VOID FORMATION AND DISTRIBUTION DURING CFRP CURING PROCESS

Dongkangkang Chen[1], Yumin Zhang[2], Yufeng Zhou[3]

[1] Science and Technology on Advanced Composites in Special Environments Laboratory, Harbin Institute of Technology, Harbin 150001, People's Republic of China, kathychen@hit.edu.cn
[2] Science and Technology on Advanced Composites in Special Environments Laboratory, Harbin Institute of Technology, Harbin 150001, People's Republic of China, zhym@hit.edu.cn
[3] Science and Technology on Advanced Composites in Special Environments Laboratory, Harbin Institute of Technology, Harbin 150001, People's Republic of China, zhouyf@hit.edu.cn

Keywords: CFRP, porosity, curing reaction, distribution characters, industrial CT

ABSTRACT

1 INTRODUCTION

The excellent properties in carbon fiber reinforced polymer composite make it receive widespread attention in the field of large aircraft design and manufacture [1-2]. The application of CFRP composites also play a key role in the constitution of aerospace plane and its components [3]. However, due to the structure and the organization form principle of the composite component, defects such as porosity and layering will occur in the CFRP composites in the process of manufacture and working. Those defects will also extent and transfer accordingly with the change of the surrounding environment in the process of bearing and service [4]. This is a huge security risk for the application and service process of large aircrafts. Thus high precise and high efficient nondestructive testing and multidimensional accurate characterization system is imperative. However, it is extremely difficult to percept and characterize the defects and damages in the large size composite component, which requires developing of current conventional NDT methods [5-7]. To accurately and efficiently detect defects and damages in CFRP composite components, in addition to the study of the effective nondestructive testing and distribution methods in multi-scale defects and damage, it is also very important to do thorough research and analysis on the produce mechanism and extension, so we can scientifically evaluate the influence of the defects and damages to the bearing properties of CFRP composites.

2 EXPERIMENTS

This paper firstly summarize, calculate and simulate the qualitative and quantitative change of various parameters in the process of CFRP composites curing. Secondly the qualitative change curve and quantitative equations of the various parameters change with curing time will be acquired. Those parameters include the curing temperature, curing pressure, viscosity, surface tension, saturated solubility and so on, as shown in Figure 1, Figure 2 and Figure 3. The parameters will directly affect the pore nucleation and growth during the curing process. Thirdly the influence of various curing parameters on the formation, size and distribution of porosity will be analyzed from qualitative and quantitative angles. Fourthly after the fluid analysis and finite element analysis, the calculating formula and simulation curve of both the nucleation and growth critical size of pore occurring during the curing process will come out. Finally I can get the growth curve of the single pore in the process of curing from the data of nucleation and growth critical size with the change of curing time. The growth curve include the complete growing process of a single pore during curing, from its nucleation to the gradually growth, and to the final stable curve. By analyzing the three curves we can visually analyze the produce mechanism and propagation behavior of defects and damages during the CFRP composites preparation.

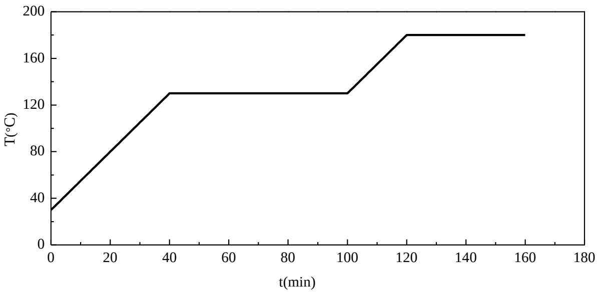

Figure 1: Temperature as a function of time during curing process.

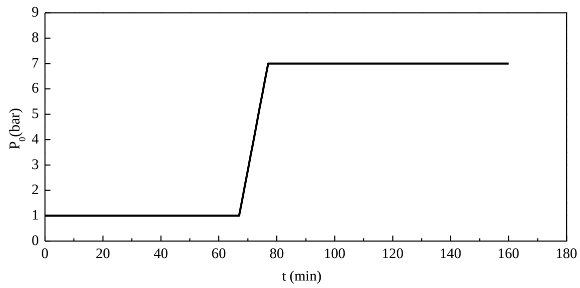

Figure 2: Pressure as a function of time during curing process.

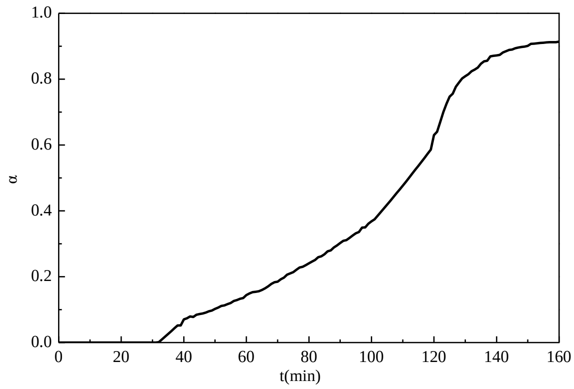

Figure 3: Curing rate as a function of time during curing process.

3 RESULT AND DISCUSSION

The paper measures the porosity of CFRP composites layer-by-layer by the means of the industrial CT, and observe the microstructure morphology of porosity. Then the paper use the Image Pro Plus software to summarize and analyze the images get from computed tomography, as shown in Figure 4. The rule of the shape, size and distribution of the pores in composites are qualitatively and quantitatively analyzed. The 3D porosity distribution patterns are produced. After analyzing the change of porosity in different direction, the paper receive the colorful pictorial diagram of porosity distribution and the law of porosity distribution of each CFRP composites section in different resolution, as shown in Figure 5.

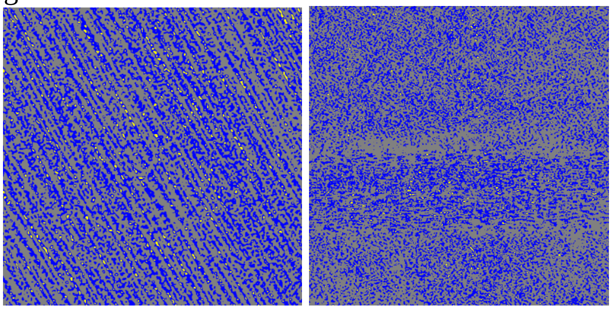

Figure 4: Void distribution in lateral and longitudinal direction (1μm solution) .

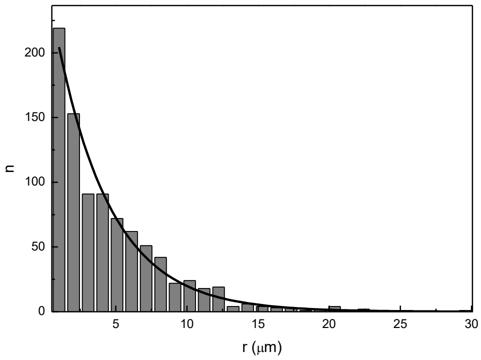

Figure 5: Rule of void size distribution in 1μm solution.

4 CONCLUSIONS

By the research of this topic, the paper will provide useful reference for the microscopic, mesoscopic and macroscopic characterization techniques of CFRP composites. It can also provide data of the produce mechanism and extension behavior of the defects and damages in the process of CFRP composites preparation. This is very significant for the study of multiscale composites damage and the research of defects of large composite bearing component. What's more, it is also very useful for the decision of the physical and geometrical forms of defects and damages in CFRP composites. Thus the paper lays a certain foundation for the study of precise and effective nondestructive testing principle and method of large composites components in aerospace plane.

REFERENCES

[1] Loos A C, Springer G S. Curing of Epoxy Matrix Composites [J]. *Journal of Composite Materials*, 1983, 17(2):135–169.

[2] Kardos J L, Dave R, Dudukovic M P. Voids in Composites [M]. New York: ASME, New York, NY, USA, 1988:v.

[3] Kardos J L, Dudukovic M P, McKague E L, et al. Void Formation and Transport During Composite Laminate Processing: An Initial Model Framework [J]. *ASTM Special Technical Publication*, 1983:96–109.

[4] Tang J M, Lee W I, Springer G S. Effects of Cure Pressure on Resin Flow, Voids, and Mechanical Properties [J]. *Journal of Composite Materials*, 1987, 21(5):421–440.

[5] Grunenfelder L K, Nutt S R. Void formation in composite prepregs – Effect of dissolved moisture [J]. *Composites Science and Technology*, 2010, 70(16):2304–2309.

[6] Page S A, Mezzenga R, Boogh L, et al. Surface Energetics Evolution during Processing of Epoxy Resins [J]. *Journal of Colloid and Interface Science*, 2000, 222(1):55– 62.

[7] Garschke C, Parlevliet P P, Weimer C, et al. Cure kinetics and viscosity modelling of a high-performance epoxy resin film [J]. *Polymer Testing*, 2013, 32(1):150–157.