**Aerospace Europe Conference 2023**
**Joint 10th EUCASS – 9th CEAS Conference**

# Effect of molted or machined surfaces on small scale SMR ignition

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## Abstract

Transient phases during Solid Rocket Motors (SRM) operating have to be studied with a specific care and modelled with accuracy. Considering these events, ignition is a critical phase: its duration can delay the complete operative phase of the engine, pressure oscillations can induce strong mechanical stresses into the structure. In the frame of studies funded by the French ministry of Defence (DGA) and in cooperation with Onera, ArianeGroup has developed a dedicated approach based on experimental characterisations and numerical simulations to better understand and master physical phenomena involved in the ignition of SRMs. This paper presents the different steps required to simulate the ignition of a small scale study motor. A specific focus is done on the surface characterisation (machined or moulted) and its effect of the complete ignition of a small SRM.

As the ignition is based on the energy balance at the propellant surface, the characterisation of the thermal properties of the propellant is the first step. In this purpose, density, thermal conductivity and calorific capacity are assessed at room temperature at one atmosphere. Fort this paper, only a composite non aluminized propellant is considered and formulated in that purpose.

The second step regards the determination of the ignition time for a small sample of propellant exposed to a heat flux. As the study's goal is to build a numerical model of the ignition, the discrepancy between the two propellant surface configurations is analysed. Experimentally, it is observed that the moulted faces ignite with a 20-30ms delay compared to a machined surface. This characterisation test of ignition is the base line for the numerical model. Such behaviour is afterwards numerically reproduced to calibrate the ignition model. In addition, the experimental data are firstly analysed and reproduced by a numerical simulation thanks to "Cosmetic", an AGS in-house code. Then, both experimental and numerical results are used to determine the parameters of a ignition model implemented into the Onera CFD code. This model, developed by Onera, is based on the resolution of the heat equations in the solid material with a specific treatment of the energy balance on the surface to take into account during the propellant ignition. The used model considers a detailed description of the flame. Several parameters have to be defined to correctly simulate the ignition delays that were experimentally obtained.

To validate the selected parameters, a small-scale experimentation was designed. A sample of propellant is ignited in its centre by a laser and the flame radially spreads on the sample surface. By recording the position of the combustion front, it is possible to estimate the flame spreading velocity. The result is that the measured velocity is lower for a moulted than for a machined surface. This behaviour is then reproduced by the cosmetic code. Then the global model is applied to the simulation of the flame spreading. It allows validating the selected model during the propellant ignition phase.

Based on the two models calibrated on the moulted or machined propellant surface tests, the global models are applied to simulate the ignition of a small SRM and analyse the effects on the delay or evolution of the ignited surface.