Modeling of a Multilayered Propellant Extrusion in Concentric Cylinders

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Abstract

A novel propellant technology requires extruding two formulations with differential burning rates (slow and fast) together as a multilayered propellant. This multilayered propellant is processed into a concentric cylinder configuration, in the form of slow-fast-slow with single perforation. The main challenge originated from the different path lengths between the inner and outer sections of the die, both coming from the same pressure driven flow. Figure 1 shows the cross-section of flow characteristics from different paths to form a multilayered propellant.

This study uses COMSOL Multiphysics® software to optimize the unique die design that enables a wide range of materials with different rheological properties, while keeping consistent flow balance. The model uses the CFD Module and the Heat Transfer Module to study the non isothermal steady state flow behavior, including viscous heating and heat transfer between each layer of extruded materials. Fluid and rheological properties were specified by the user. The viscosities were expressed as a function of temperature and shear rate using a classical power-law model where the shear thinning index "n" is a characteristic property of the fluid. A satisfactory description of the flow geometry was obtained with approximately 500,000 tetrahedral elements. The modeling study considered die design iterations where angles and channel sizes were modified in order to optimize the flow behavior of propellant paste extrusions.

Results emphasize the relevance of the viscous heating and the shear thinning behavior of this rheologically complex fluid in the design process of the extrusion dies. Figure 2 illustrates the velocity profile and Figure 3 represents the thermal distribution under steady flow conditions. The propellant dough being a poor thermal conductor, the inner section becomes warmer than the mid and outer section due to viscous heating. These higher temperatures lower the viscosity of the paste in this particular section. The simulations shade light on the interaction between the power law index "n" and the viscous heating in the die design. The results obtained by finite elements simulations have been validated experimentally.

Figures used in the abstract

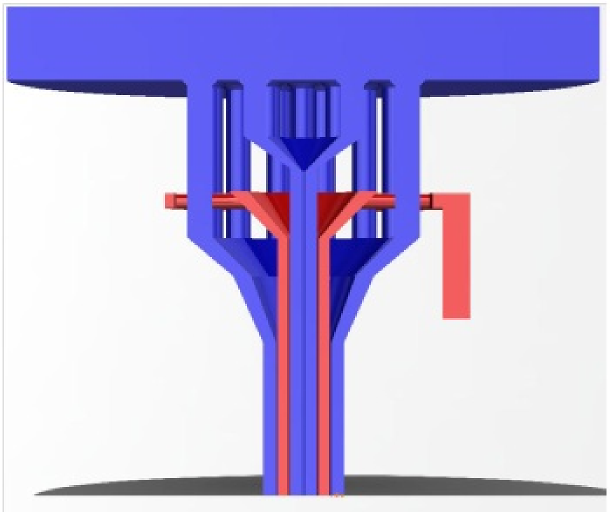

Figure 1: Cross-section of the die design processing multilayered propellant.

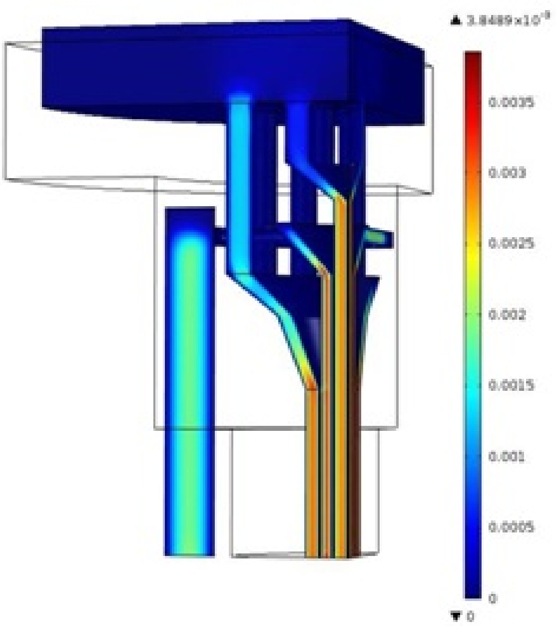

Figure 2: Velocity profile distribution in the multilayered die.

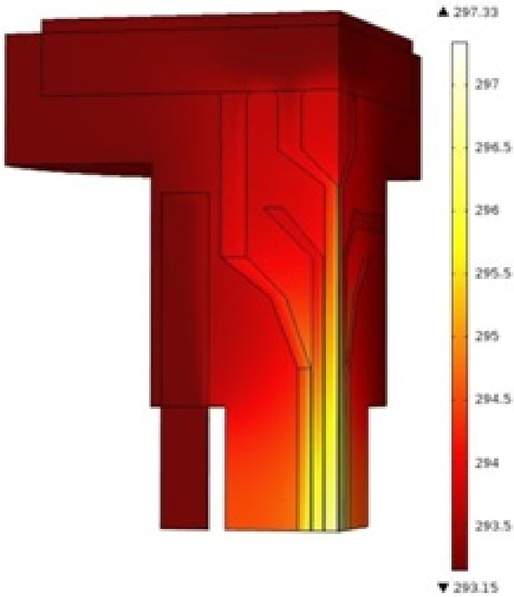

Figure 3: Thermal profile distribution in the multilayered die.

Figure 4