# PRICE

**Carbon-epoxy Prepreg For Aerospace Applications**

**IMAST partners involved:**

- **Avio** S.p.A.
- **CNR** - Institute of Composite and Biomedical Materials (IMCB)

The research activities, carried out in the frame of the project PRICE, were focused on the application of filament-winding technology to the production of motors cases for space launchers, by using a carbon-epoxy composite material.

Avio produces solid- and liquid-propellant propulsion systems for space launch vehicles. For Vega, Avio is responsible for the three solid propellant motors implementing innovative carbon fiber engine structures allowing a significant weight containment through the use of filament-wound composites.

Composites industry is largely based on epoxy resins whose performance are strongly influenced by the constituents chemical-structural properties and by process conditions. Moreover, chemical stability is also a key issue to optimize the productive cycle.

**Achievements**

The objective of PRICE is the development of innovative epoxy resin able to satisfy the requirements of innovative prepreg tow (carbon fiber with 12-18k filaments impregnated with epoxy resin) and tape (tow placed side by side at variable width and length).
In the frame of the PRICE project, a thermosetting formulation characterized by a long shelf-life and high thermomechanical performance was identified. Two epoxy components (based on DGEBA) and a reactive diluent have been cured with DDS in order to control the rheological features with respect to temperature and the reaction conversion degree. DDS curing agent was selected to achieve low reactivity at room temperature and improved thermo-mechanical features at the end of the conversion cycle. Reticulation kinetic for the identified epoxy formulation has been studied by analysing the dependency of viscosity with respect to temperature and conversion degree through DSC and rheological tests. Calorimetric data were analyzed using the most recently developed models proposed in literature. It was confirmed that the reaction goes on through an autocatalytic mechanism with a total order of reaction of 1.8 and an activation energy of 54 KJ/mol.
Numerical tools were realized to simulate the impregnation of dry fibers when subjected to the calendering process. The models integrate Navier-Stokes and Darcy equations. A multi-objective optimization process was carried out to identify the optimal working conditions to maximize impregnating resin and, at the same time, minimize dispersed resin.
Process parameters have been selected to optimize the curing process of laminate composite coupons. Compacting parameters have been determined through a testing campaign aimed to obtain an innovative composite coupon with tested mechanical, chemical and physical properties.

Very slow (1 °C/min) temperature ramps including long plateau (18-20 hours) have been used as reference. Starting from these reference cycles, a number of tests have been conducted to correlate the Tg with the curing cycle. On the basis of the Tg obtained, post-curing was adopted, exposing coupons to additional heat. Post curing consists in putting a cured composite component at an elevated temperature to complete cross linking in the epoxy to improve it's strength and temperature resistance. Through the post curing phase, a 170°C Tg was achieved.