A mixed shimming method in eliminating the gaps during the assembly process of the complex structures

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Abstract. The assembly gaps has been an essential part in the quality assessment process in the field of building the aircrafts. To figure out the changes of the whole structures caused by the assembly gaps, some specific experiments are carried out by recording the shape deviations of the relevant components. And the specific shim with the epoxy and glass fibre mixed is utilized for compensating the gaps, where the solid shim can also be applied. The comparison of compensating effects of the different shims has been illustrated as follows, in which the deformations was prevented effectively with the aid of either of shims. However, deformations in the roots of the gaps can be better limited by the mixed shim, where the max strain can be decreased by around 20%.

1. Introduction

Large CFRP components are more likely to suffer deformations and variations compared with others. In the aerospace manufacturing industry, the deviations from the components has been a trouble which should be carefully avoided. The deformations of the components can cause a lot of problems constricting the final product quality. That is the reason why the size and tolerance are kept tight during the quality assessment process. Assembly gaps are the most obvious improvement of the deformations existing in the components. The assembly process suffers the deformation influence gathered from the manufacturing process and materials preparation process such as drilling deviations of tough materials, the warping of the forming mould. Moreover, the various sub-assemblies could also generate shape deviations of the components. Assembly gaps may produce unexpected effect on the whole structure. Some people have studied the assembly gaps for many years.

McCarthy found the gaps between the components can influence the assembly accuracy of the structure [1]. McCarthy found the gaps between the bolts and holes can affect the joints stability [2]. Zhai illustrated the influence of gaps during the wing box assembly process [3]. To promise the assembly quality of the products, some compensating methods should be carried out. Shimming method is one of the most effective way to fill up the gaps. Shimming methods can be classified by the material forms, which is fluid, solid, separately. The liquid shim is usually used for the tiny-sized gaps (smaller than 0.7mm) [4]. Quick shimming method have also been researched by many people. Fabian tried to evaluate the shapes of the gaps relying on the 3D scanning method and produced the shims by 3D printer [5]. Comer analysed the Thermo-mechanical fatigue of the liquid shim used in the hybrid joints [6].
Wang researched the mixed shims and studied the function of mixed shims in the assembly automation process [7].

The application effects of the mixed shims on the assembly gaps are studied in this paper. The comparison between the solid shims and mixed shims are illustrated by the measurement of the deformations. The measuring results of strain on the testing structure are demonstrated in next chapters.

2. Experimental Process

The experiments about the effect validations of the mixed shim were based on the deformations detecting of the wing box. The wing box was constructed by four composite components as well as several carbide bolts and nuts, shown as figure 1. The assembly process of the wing box can be established in three steps:

1. Complete assembly parts (ribs, upper surface and lower surface).
2. Drilling on the ribs and surfaces.
3. Bolting of the ribs and surfaces.

The gaps could be generated in the first two steps. And the gaps between assembly components were usually unpredictable in shape features. The gaps in this wing box were unequal in depth while the positions of them perform the same regularity, which are at the combination of the end of the ribs and the surface. Each rib contains two places of curvature changes, existing on both sides of the structure.

![Figure 1. The structure of the CFRP wing box (a) ribs; (b) upper surfaces](image)

Mixed shims were hybrid of glass fibre and the epoxy EA9394. The glass fibres performs good strength of resistance to compression, while the epoxy contains good mobility which can fill up the small gaps. Compared with the shim of single state, the combination of them can perform better in resisting compressing and the completeness of the filling shim. The glass fibres and the liquid epoxy are shown in figure 2(a), (b).

![Figure 2. The demonstration of the raw materials used in mixed shim (a) glass fibre; (b) epoxy EA9394](image)

The testing of the structure deformation was finished by measuring the strains. Strains of both the ribs and skins were measured at the same time. Furthermore, the positions of the strain gauges were also picked up according to the structural features. In this wing box, the strain gauges were mainly installed in the maximum gaps and the places of gaps generations where the related positions of surfaces and ribs are involved. To manage the gauges better, they were divided into two groups based on the distribution of shim, which are “gapping” group and “filled” group. Gauges stuck on surfaces and ribs separately were also distinguished by the positions and the corresponding subscripts of the groups are “S” and “R” in the pictures. Practical measurement set up can be seen in figure 3. The results of the strains on both ribs and upper surfaces were listed in next chapter.
3. Results and discussion
The effectiveness of mixed shim is validated by comparing the deformations illustrated as strains of ribs and surfaces. The strain gauges pasted on ribs and surfaces were recorded during the loading process, where the applied torque contains two mainly stages: 4Nm and 8Nm respectively. Besides, the tightening sequence of the bolt was also kept the same.

Strain gauges were mainly grouped into two, the gapping one and the filled one. The gauges of two groups were pasted based on the same principle. Measuring results are shown in figure 4. From the figure 4(a) (b), the strains of the group Filled (4, 5, 6) are much smaller than group Gapping (1, 2, 3) under torques 4Nm whether in the surfaces or the ribs. After increasing the values of torques from 4Nm to 9Nm, the difference of strains between the two groups are also quite evident, which perform the same trend like that under the torque 4Nm. The detailed results are shown in figure 4(c) (d). Furthermore, the maximum strain of the whole structure happened in the places of gaps generation, which is much more obvious than that of other places whether in ribs and surfaces.

**Figure 3.** Position of strain gauges

**Figure 4.** Measuring results of the shape of surface: (a) strain of upper surfaces at 4Nm; (b) strain of ribs at 4Nm; (c) strain of upper surfaces at 9Nm; (d) strain of ribs at 9Nm
For these uneven gaps of the assembly structures, the regular solid shims cannot fit the shapes very well, especially the birthplace of the gaps, shown as figure 5. The unfitting of the gaps and shims will affect aerodynamic performances of structures. The shims mixed of glass fibre and epoxy, containing both mobility and sturdiness of the two materials, can solve the fitting problems very well. Moreover, the mixed shim can promise the balance between product quality and efficiency while the labour force can be economized.

![Figure 5. Different shims on gaps: (a) solid shims; (b) mixed shims](image)

4. Conclusion
In this paper, some experiments of designed shim are produced and executed. Some specific shaped assembly gaps are gathered in an assembled wing box. To meet the fitting demands of the compensating, some glass fibre are mixed with the liquid epoxy for the better performance. And the mixed shims have proved its effects in filling up small-sized assembly gaps. More experiments should be designed for the improvement of the mixed shims in large-sized gaps in the future.

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