REVIEW OF AUTOMATED TAPE LAYING TRAJECTORY PLANNING

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Introduction

It is commonly known that composite materials possess many advantages, such as high strength-to-weight ratio, stiffness-to-weight ratio and fatigue resistance, good shock absorption, and versatility in meeting design requirements.[1] Advanced Composite Materials (ACM) is now widely applied in areas of aerospace, aeronautics, defense and civil industry. How to reduce the manufacture cost is one of the essential subjects in ACM research. Automated Tape Laying (ATL) is a low-cost automatic processing technique. During the modeling process, a single prepreg tape is laid side-by-side on the mold surface driven by the robotic layer head.[2]

This composites manufacture method overcomes the restrictions of filament winding ("cyclical", "stability", "non-bridging" and the "nature path" trajectory design method) as well as succeeding its advantages.[3] The mechanical property of composite structures will be dramatically affected by the trajectory planning, since that it depends on the fibers mostly. Therefore, trajectory planning becomes into a significant subject with the development of ATL technique.

ATL trajectory planning based on the "Natural Path" method

The "Natural Path" is a typical ATL trajectory planning method, and this classic method is widely adopted in the ATL process in the past years, especially for open surfaces.

In 1987, Henry W. Lewis et al.[4] introduced the so-called "Natural path generation means". The essence of this algorithm lies in about the status of the prepreg tape, i.e. ensuring the tapes are laid without stretching or puckering. In this process, a step length the must be defined, which controls the moving distance of each point This is one of the earliest promoted algorithms of ATL, and based on ideal imagination. Within this algorithm, the edge points nearly move along with the direction of their own geodesics. However, the calculation accuracy is greatly affected by the step length, and a little reduction of the step length will cause a great increase in the calculation efficiency.

After the introduction of the "Natural path", many researchers were dedicated into its improvement. In 1991, Nobuo Shinno et al.[5] came up with a new method to control the tape affixing direction. To complete the calculation, the surface of an adhesion form should be finely divided in the form of a lattice in advance. In Reference [5], described is the way to find out the direction in adjacent quadrilateral, by the guide of the original line in the former quadrilateral. In this way, the geodesic lines can be easily generated. In 2007, Hu Cuiling[6] further the understanding of "Natural path". In Reference [6], the authors demonstrated that the "Natural Path" on developable surface equals the geodesics. In other words, if the laying surface is developable, the tape is affixed along the geodesic line within this algorithm. Meanwhile this Reference solves the trajectory planning problem by dividing the surface into triangle facets, in the similar way with Shinno's method. Moreover, Luo Haiyan et al.[7] adopted triangle meshes to approach a free-form surface through a commercial CAD software to output surface triangle list (STL) files. And then they also analyzed the surface in triangle mesh and generated the natural paths. In addition, the special situations are analyzed, i.e. the calculation of the path on surface boundaries is studied and the singularity

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question of passing the triangle vertex is solved.

ATL trajectory planning based on geometric shape

The complicated calculation is one of the defects of "Natural path generation means", which limit its application. Another type of ATL trajectory planning method is developed on the base of geometric shape. This kind of algorithm is suit for the trajectory planning of ATL products in regular shapes, especially in cones.

Zhang Zhenfu et al.[8] studied the ATL method for 0° plies for conical shell to improve the longitudinal performance of the composite conical shell. The prepreg tape should be cut into pieces of right angle trapezoid shape, according to desired dimension, and then laminated the prepared tapes on the mold. In this way, the production waste can be cut significantly.

In addition, Li Yong et al.[9] improved the former trajectory planning method and proposed the laminating method of manufacturing spiral-path plies in composite conical shell. The newly approved method can be applied to produce conical shell in different helix angles, thus it can meet the variety of demand in the producing process.

Summary

This article briefly reviews two kinds of major methods for ATL trajectory planning - ATL trajectory planning based on the "Natural Path" method and on geometric shape. As mentioned above, the former one guarantees the status of the tape, while it has the restriction for the low efficiency. And the later one makes the calculation more efficient, while it can only used on the regular shapes.

The popularizing of ATL, the ATL trajectory planning problem will be further studied for curtain. According to the works done by now, the future algorithm should balance both the calculation efficiency and the commonality.

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