CHAPTER 10

CURING OF EPOXY MATRIX COMPOSITES

A.C. Loos
Virginia Polytechnic Institute, Blacksburg, VA, USA
and
G.S. Springer
Stanford University, Stanford, CA, USA

ABSTRACT
Models were developed which describe the curing process of composites constructed from continuous fiber-reinforced, thermosetting resin matrix prepreg materials. On the basis of the models, a computer code was developed, which for flat-plate composites cured by a specific cure cycle, provides the temperature distribution, the degree of cure of the resin, the resin viscosity inside the composite, the void sizes, the temperatures and pressures inside voids, and the residual stress distribution after the cure. In addition, the computer code can be used to determine the amount of resin flow out of the composite and the resin content of the composite and the bleeder.
1. INTRODUCTION

Composite parts and structures constructed from continuous fiber reinforced thermosetting resin matrix prepreg materials are manufactured by arranging the uncured fiber resin mixture into the desired shape and then curing the material. The curing process is accomplished by exposing the material to elevated temperatures and pressures for a predetermined length of time. The elevated temperatures applied during the cure provide the heat required for initiating and maintaining the chemical reactions in the resin which cause the desired changes in the molecular structure. The applied pressure provides the force needed to squeeze excess resin out of the material, to consolidate individual plies, and to compress vapor bubbles.

The elevated temperatures and pressures to which the material is subjected are referred to as the cure temperature and the cure pressure. The magnitudes and durations of the temperatures and pressures applied during the curing process (denoted as the cure cycle) significantly affect the performance of the finished product. Therefore, the cure cycle must be selected carefully for each application. Some major considerations in selecting the proper cure cycle for a given composite material are:

a) the temperature inside the material must not exceed a preset maximum value at any time during cure,
b) at the end of cure, all the excess resin is squeezed out from every ply of the composite and the resin distribution is uniform,
c) the material is cured uniformly and completely,
d) the cured composite has the lowest possible void content, and
e) the curing process is achieved in the shortest amount of time.

At the present time, the cure cycle is generally selected empirically by curing small specimens and by evaluating the "quality" of the specimens after cure. Such empirical methods have several drawbacks; a) an extensive experimental program is usually required to determine the proper cure cycle for a given material, b) a cure cycle found to be satisfactory for a given material under one set of conditions may not apply under a different set of conditions, and c) they do not ensure that the composite was cured completely in the shortest amount of time.

The shortcomings of empirical approaches could be overcome by use of analytical models. Models applicable to different aspects of the curing process have been proposed by Springer and Loos [1-3]. In this paper, the different models are extended and combined into a comprehensive model which relates the cure cycle to the thermal, chemical and physical processes occurring in continuous fiber-reinforced composites during cure, and which then can be used to establish the most appropriate cure cycle in any given application.