Abstract

Aircraft brakes are subjected to friction-induced instabilities. These vibrations are a threat for the brake and landing-gear structural integrity and represent an issue in terms of integration. Thus Safran Landing Systems has to comply with aircraft manufacturers' strict requirements on the vibration amplitude its product is likely to generate. Compliance to these requirements is assessed by long and costly braking test campaigns. The objective of the research presented here is to reproduce by simulation the brake dynamic instabilities with numerical tools that could be integrated in the design process. Brake squeal has been a research topic since the early XXth century. However it remains a rather ill-understood phenomenon, especially in aeronautics. Unstable vibrations regularly appear on the whole 0-2kHz frequency spectrum. In the last decade, an instability located around 200 Hz called *whirl 2* persistently appeared on the newly developed wheel and brake assemblies, sometimes exhibiting critical vibration amplitudes. Consequently, Safran Landing Systems wishes to develop numerical tools able to simulate both the occurrence and the amplitudes associated with friction-induced instabilities, especially with the *whirl 2* mode. In the first part of this report, an experimental analysis of the brake is conducted, on both laboratory and in operational set-ups. The modelling of the wheel and brake assembly using the finite element method is then described. The system stability in a Lyapunov's sense is studied and shows good correlation in both frequencies and mode shapes with the experiments. This finite element model is too big to be used to perform the transient simulation of the nonlinear amplitudes. In the second part, two reduction methods, tailored to the complex aircraft brakes architectures, are thus presented. The first method is a semi-analytical. It shows excellent performances up to 500 Hz. The second reduction method is the double modal synthesis, implemented under its classical version. It is then successfully improved and called "complex double modal synthesis". The third part is dedicated to the study of the nonlinear dynamics of the *whirl 2* through transient analyses. The nonlinear amplitudes simulation requires taking into account the relevant nonlinear brake behavior. However, it is first observed that, contrary to a commonly accepted hypothesis, the contact nonlinearities located at the friction interfaces cannot single-handedly account for the vibration amplitudes saturation observed in the tests. The need to identify the relevant physical phenomena leads then to consider the interaction between the squealing brake structure and its hydraulic command circuit. The modelling of the hydro-mechanical coupling provides an unprecedented insight and allows to prescribe design rules. Finally, we study the impact of dry friction in the peripheral contacts between the braking discs and the structure. This phenomenon, neglected until now, appears to have a major influence. Sensitivity studies exhibit a good correlation with tests, allowing to highlight, in a robust manner, the impact of brake design and braking scenarii on the nonlinear vibration amplitudes.

Keywords : Brake squeal, Nonlinear dynamics, Model reduction, Transient analysis, Hydromechanics, Friction, Finite element model.