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LOW COST FILAMENT-WINDING TECHNOLOGY FOR SMALL AEROSPACE LABORATORIES AND STARTUPS

Abstract

Despite the fact that the winding technology has been used intensively in aerospace industry since early 1940s, the acquisition of composite structures having unique shape of revolution and dimensions by university laboratories or small startup companies is a very expensive undertake. The presented paper reports the current status of the development of low cost filament winding technology for fabrication of expendable and/or reusable composite structures for aerospace applications, such as tubes, motor casings and pressure vessels. The main objective of the paper is to exchange experiences and best practices in the development of computer-controlled equipment, auxiliary tooling and control codes for the filament winding process of the small-size hybrid propellant motor casing with hemispheric ends and port openings. The main achievements are presented in three sections. In the first section, the target structure is defined with a design specification. The constituent materials, primary layup and stacking sequence of the composite structure are preselected. The structural analysis of the casing is performed by the methods of classical lamination theory and finite element method. The second section reveals the results of the design process of a 4-axis filament-winding machine and auxiliary tooling. The technology relies on wet winding technique. The descriptions of the general kinematic diagram of the machine and its principal mechanisms, the control system and its components, the computer configuration and control software, the geometry and composition of the mandrel are given in details in the section. The main components of the machine are aluminum profile for the structure and low cost electronic and electrical parts for the control system. The final section reveals the results of fabrication and testing of the casing. The nonslip geodesic path on the cylindrical surface and non-geodesic path on the spherical surface are obtained from the analytical solutions of the differential equations for the filament equilibrium on the surface that have been well documented in the literature. The G-code for controlling the four axes of the filament-winding machine is compiled manually after discretization of the analytical solution. This approach permits to avoid the use of expensive software for automated G-code generation. The testing procedure of the casing includes thickness measurements, non-destructive pressure test and static fire test. The cost of the project and recommendations for its further reducing are presented in the conclusion.