Ritz Method Analysis Of Rectilinear Orthotropic Composite Circular Plates

The implementation of composite materials is steadily growing in many industrial sectors, motivated by the increasing necessities, especially of the most demanding applications, of gathering high mechanical performances together with a limited mass amount. Therefore, the percentage of composite components in the overall project are continuously growing and, as a consequence, the problematic of assembling them arises in mechanical design. In this order of ideas, bolted joint connections represent the primary application because of their reliability, ease of installation and inspection. Moreover, the guarantee the possibility of disassemble the junction and, in addition, put together parts of different nature, such as composite and metallic ones. Consequently, the proper design of bolted joint connections turns out to be a critical task to accomplish within the realization of a complex mechanical device. Therefore, the proper simulation of these connections must be realized with high accuracy, even for the complex physical phenomena triggered by a bolted joint in its surroundings area as pointed out in many papers devoted to this topic.

The implication of these design issues are particularly important for the overall structural integrity. Subsequently, the final authors' objective regards the obtainment of a reliable, low-computationally demanding, custom Spot Joint Element capable of accurately simulating the structural behavior of a region surrounding the bolted joint, comprising the bolt and a circular portion of both the plates.

The Spot Joint Element was initially presented it is a finite element assembly devoted to the analysis of spot welded joint for metal sheets or riveted joints. The heavily reduced number of DOFs needed to perform the FE analysis of the spot joint - with no penalization in results accuracy - makes the architecture of this simulation tool very interesting even for the FE analysis of composite bolted joints, especially in case of multi-jointed structures. The theoretical formulation of this element is derived from the full analytical solution of the spot joint theoretical reference model, even beyond the elastic limit. According to the original formulation of the Spot Joint Element, the theoretical reference model consists in an annular plate characterized by a rigid core (when a bolt connection is considered) applied to the inner radius and fully clamped conditions at the outer edge along with isotropic material properties.

Preliminarily, the obtainment of the updated Spot Joint Element aimed to the accurate modeling composite and hybrid composite-metal bolted joints (object of future works) implies a mandatory preparatory phase which regards the characterization of its stiffness matrix terms. Therefore, the analytical study of the composite bolted joint theoretical model turns out to be necessary; this theoretical model consists in an annular plate realized in rectilinear orthotropic composite material with clamped outer radius and a central rigid core that must be solved under the action of various load typologies. The introduction of the rectilinear orthotropic material properties represents one of the most challenging issues to deal with in order to analytically solve the theoretical reference model; contrariwise, the current Spot Joint Element is based on an isotropic annular plate theoretical model and it features the capabilities of simulating of metal sheet spot joints with high accuracy.

With reference to the material properties, the composite circular plates are ascribable to two categories in relation to the disposition of the reinforcing fibers within the layers that compose the overall plate and, as a consequence, they are definable as circular orthotropic or rectilinear orthotropic. The category of circular orthotropic material properties, on the one hand, designate laminates in which the layers composing the composite circular plate present fibers organized along the circumferential or the radial direction and, as a consequence, the overall composite plate stiffness properties turn out to be axisymmetric. Conversely, the second group encompasses composite circular plates made up of layers, orientated as stated by the stacking sequence, featuring fibers arranged along rectilinear trajectories and consequently the global stiffness properties results to be dependent on the circumferential coordinate; i.e. these plates can be considered as if it were extracted from a common rectangular composite laminate. The last case is the one of interest for the theoretical definition of a custom composite bolted joint finite element.