SPACE PROPULSION SYMPOSIUM (C4)
Propulsion Systems II (2)

Author: Ms. BALLEREAU Séverine
Safran SME, France, s.larrieu@snpe.com

TWO MINUTES INSIDE THE A5 SRM : EFFECTS OF DIFFERENT SOURCE OF PRESSURE OSCILLATIONS DURING OPERATION

Abstract

A number of large solid rocket motors (SRM), including Ariane 5, Space Shuttle or Titan family, are reported to exhibit instabilities during operation. Those instabilities are assimilable as a thrust oscillation that involves vibrations detrimental to payloads. During past years, extensive research on such instabilities showed that they are mostly dominated by coupling between chamber acoustics and hydrodynamic instability. The latter arises from vortex shedding stemming either from unstable shear layer (caused by a protruding inhibitor for instance), or surface instability for large L/D ratio SRM. These sources of pressure oscillations are named hydrodynamics instabilities as an unstable flow is developing in the combustion chamber and couples with the motor acoustic modes. These phenomena are characterized by the presence of vortex shedding that develops in the combustion chamber. It may be observed the apparition of burst of instabilities whose levels are linked to a correspondence between the hydrodynamic frequency and the combustion chamber acoustic one. Analysis of these instabilities has been supported by experimental, numerical or analytical theories and it has been evidenced they are a powerful source of instability in long SRM. In parallel, in the case of propellant with aluminium, an enforced source of instabilities may also be provided by the alumina dispersed phase in SRM. These instabilities are named combustion instabilities. Ariane 5's boosters operation lasts for a little more than 2 minutes. During these two minutes, a combination of all sources of instabilities previously described is encountered. SNPE Matériaux Energétiques (SME) has been working on analysis of the complex phenomena for over 20 years. Studies carried out in France during this time (especially POP and ASSM CNES Programs) allowed to identify the various origins of these instabilities, to better understand the condition and the mechanism of their development. Recently a new RD program (with support from CNES and in cooperation with ONERA) was initiated to complete full understanding of these phenomena, to stress the effects of new parameters and the role of some couplings. Thanks to this program, the Ariane 5 unsteady behaviour has been more precisely defined. Large parametric simulations were performed in order to simulate whole motor performance at various time step. Simulations have underlined ways and rules of couplings between the different sources of instabilities. But over all, this study allowed to demonstrate that each phenomenon has its own weight during the combustion which is varying depending on the time (mean on the geometry) of the functioning. Since each of these phenomena has specific condition to appear and being maintained, SME generalized the experience based on the Ariane 5 studies to develop a systematic and more complete methodology in order to tailor and control ODP. Tools include analysis of flight data available (most of them being also simulated by CFD), experimental subscale SRM data, stability theories investigations, rule-of-thumb methods as well as state-of-the-art CFD computations. Final goal is to propose ways to predict and limit ODP as early as motor conception phase level. Thanks to these RD works - under the auspices of CNES - and also to a new program aimed at "ODP-oriented" SRMs functioning (reduced scale motors defined to be representative of full-scale functioning), pressure and thrust oscillations are expected to be controlled and drastically reduced in the next future, leading to an improved payload comfort.