Correction Method for Thermal Cure Deformation of Composites

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ABSTRACT

This paper takes composite fender as an example, based on the analysis of the existing problems of the traditional forming process on the overall thermal solidification forming of composite materials, combined with the actual situation of the manufacturing of composite fenders, and after the data model is analyzed, corrected and compensated for errors, the composite products are made, so as to meet the requirements of product accuracy.¹

INTRODUCTION

Composite material has the characteristics of high specific strength, high specific stiffness, high specific modulus, good durability, strong designability and easy integral molding, etc., which is highly favored by aircraft structure designers and has been widely used in aeronautical product design. Composite materials can make complex integral components with less number of components, high rigidity and good reliability. And, the composite material is used to make the fender 20 to 30 percent lighter than the metal parts[1]. The weight reduction effect is remarkable, and the weight reduction can effectively increase the vehicle's range. However the thin-walled composite material fender in the integral hot pressing solidification molding process, due to the thermal expansion and contraction characteristics and chemical shrinkage, causes composite material fender curing deformation, such as forced assembly must cause assembly stress, poor sealing etc., and reduces the

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duration of composite structures. Therefore, the analysis and controlling of solidification deformation are key technology in the structural design of composite materials.

The Analysis and Existing Problems Of Integral Hot-pressed Solidification Molding Deformation

Composite materials fender molding method commonly used autoclave integral solidification molding, fender belongs to the thin wall piece and job production, which cannot be obtained from mass production to the deformation law of the composite materials forming, so the deformation on the effect of the product precision cannot be well resolved, affects the composite product precision, and even affects the use, which mainly has the following three disadvantages:

1. Solidification deformation. Composite structure after high temperature curing and cooling process, due to the effect of thermal expansion and contraction, the chemical shrinkage effect of matrix resin, as well as composite materials with molding mould materials used on the thermal expansion coefficient of significant differences\(^2\), makes the parts between free shape precision and the design requirements at room temperature produce a certain degree of deviation, results in inaccurate stamping shape.

2. High mold cost. Metal material integrate processing and manufacturing is mostly used in the design manufacture of molds, the cost of materials and the processing cost are higher, cycle is long, the main material of composite mold tooling manufacture is Q235A, Invar and other metal materials, thickness of Q235A with complete specifications, the advantages of cheap, plentiful, but the difference between the thermal expansion coefficient and parts is bigger, so which is not suitable for manufacturing fender with precision composite parts; However, the Invar cost of thermal expansion coefficient close to the part is too high, and the thickness and specification are limited\(^3\), so it is difficult and costly to manufacture the die surface by cutting.

3. Long r & d cycle. In order to control the curing deformation, the traditional method is on the basis of trial and error (design, production samples, sample test) repeated adjustment and compensatory corrected on moulding surface used in curing process, to control the deformation degree and effect\(^4\), but the material is charge, and efficiency is low, especially for the large structure of the integral wing wall.

Compensation Method For Integral Solidification Of Body Fender

Using the body parts data model of profile as the raw data, and the data of geometric characteristics from the model of composite material specimens, deformation of the correction data is obtained by test specimens, considering the forming process and other influencing factors, the component data model of profile modification calculation and compensation caused by the error after molding, with the result of the correction data to build a profile, to make the mold molding, to
make composite material product, reduce the error and achieve precision molding. The method includes the following steps:

(1) Preparation of specimens. According to the raw data of the different type of the structure, characters of composite materials and parts for model, choose the appropriate area in specimens in the preparation of special die area to make specimens, the specimens orientations, layer number and curing process are the same as the composite material parts which need to manufacture, to ensure the similarity of specimens and the composite parts. The sample specimens preparation of the special mold is shown in figure 1.

(2) Acquisition of test piece deformation data. After the test piece was completed, the test piece was measured, and the measured results were analyzed and compared with the original data of the special mold surface, to obtain the relationship between the curvature radius before and after the test piece deformation, the Angle relation of the model surface, the expansion rate and other parameters, and to establish the test piece deformation database.

(3) The extraction of geometric features of the moulding surface of composite materials. Three main parameters were extracted from the original data of the part number model surface: F of the part forming surface, modified calculation datum line B and datum point P, as shown in figure2.

(4) Process the original section curve before modification and calculate the new section curve after modification. The original section curve before modification is processed according to step (3), and the modified data is obtained according to step (2). The new section curve of composite material part profile is modified and calculated. The specific content and steps of the modified calculation are as follows:

① The rest is based on the geometric features extracted from step (2), starting from point P on the base line B, taking points by spacing or ratio, and taking the number of points by interval or ratio as i, i =1, 2... N, as shown in figure 3. Where, the end point of B is a must-choose point, and n is the maximum number of points to be selected. The larger n is selected, the more i is selected, the higher the precision is.

② The original section curve before the correction is extracted, the normal plane of B is made for the selected point, and the intersection line between the normal plane and the formed surface F is obtained. Every point i selected by steps is a section curve, so a set of section lines are respectively L1, L2 Where n is the number of section curves, as shown in figure 4;

③ Each original section curve obtained by step ② is processed by subsection. The selected section points are Pt, and the number of section points is t=1, 2... M, and m is the number of segment points, the principle of the piecewise point Pt selection is an original cross section curve of each curve radius of curvature difference less than the theoretical value of the part in this section curve, the start point of Pt on the basis of whether the parts are symmetrical, when the part is symmetric structure, based on cross section curve midpoint to both ends of the
fragment, otherwise based on one of the endpoint to the other end of the block, as shown in figure 5.

Based on the test results, calculated the curvature radius change of each section curve of the original section, as shown in figure 6, and calculated the length and size change according to the heat expansion formula

$$\Delta L = a(t_1 - t_2)L$$

(1)

Where, $\Delta L$ is the length change of the intercepted curve segment;

$a$ is Linear expansion coefficient of composite material;

$L$ is the length of the intercepted curve segment;

$t_1, t_2$ are the initial temperature before and the termination temperature after heating of the composite.

The section radius, length and geometrical position relation of each section of the original section curve were calculated, repeat step ①~④ and obtain the location and shape of the section curve.

Draw the mold surface after compensation. According to the modified section curve, 3d CATIA software is used to automatically generate the formed surface after compensation. The formed surface after compensation is used as the formed surface of the composite manufacturing mold.
CONCLUSIONS

(1) Aiming at the disadvantages of traditional process method of integral thermal curing molding of composite body panels, this paper proposes a set of practical deformation analysis and compensation control method, which has been proved to be effective in reducing wing deformation, reducing cost and shortening research and development cycle through trial production of specimens.

(2) The method of deformation analysis and compensation control is to obtain deformation data, modify wing data model, rebuild mold mathematical model with modified data, reconstruct mold numerical model with reconstructed mold, and make composite products with modified data, finally achieving precision requirements and achieving precision molding.

ACKNOWLEDGEMENTS

Heilongjiang higher education teaching reform research project (SJGY20170318);
East University of Heilongjiang core curriculum program (1720403);
East University of Heilongjiang core curriculum program (1810405);
East University of Heilongjiang university level horizontal item project (HDFHX180110).

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