Substitute models for structural components loads estimation based on flight parameters and statistical inference methods

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The knowledge about loads of the aircraft structure occurring during aircraft operations, is one of the fundamental elements of not only damage tolerance approach to aircraft design. Nowadays Operational Loads Monitoring (OLM) programs are essential elements of airworthiness policy of Ministry of Defense in some NATO countries. In the OLM case, aircraft loads related information could be available from a sensors network e.g. strain gauges or even Fiber Bragg Gratings (FBG) permanently mounted in the aircraft structure and measuring its local strains (direct loads monitoring). One of the key issues for direct loads monitoring, is to identify different distribution of stresses occurring in the structure, in order to apply appropriate models for prediction of damage evolution. When identified, number of load cycles of each type can be determined and their contribution to fatigue can be calculated. For this particular purpose, i.e. determination of independent loads acting on a component, statistical dimensional reduction methods, e.g. Principal Component Analysis, can be applied. Those methods can provide a set of uncorrelated combinations of strain gauges readings, which should correspond to different modes of stress distribution.

Due to complexity and costs of OLM programs with direct loads monitoring, indirect loads monitoring approach, based on flight parameters analysis, has lost nothing of its attractiveness. What is available instead of local strains distribution, is a set of recorded flight parameters, which by the laws of inertia and aerodynamics should determine dominant part of loads, acting on a given element. In that case, OLM systems are installed only for limited number of aircrafts performing flight test campaign, which should represent all of the maneuvers occurring during usual aircraft operation. Comparing to direct load monitoring, an additional difficulty emerges. Beside identification of different stress distribution, also functional relation between stress field and flight parameters needs to be established. In the presentation, Canonical Correlation Analysis (CCA) method will be discussed as an useful method for selection of flight parameters which can properly predict aerodynamic loads acting on a given structure. CCA allows both for identification of different modes of stress distribution as well as identification of flight parameters which are the best suited for their prediction. The method will be illustrated for the use case of prediction of aerodynamic loads acting on the structure of vertical fin of a twin-tail fighter aircraft.

Keywords: structural loads monitoring, statistical methods for loads prediction