THERMO-STRUCTURAL ANALYSIS OF CURING PROCESS AND DEMOULDING OPERATION USING ANSYS COMPOSITE CURE SIMULATION

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INTRODUCTION

The performance of the composite materials are strongly influenced by the production processes. In particular, for thermosetting resins, there are many factors causing residual stresses and distortions, such as thermal expansion, cure shrinkage and tool-part interaction. These lead to higher cost and lower component performance. Therefore, it is important to predict composite properties evolution during the manufacturing processes. Ansys Workbench and Ansys Composite Cure Simulation (ACCS) allow to study curing processes and demoulding operations by means of thermal and structural FEM analysis.

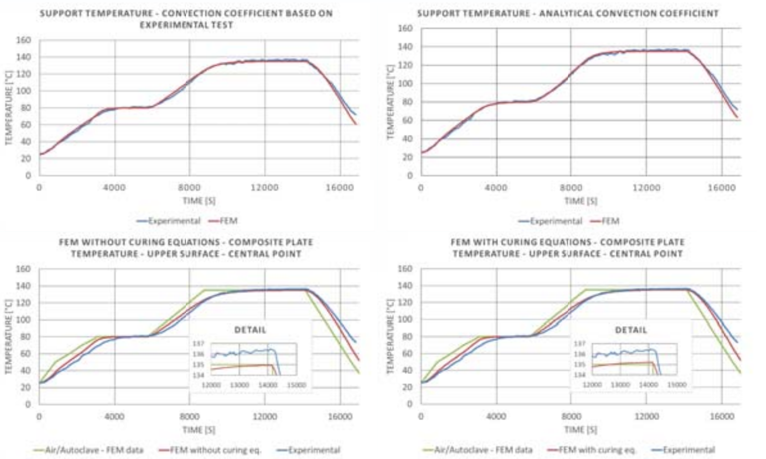
STUDY OBJECTIVES

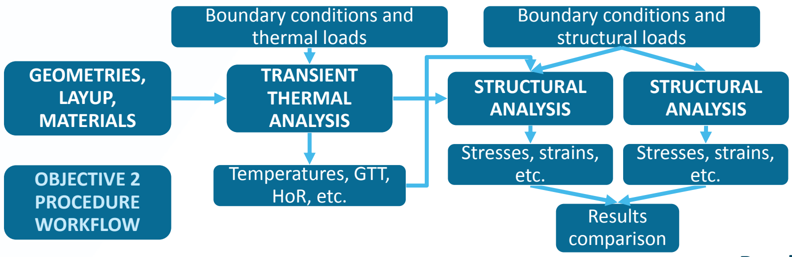
1. FE curing model design and calibration using experimental results for a composite plate (thermal analysis only)
2. Evaluation of aeronautical stringer performance after curing process and demoulding operation (thermo-structural analysis)

OBJECTIVE 1

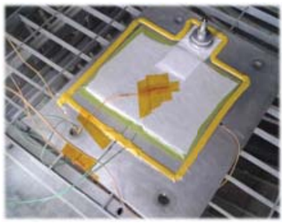
A numerical procedure for thermal analysis was developed.

- A laminated composite plate was cured in autoclave. During the process, mould and component temperatures were measured.
- Using experimental measures, different studies were carried out and a procedure to calculate the convective heat transfer coefficient was developed.
- Autoclave, support and composite plate were modelled in the virtual model; the vacuum bag was not created. Material data, composite stacking sequence and curing cycle were set up according to experimental test.
- All heat transfer modes (radiation, conduction and convection) were modelled and set up according to experimental data, analytical results and conservative suppositions;
- Two analysis were performed: with and without the activation of curing equations.

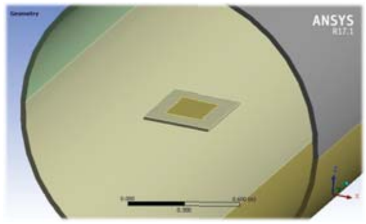




REAL MODEL



VIRTUAL MODEL



Results

The FE model permitted to obtain a good evaluation of the components behaviour during the curing process. Support and composite plate FEM results were in good agreement with experimental measures. In particular:

- the convection coefficients based on experimental data and analytical calculations allowed to obtain almost the same results. The developed procedures could be considered correct;
- thermal model without ACCS curing equations didn't predict the exothermic reactions, but it followed the experimental trend;
- thermal model with ACCS curing equations was in good accordance with experimental results, including exothermic reactions.

Future developments

Experimental campaigns will be executed in order to obtain more accurate materials data and to improve the composite material cure kinetic model; consequently, more realistic FE results could be achieved.

OBJECTIVE 2

A numerical procedure for thermo-structural analysis was developed.

- The thermal analysis model was similar to the previous one in the objective 1. The convection coefficient was set up using analytical procedure.
- ACCS curing equations were activated.
- A composite material aeronautical stringer made of AS4-8552 was analysed. Composite material data came from ACCS and ESAComp libraries, symmetric stacking sequence was supposed and curing cycle was set up following material datasheet.
- Only the stringer was modelled in the structural analysis.
- Constraints and loads reproducing the different operating conditions were used during the structural analysis steps.

Results

- Using the ACCS post-processing capabilities, it was possible to plot temperature trends and material properties evolution during transient thermal analysis. They were compatible with composite materials behaviour during the curing process. They allowed to evaluate the final material properties and performance.
- Structural analysis highlighted the spring back angle and the high induced stresses after demoulding operation.
- The comparison with the structural analysis without the cure effect showed the different performance influenced by induced stresses and strains.

Future developments

Experimental tests should be carried out in order to validate FEM results. An optimization workflow and an engineering design procedure could be developed to find the optimal support/tool compensation suitable to reduce distortions and induced stresses and strains.