertainties in the ground load calibration have been identified as affecting both the local strain and load measurements.

The next step is the propagation of the uncertainties on both strains and loads in the ground load calibration. For this, a specific regression model will be implemented using the so-called "error in the equation" method [3].

The method of propagation of uncertainty, including the implemented criterion, is independent from the aircraft type or the wing structure type.

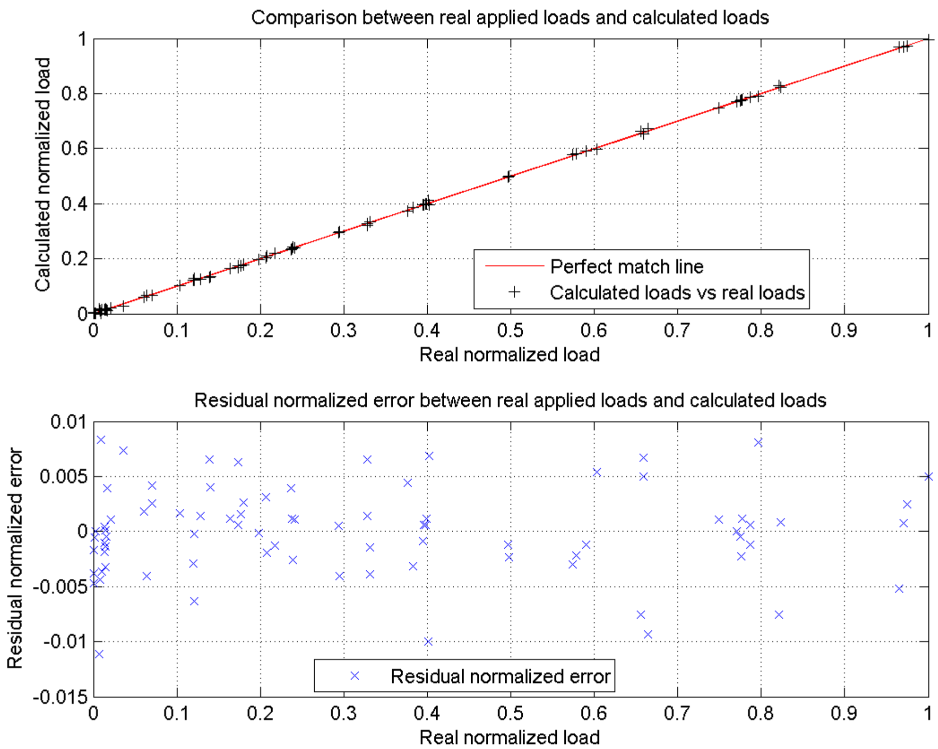

Figure 1: Identification of the structural behaviour using the new criterion

References

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