RESIDUAL STRAINS IN THERMOPLASTIC COMPOSITES: EFFECTS ON LONG-TERM BEHAVIOUR

Patricia P. Parlevliet, Harald E.N. Bersee

Faculty of Aerospace Engineering, Delft University of Technology
Kluyverweg 1, 2629 HS Delft, The Netherlands

KEYWORDS: Residual strains, non-destructive testing, thermoplastic composites, classical laminate theory, long-term effects, ageing.

INTRODUCTION

After processing and subsequent cooling of composite laminates to the service temperature residual stresses arise due to the mismatch in coefficient of thermal expansion between the fibres and the matrix. The stresses may lead to dimensional changes, lower ultimate strength and premature initial cracking of the matrix and fibre-matrix interface (transverse cracks or microcracks), see figures below. These cracks may appear directly after cooling from the processing temperature, or in time due to ageing or stress relaxation, because of the time-dependent (visco-elastic) nature of the polymer matrix. Time-dependent (relaxation) behaviour was shown to be present [1] with the decrease of curvature for unbalanced composite laminates and increase in transverse crack density with time.

The state of internal stress within the polymer matrix will affect several physical properties of the polymer, such as the glass transition temperature ($T_g$), diffusion constants, refractive properties and barrier properties, and the residual stress might also interact with the time-dependent phenomena within the polymer, such as physical ageing. There are indications that ageing and long-term behaviour in composites develops much faster than in the unreinforced bulk polymer [2, 3]. Therefore, more research is needed in order to establish the exact mechanisms at hand.

The main goal of this project is to study the effects of residual stresses in thermoplastic composite structures in combination with the effects of ageing and the environment on the long-term properties of the composite structure. It will be investigated in literature and through experiments what the effects of these residual stresses on the properties are and in case these stresses prove to deteriorate the overall properties of the composite structures, methods to alleviate these stresses will be sought after. The materials under investigation are
thermoplastic composite structures, since in these materials the time-dependent (visco-elastic) behaviour is more pronounced when compared to thermoset materials [4] and not many research is available that studied the long-term effects on these materials, while they are being increasingly used in the (aerospace) industry.

**EXPERIMENTAL WORK AND RESULTS**

At present, several experiments are conducted that can be related to this project:

- A modified Classical Lamination Theory is applied to the Process Simulated Laminate technique by [5, 6] and verified with experimental results in order to establish the formation of residual stresses in the distinct plies in a thermoplastic composite laminate upon processing and subsequent cooling to the service temperature. (Time-dependent) dimensional changes will be taken into account.

- Several experimental techniques are studied for measurement of the time-dependent effects within the composite properties:
  1. Polarising Optical Microscopy for assessing the level of damage with time in composite structures. No mechanical or environmental treatment was given to these structures besides keeping them under normal laboratory environments and the already present residual stresses. We envisage identifying the geometrical effects on crack formation due to residual stresses.
  2. Feasibility of using hardness testing techniques to assess ageing, moisture absorption, stress relaxation, but also crystallinity level, degree of cure.
  3. Acoustic non-destructive evaluation (NDE) for detection of transverse cracks within a composite structure.
  4. Dielectric relaxation spectroscopy for measuring the effects of residual stress (relaxation) in the composite and bulk polymer.

If time allows us, we envisage studying the effects of additives or application of thermoplastic blends as a composite matrix on the durability of thermoplastic composites.

**CONCLUSIONS**

This abstract gives an overview of the current research within this project, whereas at the conference the first results for the measurements of the residual stresses in combination with the time-dependent damage (transverse cracks) in structures will be addressed.

**REFERENCES**


