Modeling of a Multilayered Propellant Extrusion in Concentric Cylinders

S. Durand[1-3], C. Dubois[1], P. Lafleur[1], V. Panchal[2], D. Park[2], D. Lepage[3], P.Y. Paradis[3]
1. École Polytechnique de Montréal, Montr®al, QC, Canada
2. US Army ARDEC, Picatinny Arsenal, NJ, USA
3. General Dynamics Ordnance and Tactical Systems – Canada, Valleyfield, QC, Canada

Introduction: This work was focused to demonstrate the effects of an extrusion die design on the flow balance between two unconnected layers, a highly viscous material separated by an inner layer of a more liquid-like material. The two viscous layers come from the same pressure driven flow but use different path lengths throughout the die.

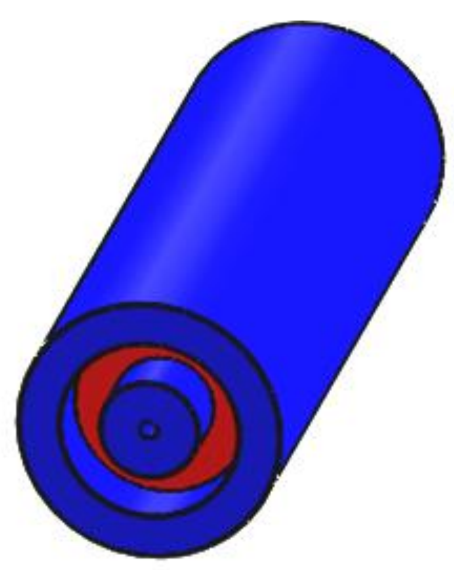

Figure 1. Multilayered propellant grain

Computational Methods: Using COMSOL CFD and Heat Transfer modules, a study has been conducted on multiple die configurations to find an optimized design that enables extrusion process of wide range od visco-elastic materials with different rheological properties while maintaining the flow model balanced. The viscosity as a function of temperature was expressed with the Arrhenius equation as follow:

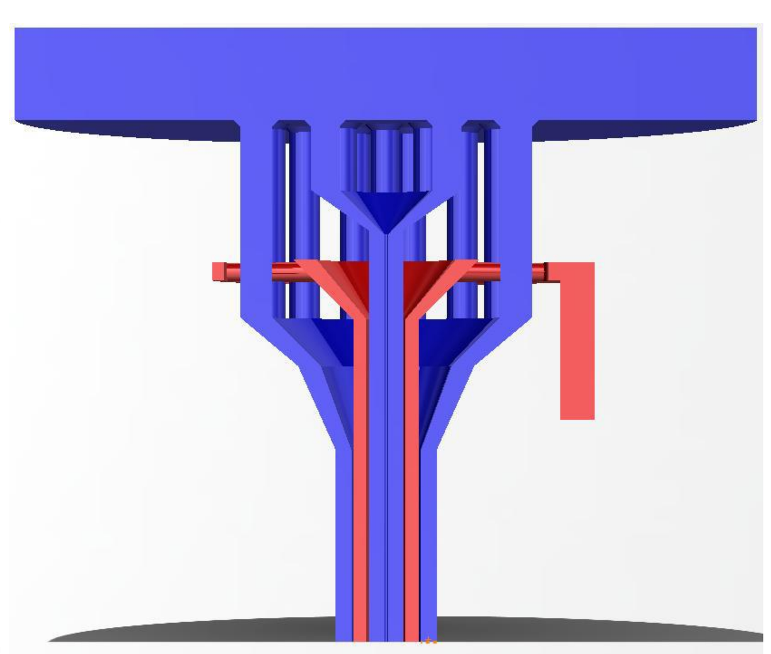

Figure 2. Cross section of die within flow model

$$\eta(\dot{\gamma}, T) = \eta_0 \exp\left[\frac{\mathrm{E}}{\mathrm{R}} * \left(\frac{1}{\mathrm{T}} - \frac{1}{\mathrm{T}_0}\right)\right]$$

Results: 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 3 illustrates the velocity profile and Figure 4 represents the thermal distribution under steady flow conditions.

The propellant dough being a poor thermal conductor, the inner section becomes warmer than the middle and outer section due to viscous heating.

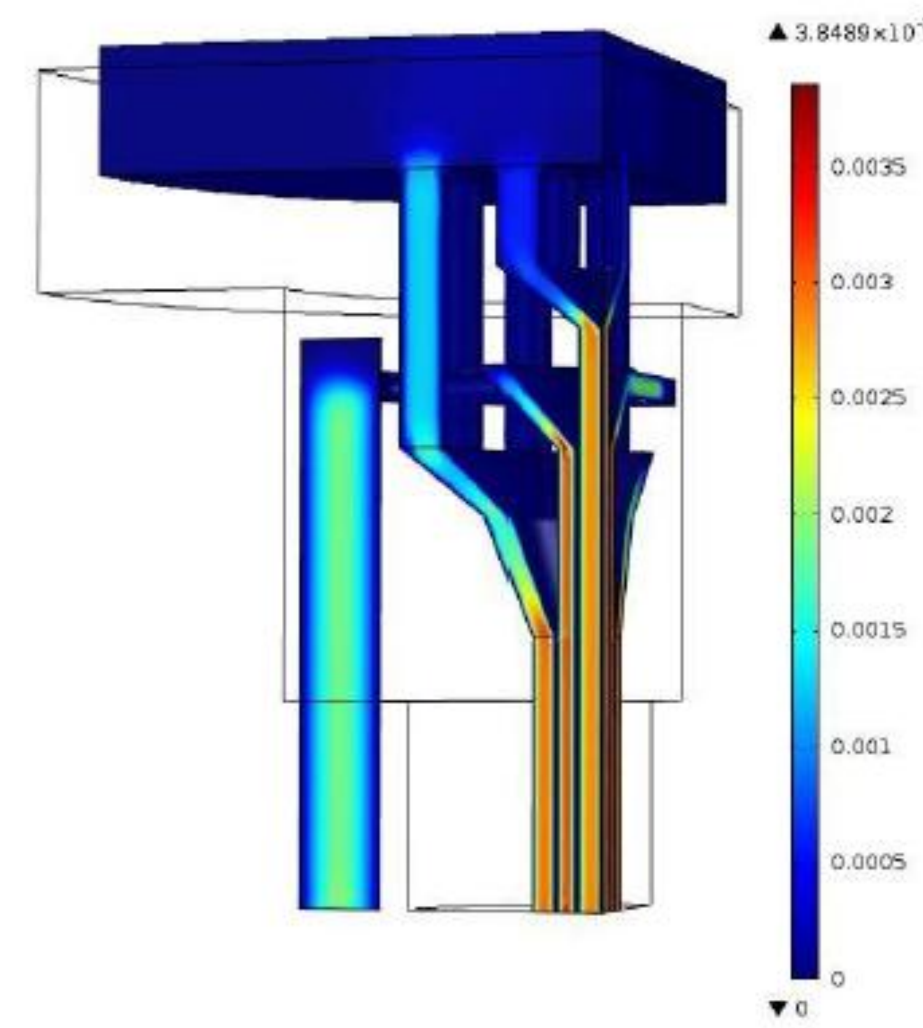

Figure 3. Velocity profile

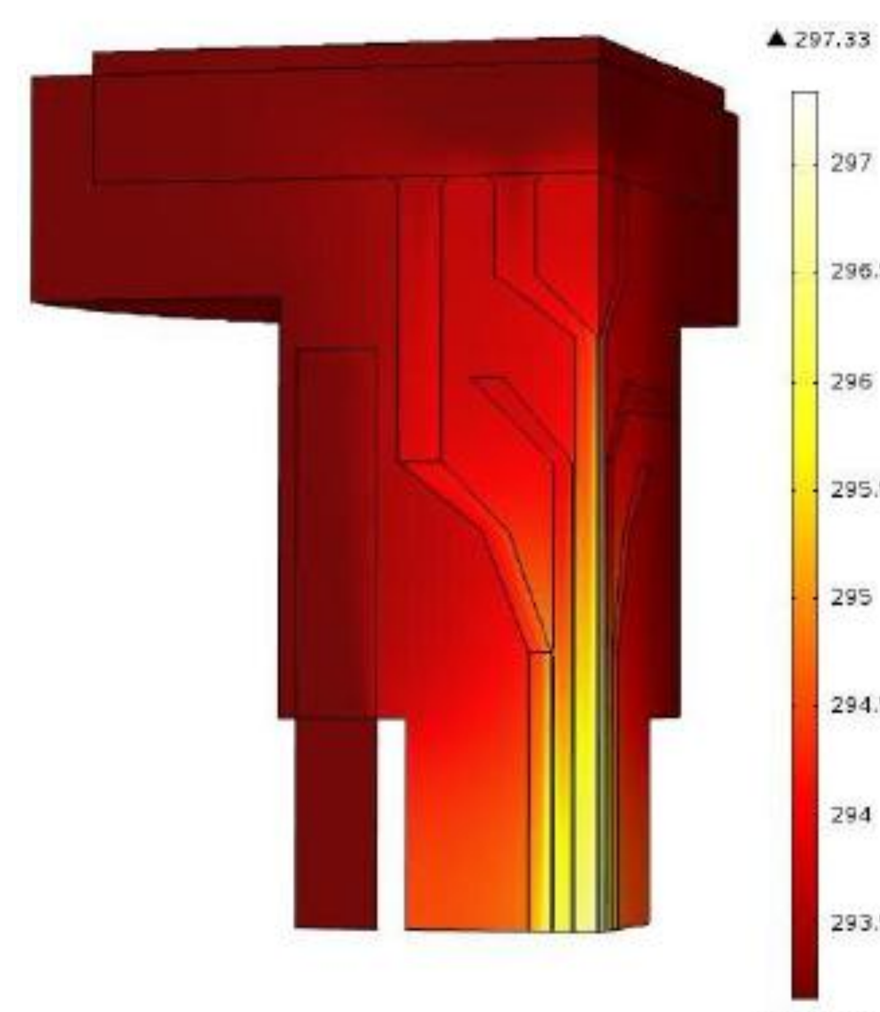

Figure 4. Temperature distribution

These higher temperatures lower the viscosity of the paste in this particular section, enabling a higher flow rate.

Table 1. Simulation data

	High viscosity propellant paste	Fast burning liquid core
Inlet pressure:	24,82 MPa	0,086MPa
Inlet temperature	293,15K	293,15K
Density:	1510kg/m³	1640kg/m³
Thermal capacity:	2000J/(kg*K)	2000J/(kg*K)
Dynamic viscosity (Pa*s):	$\eta = e^{\left(\frac{2848,8}{T}+2,606\right)} * \dot{\gamma}^{(0,205-1)}$	150
Thermal conductivity:	0,294W/(m*K)	0,3W/(m*K)

Conclusions: 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.

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