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DEVELOPMENTS IN ADDITIVE MANUFACTURING FOR SOLID AND HYBRID ROCKET PROPULSION CHARGES

Abstract

The advantages of additive manufacturing (AM) rely on the possibility of exploring shapes that cannot be produced with subtractive techniques. Moreover, AM offers great versatility and rapid prototyping. For liquid rocket engines, the application of metallic AM is granting new engineering solutions for cooling channels and injection manifolds. In turn, AM is still under evaluation for solid or hybrid rocket propellant charges. The paper aims at summarizing the current development status of these two research sectors.

In solid propellants, grain shape control is a key aspect for the evolution of thrust in time. Typically, propellant composition is based on a casted thermosetting binder cured in thermostatic ovens. The curing process also requires toxic curing agents like isocyanates. Oxidizer and fuel are mixed in powder form. Compositions of space rocket boosters arrive to a mass fraction of about 80-90%, with metal and metal oxides added to the mixture. On the basis of a co-authored patent, the Space Propulsion Laboratory (SPLab) of Politecnico di Milano and the Rocket Propulsion Lab (RPL) from Politecnico di Torino are exploring a new non-toxic curing process based on UV light. The activity is experimentally studying the properties of the polymer mixture and is working at the demonstration of the technology through the development of a 3D printing system. Such a technology offers high versatility, rapid propellant prototyping and fast curing, while eliminating the need for long thermosetting in ovens and the use of toxic curing agents such as isocyanates. For hybrid rocket propulsion, shape is envisaged either as a method to improve burning rate or, in more recent papers, to address the challenge of grain structural limits. High regression rate propellants are based on paraffin fuels which present low mechanical properties. In recent years, the SPLab has pioneered the use of a reinforced open-cell structure incorporating paraffins, made in thermoplastic polymer. Improvement of both mechanical properties and regression rate have been observed experimentally and studies are targeting the characterization of associated phenomena and the investigation of different materials and shapes.