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

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: CFDMPS / PROPHY
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Type: Oral
Status of corresponding author: Student
For student corresponding author:

Title

Simulation of heterogeneous Solid Rocket Motors with the Level-Set Method

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Abstract

New manufacturing methods such as 3D-printing enable more complex geometries for Solid Rocket Motors (SRM). With complex shapes and multiple different solid fuels, it is possible to create application tailored thrust curve of an SRM. Since additive manufacturing methods are slow model-based predictions can help developing novel SRMs. These models enable SRM geometry testing and optimization. Such models need to be able to describe both the surface regression of the burning surface and the internal ballistics in the combustion chamber.

In previous models the internal ballistics of the SRM were often solved in zero- or one-dimensional models [1]. For complex geometries it is sensible to use a multi-dimensional model. The reason is that erosive effects and local pressure differences can affect the combustion rate and to model these effects the flow inside the combustion chamber needs to be solved with a model with the same number of dimensions as the surface regression model.

An accurate description of the surface regression is very important, since the burned surface directly influences the mass flux thus the pressure in the combustion chamber. The combustion rate of solid rocket fuels is dependent on the pressure in the combustion chamber. The Level-Set-Method has been used in the past to describe the geometrical changes of the burning surface during the of an SRM [1]. Previous models were however unable to describe the surface regression for SRM using multiple different types of solid fuel burning at the same time. This issue is caused by the usual assumption of a homogenous combustion rate on the burning surface, to reduce computational cost. The new model reconstructs the surface out of the implicit information of the Singed-Distance-Function of the Level-Set Method and computes the local combustion rate for each surface element.

A new model based on the Level-Set-Method allows for the simulation of an SRM with different solid fuels and combustion behavior (pressure dependencies). The model described here combines a surface regression model for heterogenous SRMs with a CDF-model for the internal ballistics. This allows for the test and optimization of possible SRM geometries.

References

[1] Cavallini, E. (2009). Modeling and Numerical simulation of SRM internal balistics.