Evaluation of process parameters

Project done by:
UBC

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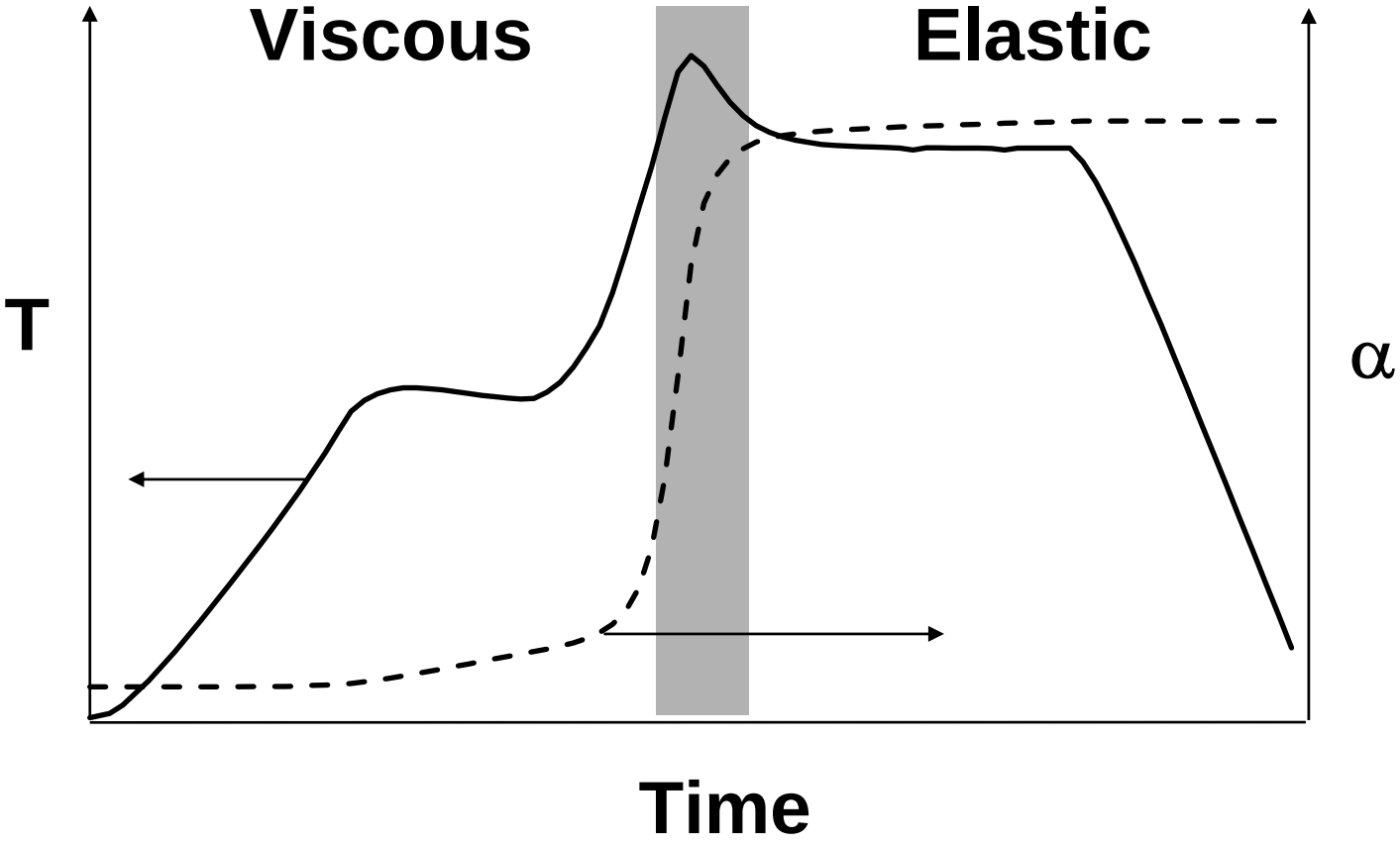
Summary:
Some simple case studies are presented to show the value of process modeling in predicting cure cycle lengths, fibre volume fraction distributions in simple shapes, and process and material variations in complex shapes.

References:

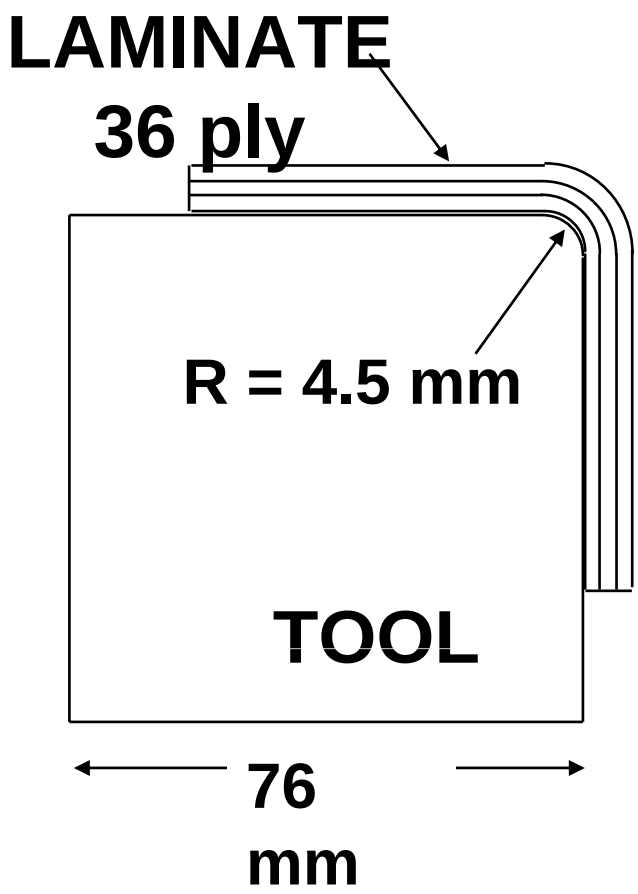
*Johnston A, Hubert P, Nelson K, Poursartip A. A Sensitivity Analysis of Factors Affecting the Warpage of a Composite Structure. Intl SAMPE Symp 1998; 43

Curing process

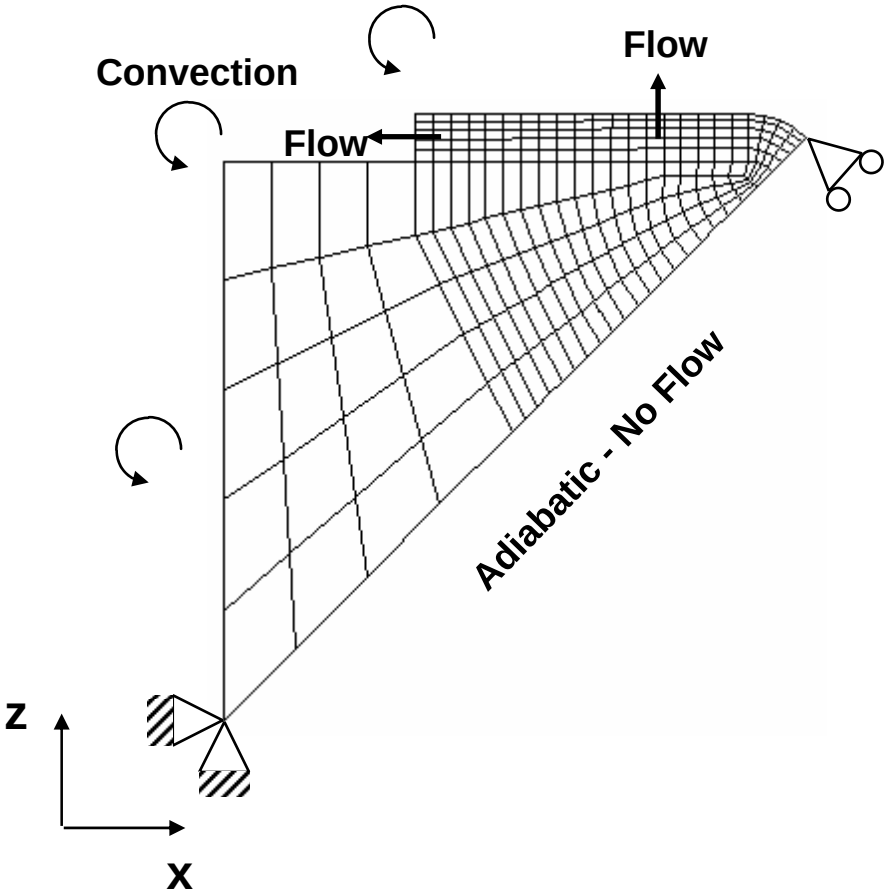
Typical temperature, degree of cure and material development during cure

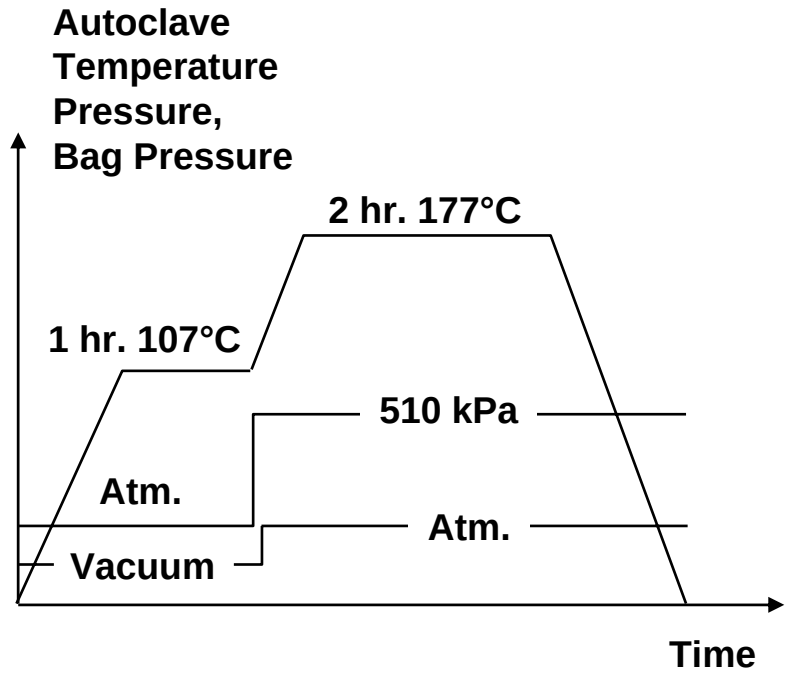


Case study – angle laminate

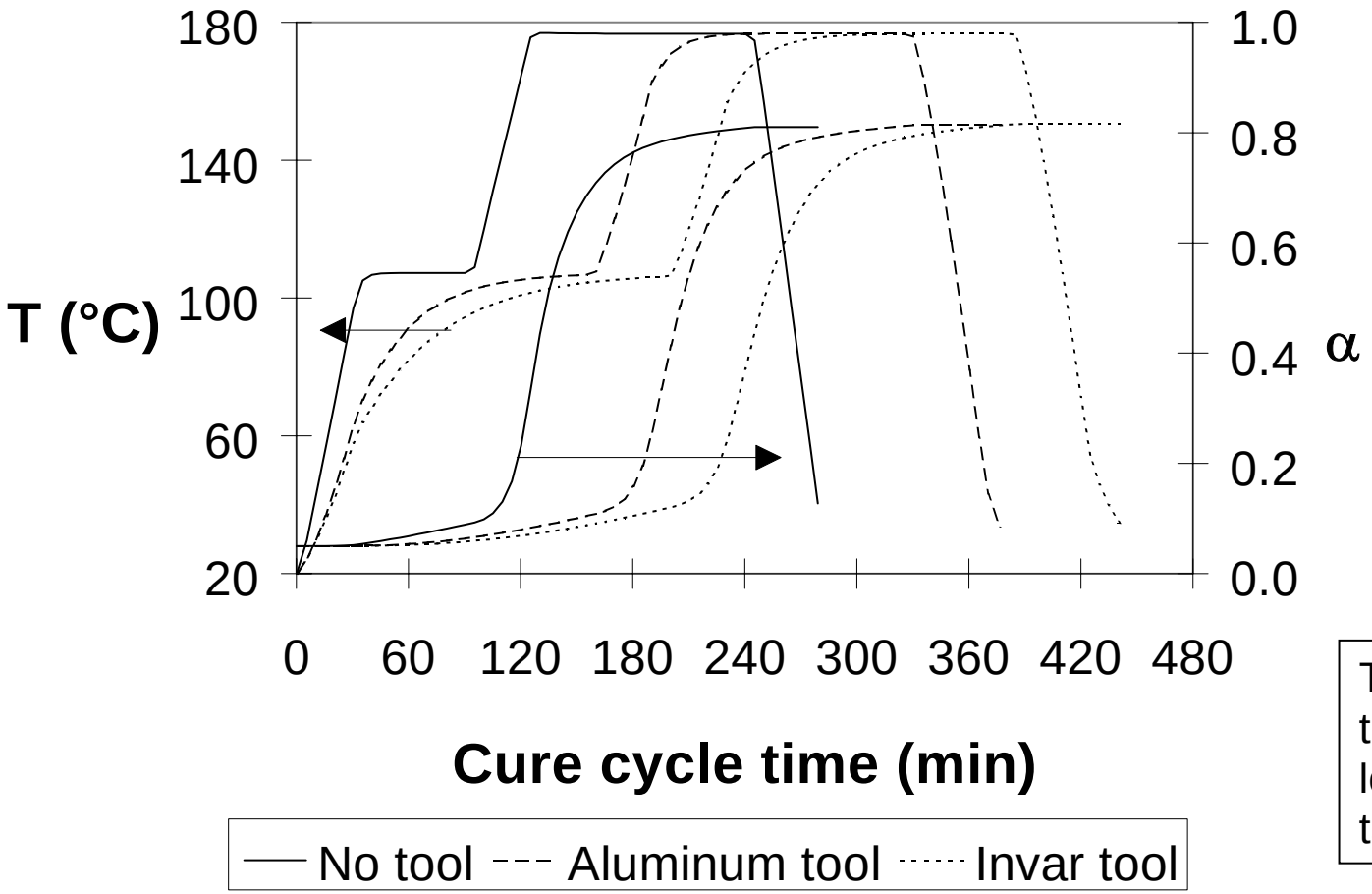


Defining the problem



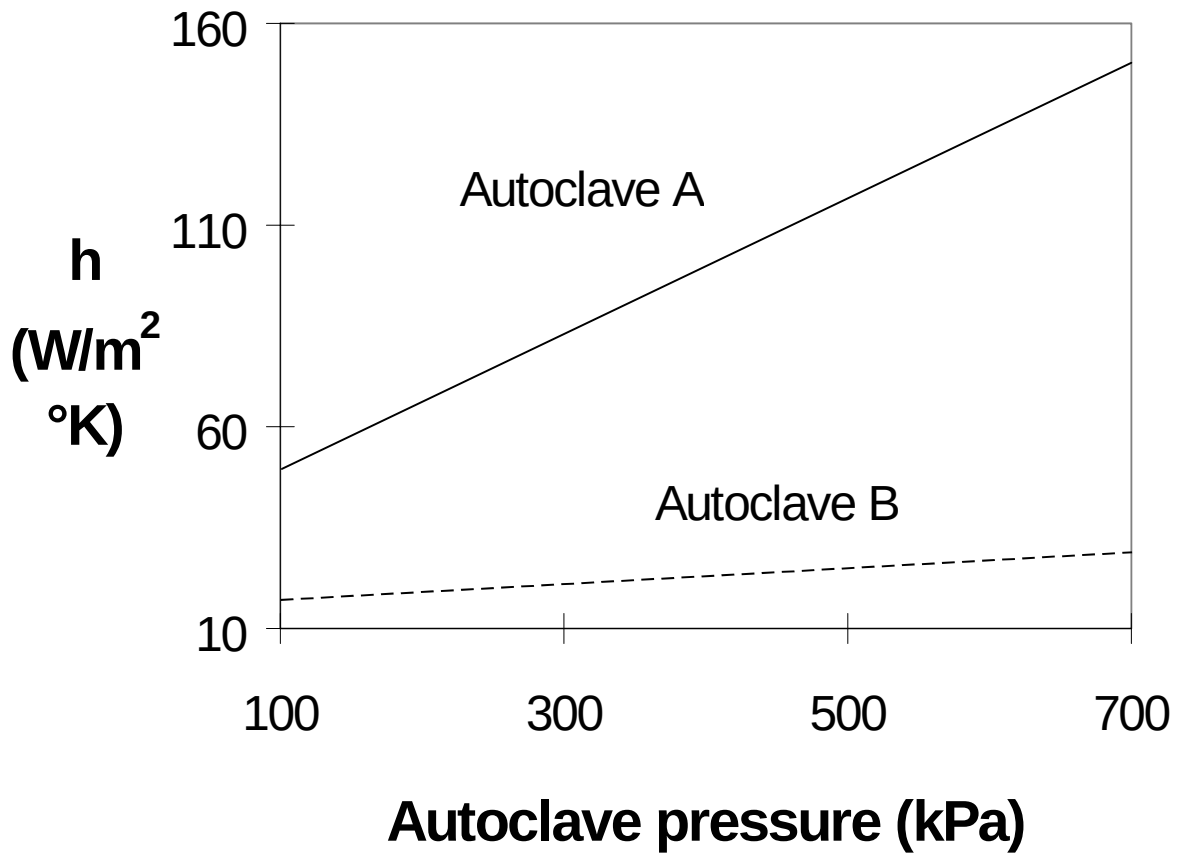


Effect of tool thermal mass on cycle time



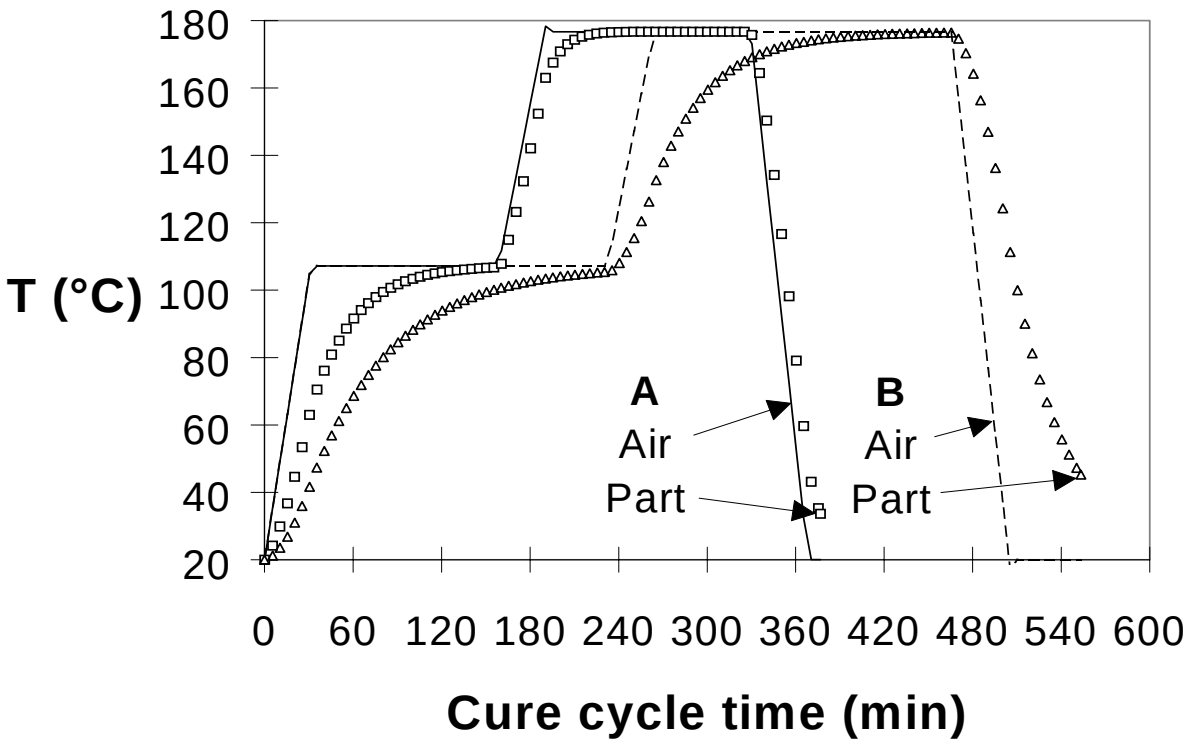
The higher the tool thermal mass, the longer the part takes to cure

Autoclave effects (1)



The heat transfer coefficient (htc) of an autoclave is an extremely important parameter. Most autoclaves are thermally mapped, but that is not the same as an htc map. Local air flow plays an important role in determining the value of htc.

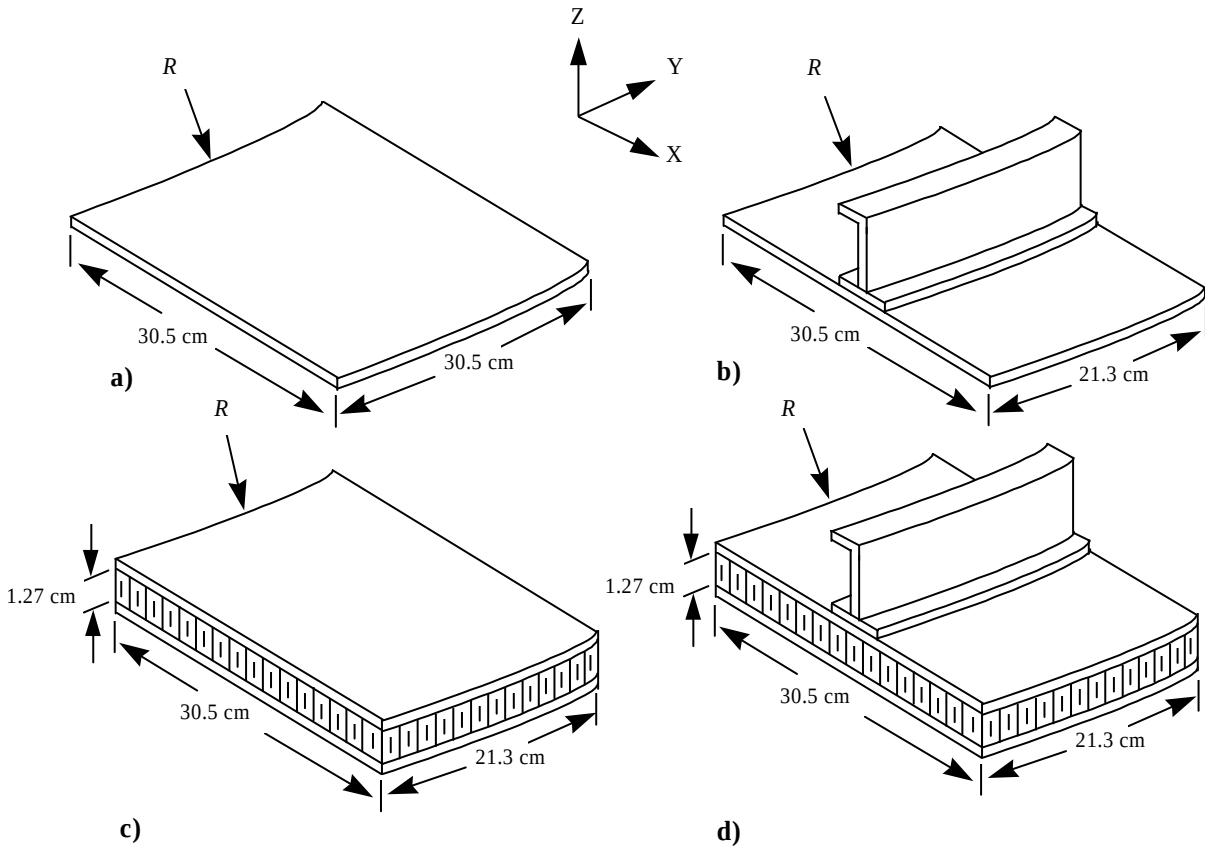
Autoclave effects (2)



Autoclave B, with a lower htc, gives a measurably longer cure cycle than autoclave A, with a high htc.

Although most industrial autoclaves have sufficiently strong airflows to avoid this kind of problem, it is still possible to optimize cycles by understanding the effect of pressure, loading, and airflow in the autoclave.

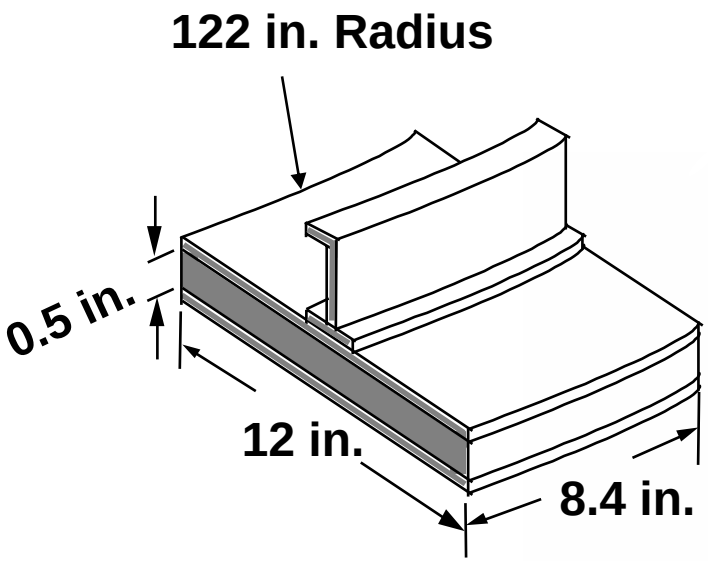
Case study: stiffened panels



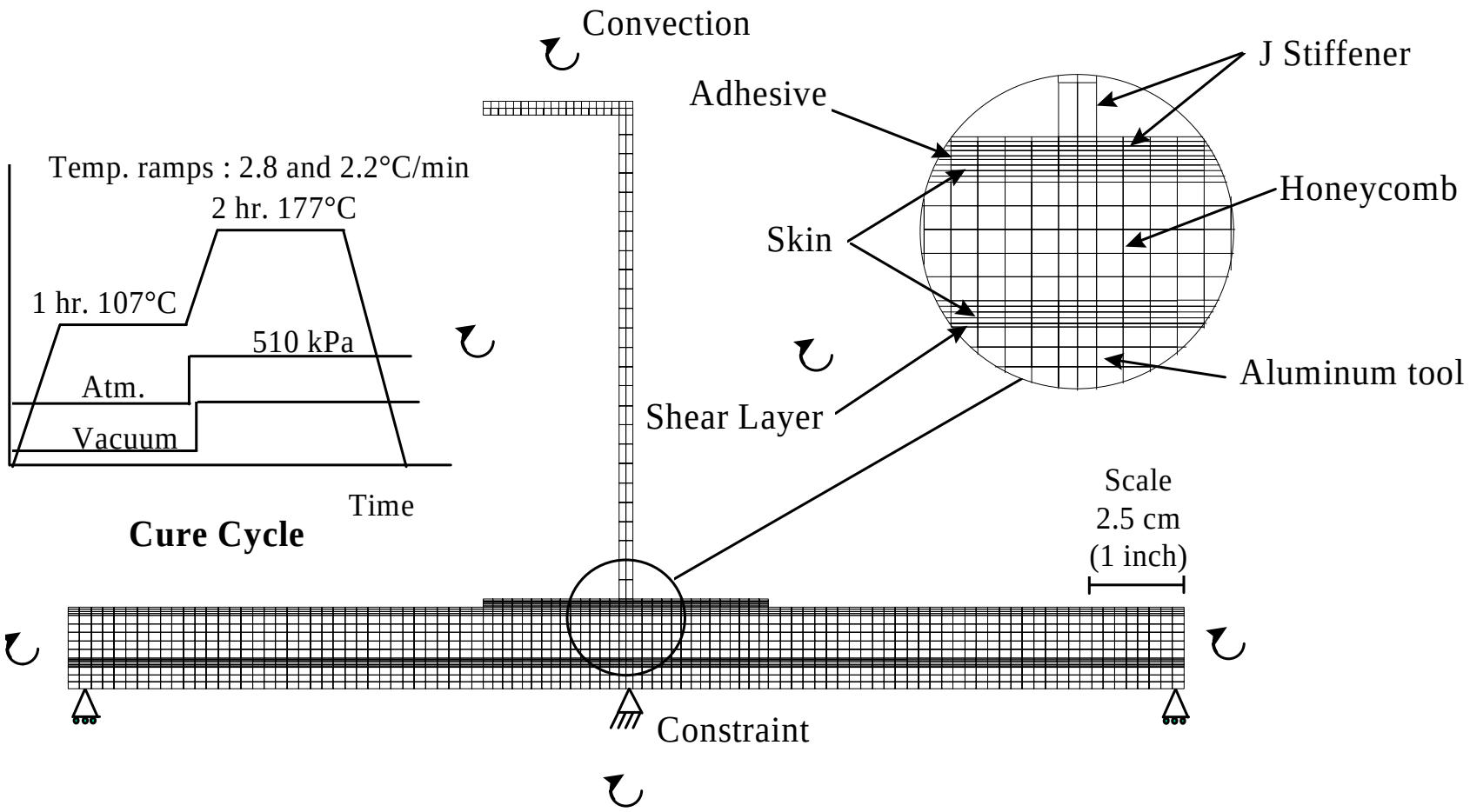
Notes:

- R = 3.10 m (tool side)
- Core - Hexcel Glass/Phenolic HRP with 130 kg/m^3 (3/16" cell dia.)
- Face sheet layup $[45/90/-45/0/45/90]_s$
- Frames pre-cured and adhesively bonded to face sheets

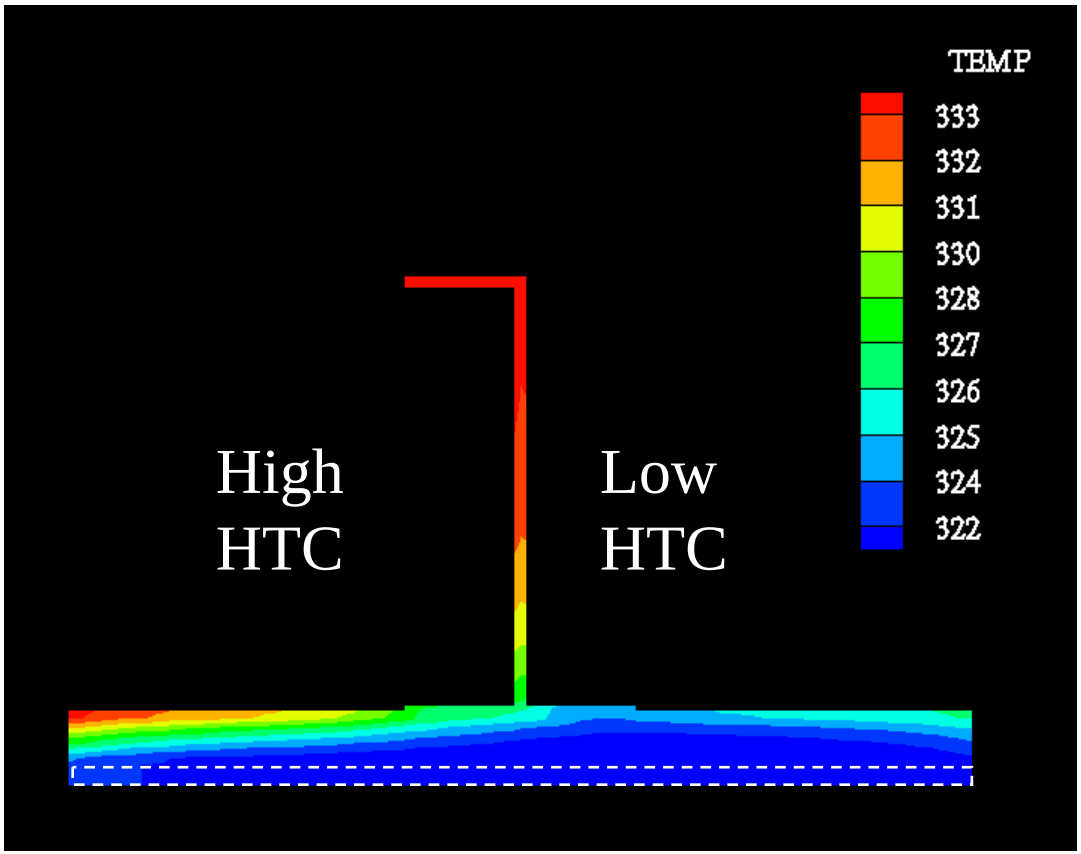
FE mesh of honeycomb panel



FE model set-up for honeycomb panel

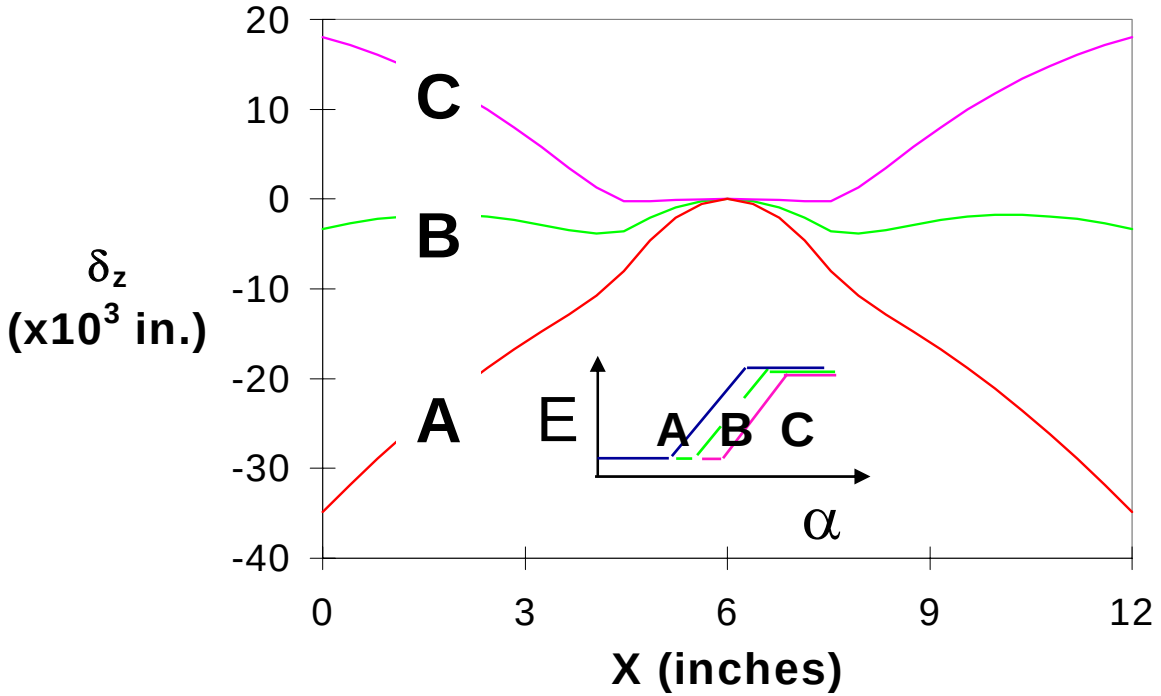


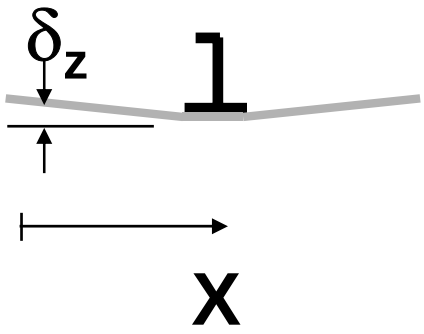
Predicted temperature gradients



Here we model the effect of a disturbance of air flow – one side of the stiffener has a lower htc than the other – as a result the temperature profile is asymmetric.

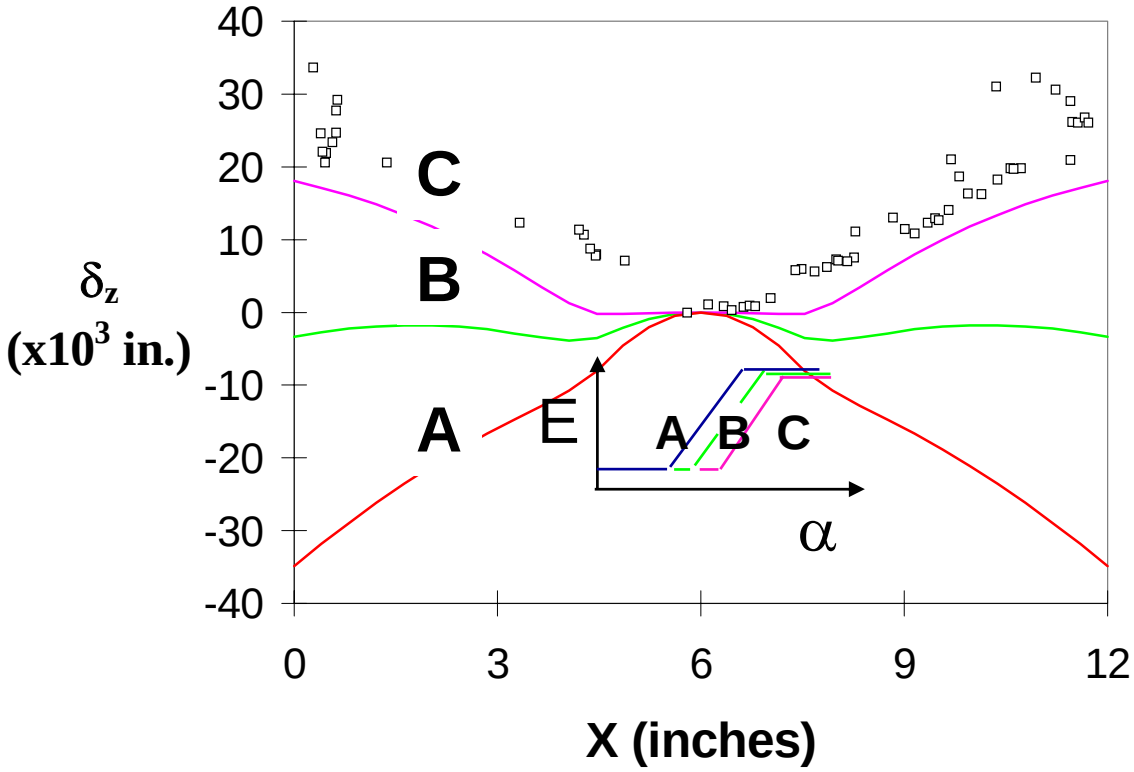
Effect of modulus development of the resin (1)

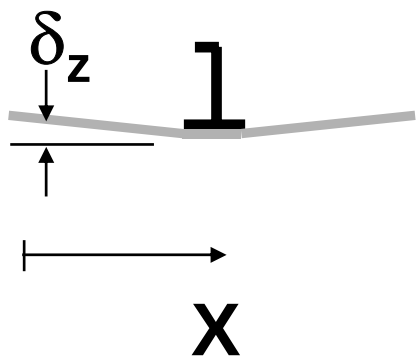




Good material data is critical – the development of modulus and load bearing capacity in the resin determines the overall distortion of the part.

Effect of modulus development of the resin (2)

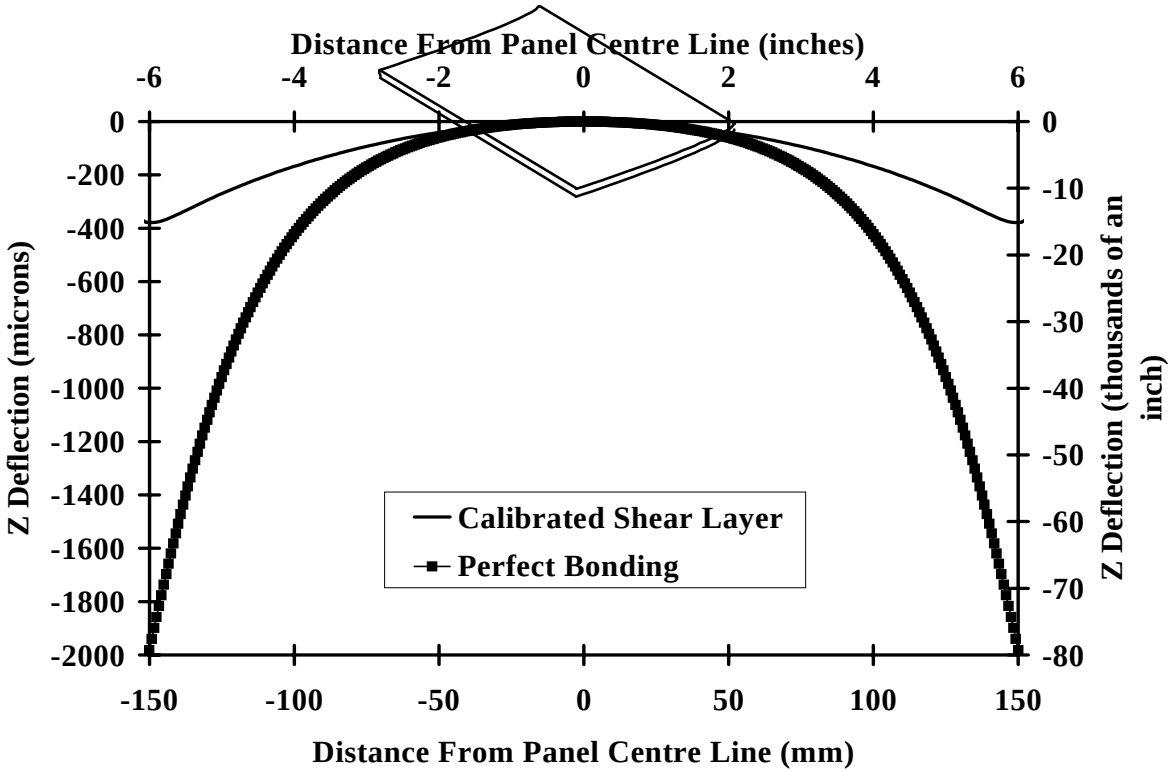




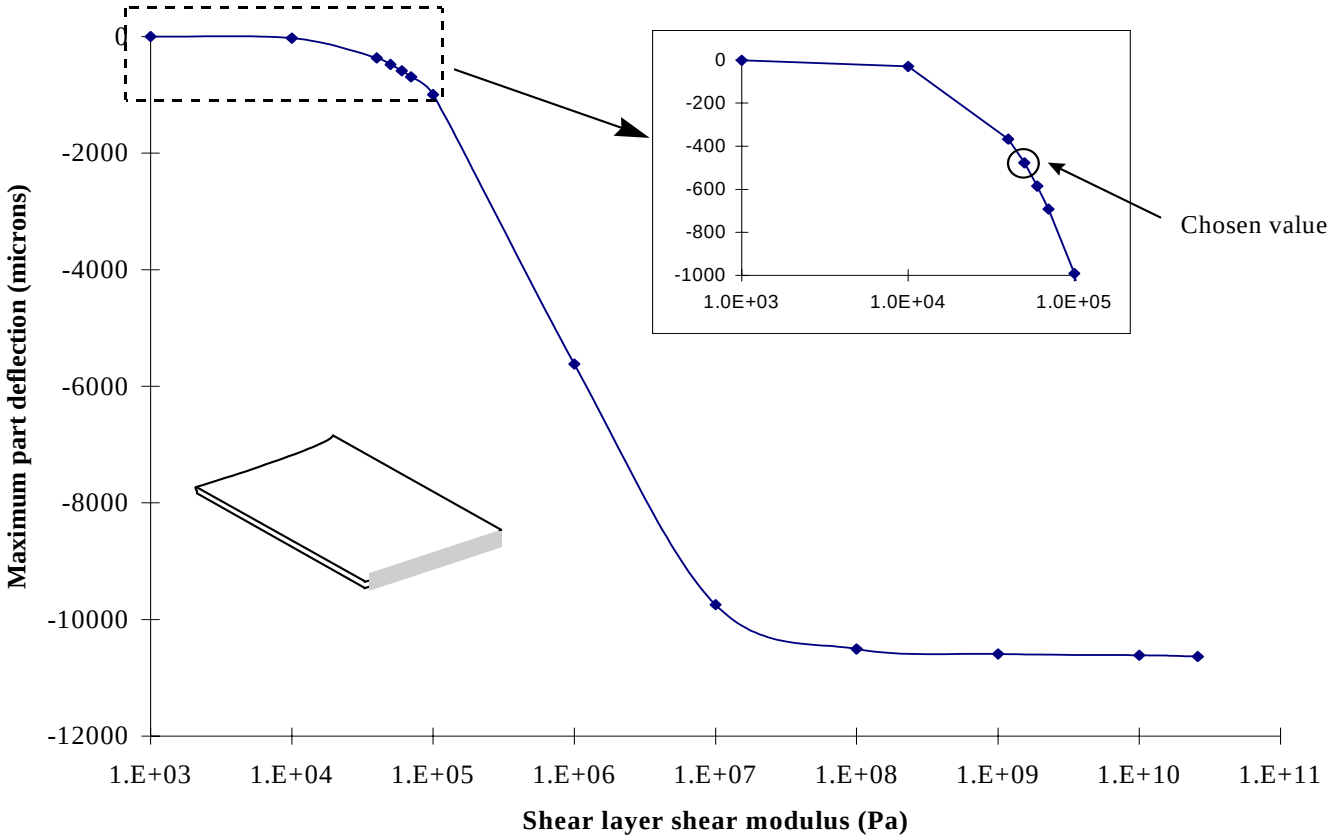
When the correct inputs are used, predictions are accurate.

Effect of shear layer stiffness

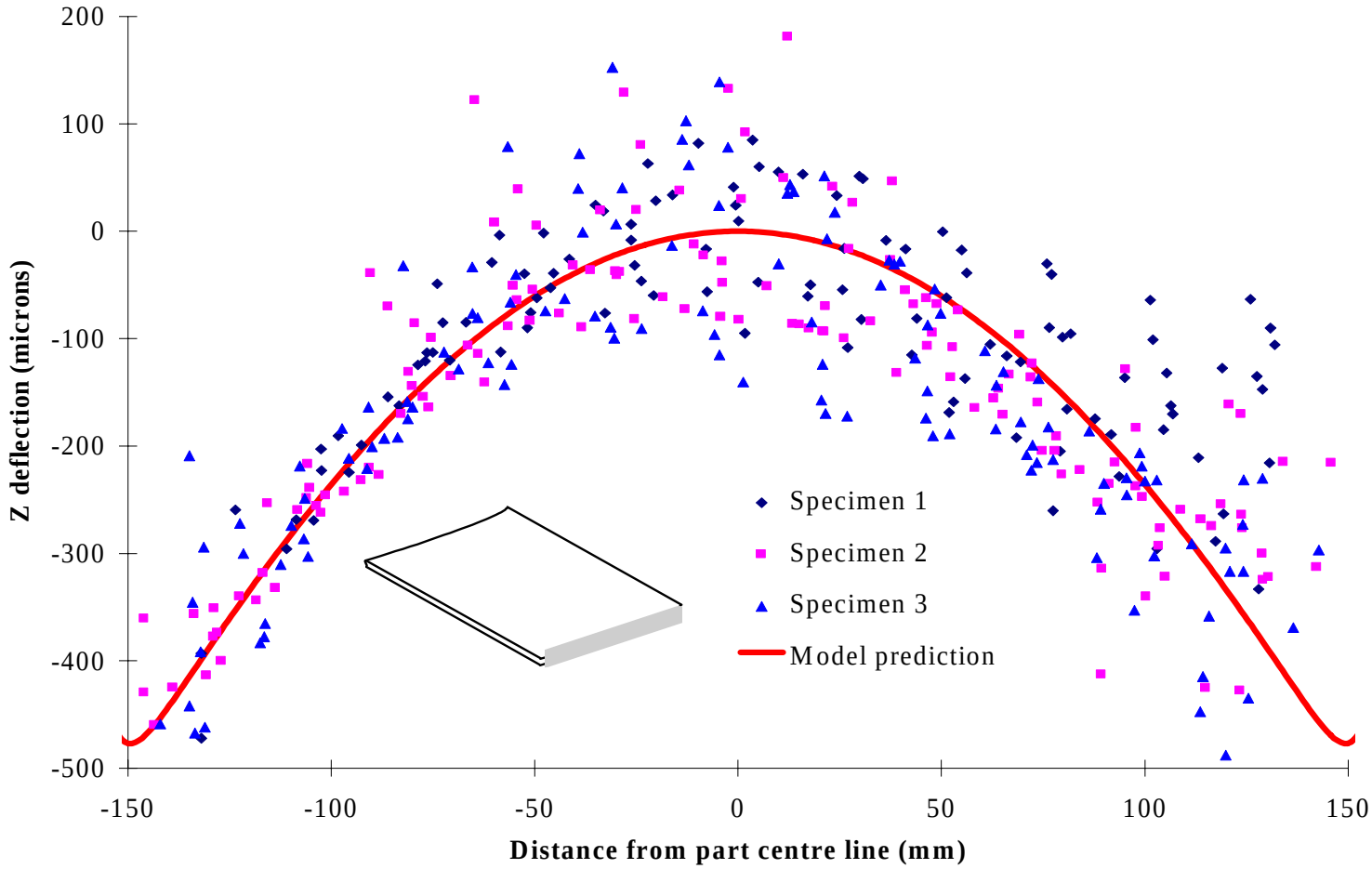
Shear layers are used to simulate the mechanical interaction between the tool and part during cure, and their properties need to be calibrated



Shear layer calibration using unstiffened skin part

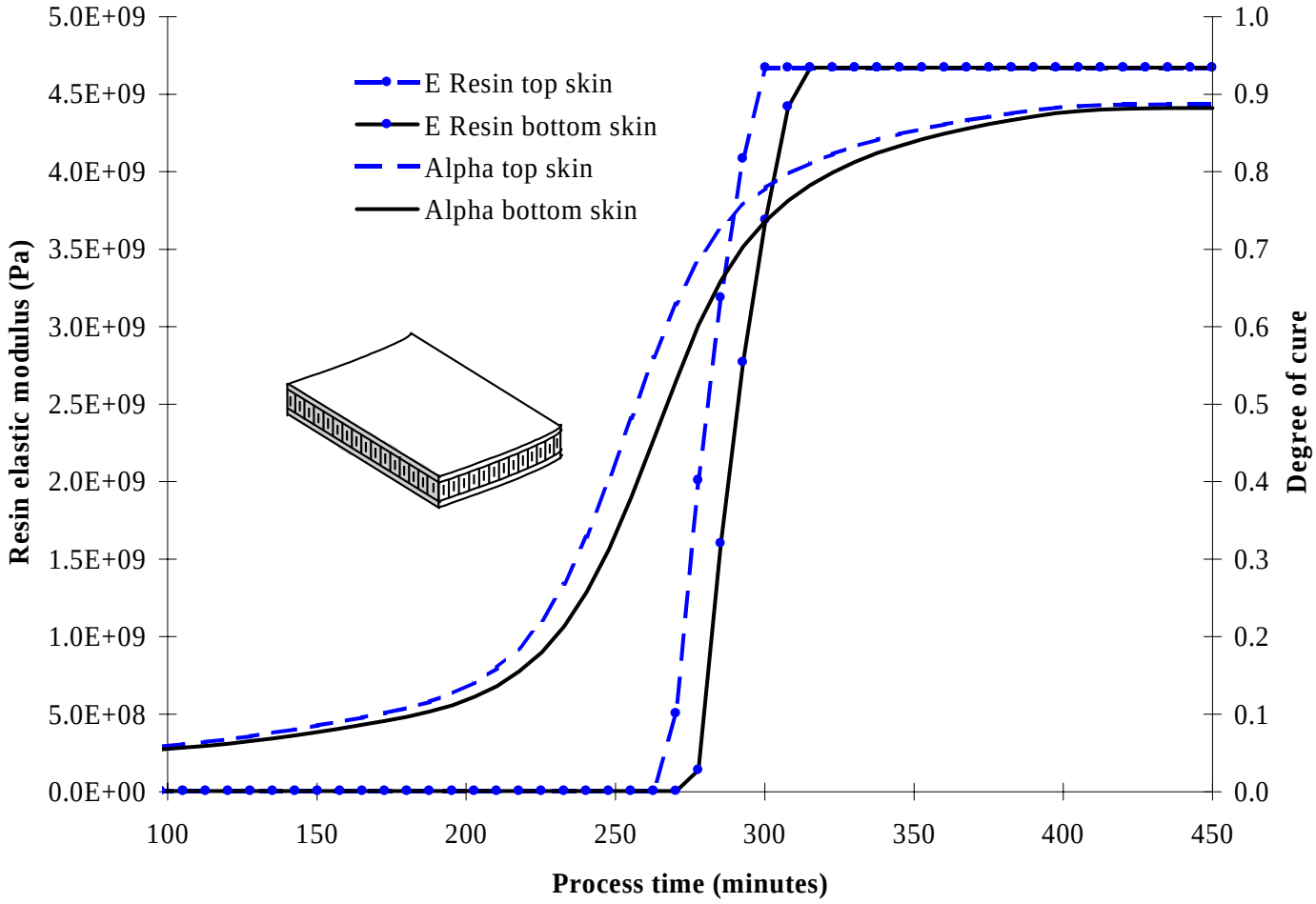


Predicted warpage using calibrated shear layer

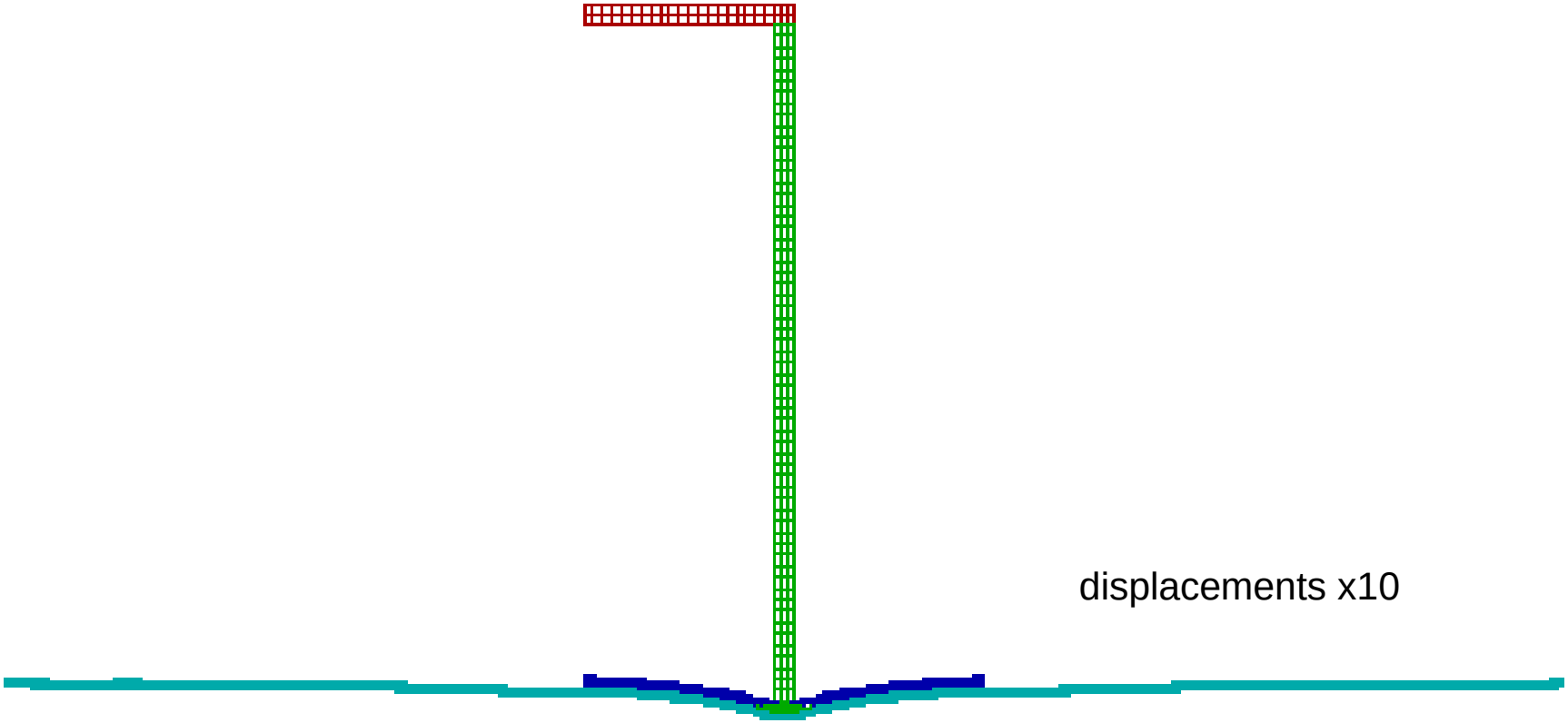


Unstiffened honeycomb structure

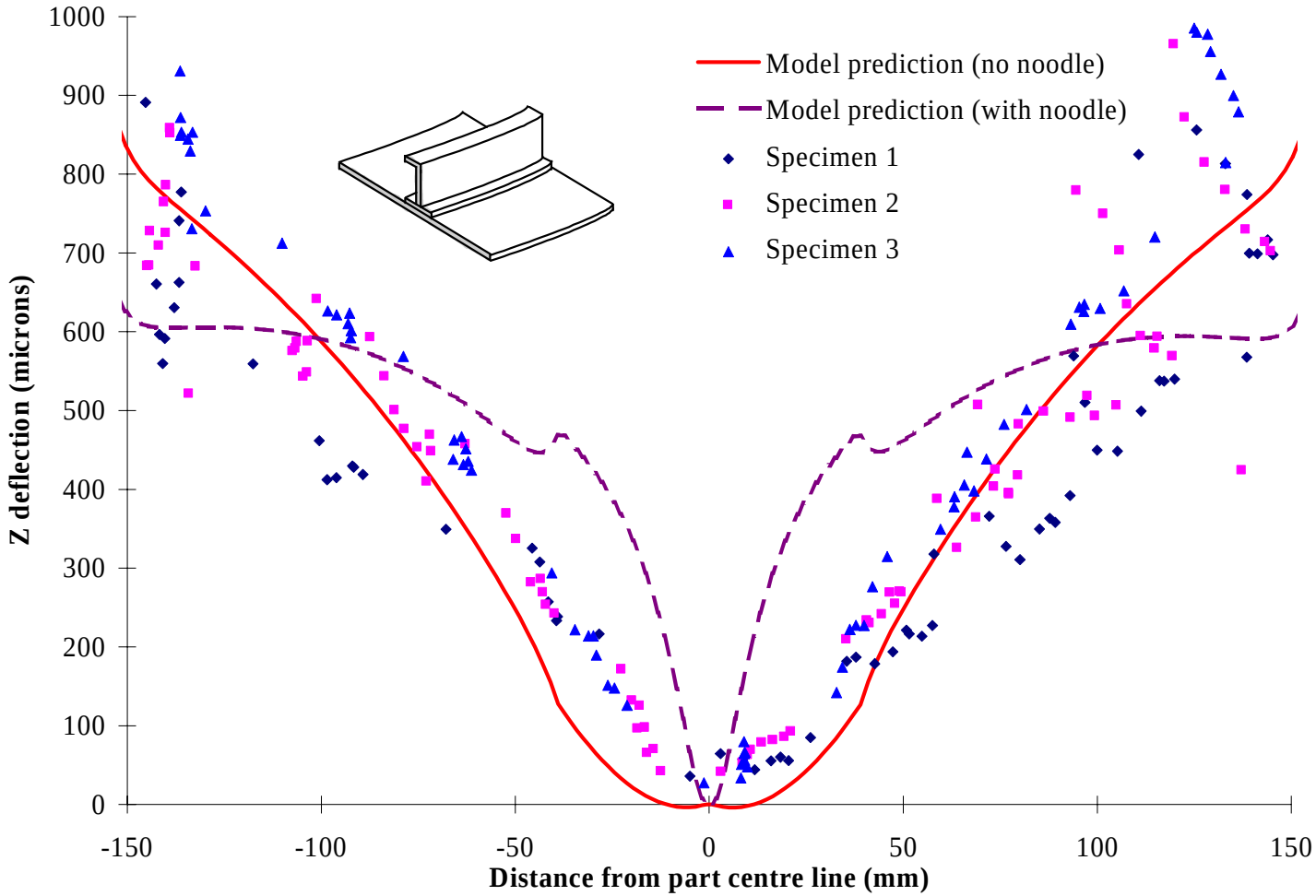
model predictions



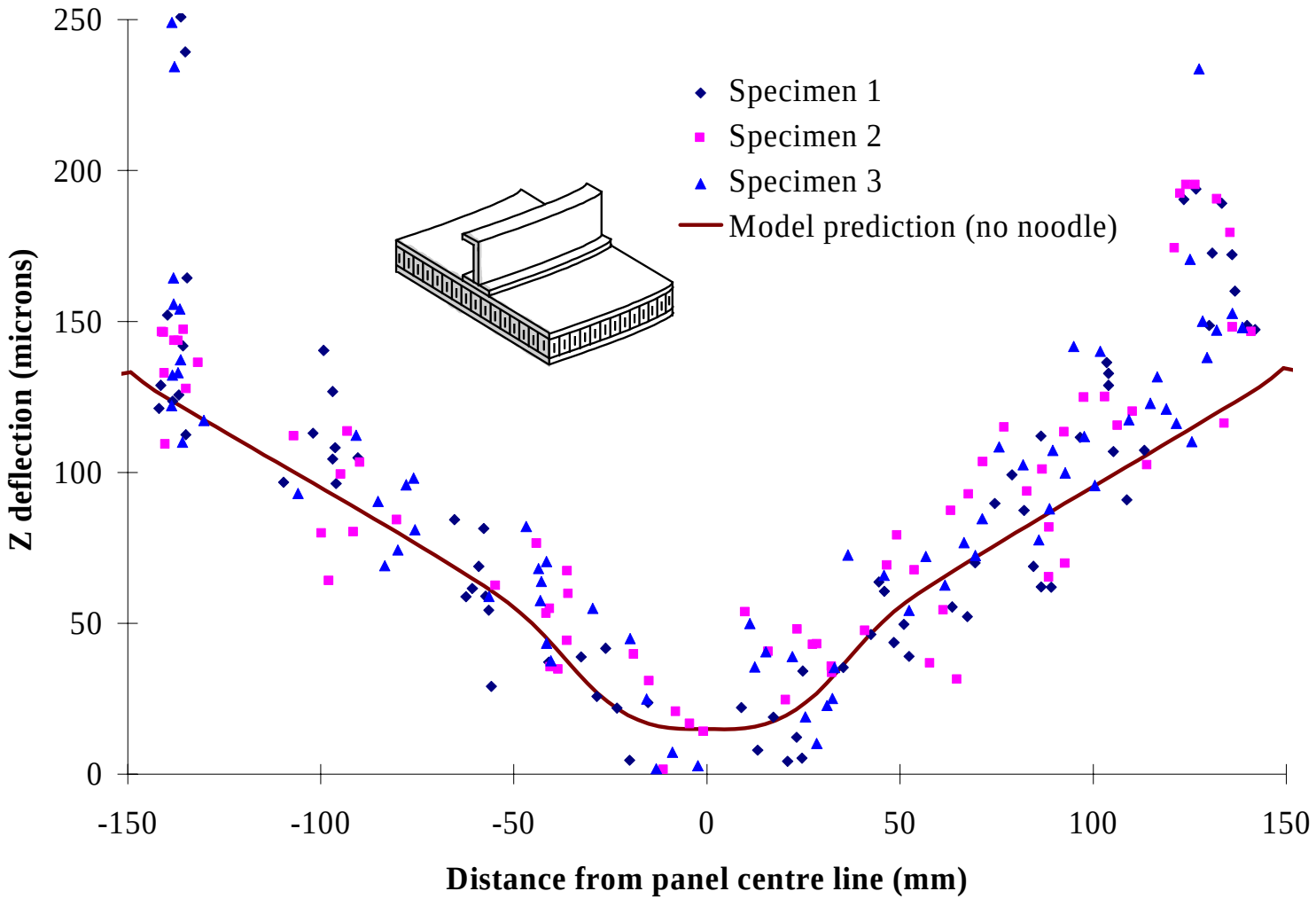
Predicted skin and frame warpage



Skin and frame warpage



Honeycomb and frame warpage



Sensitivity study of stiffened panels
parameters studied

Thermophysical

- resin specific heat capacity
- resin thermal conductivity
- fibre volume fraction
- resin heat of reaction

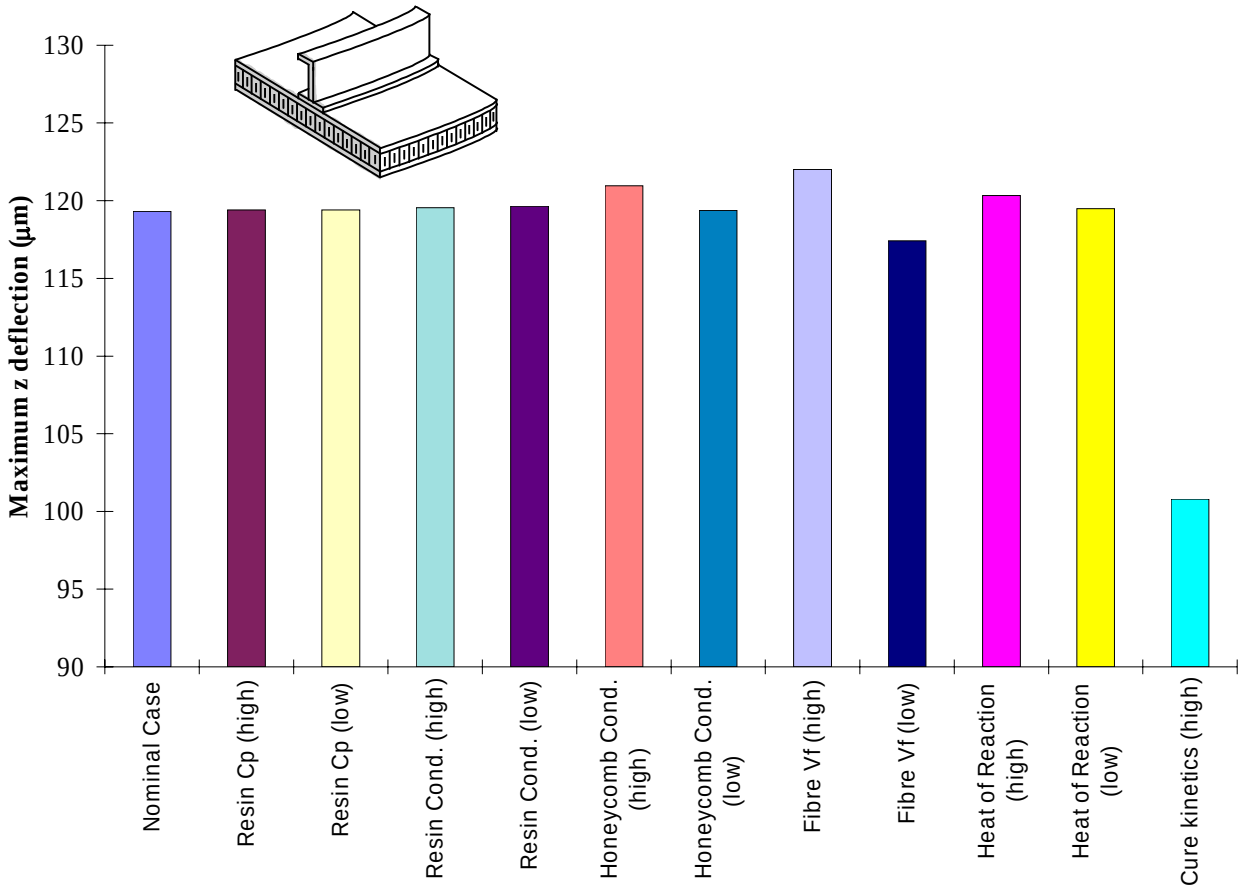
Mechanical

- resin modulus development model
- resin modulus development timing
- resin modulus development initial value
- resin cure shrinkage amount
- resin cure shrinkage timing
- composite CTE3
- J-frame CTE1
- Honeycomb moduli
- Layup accuracy

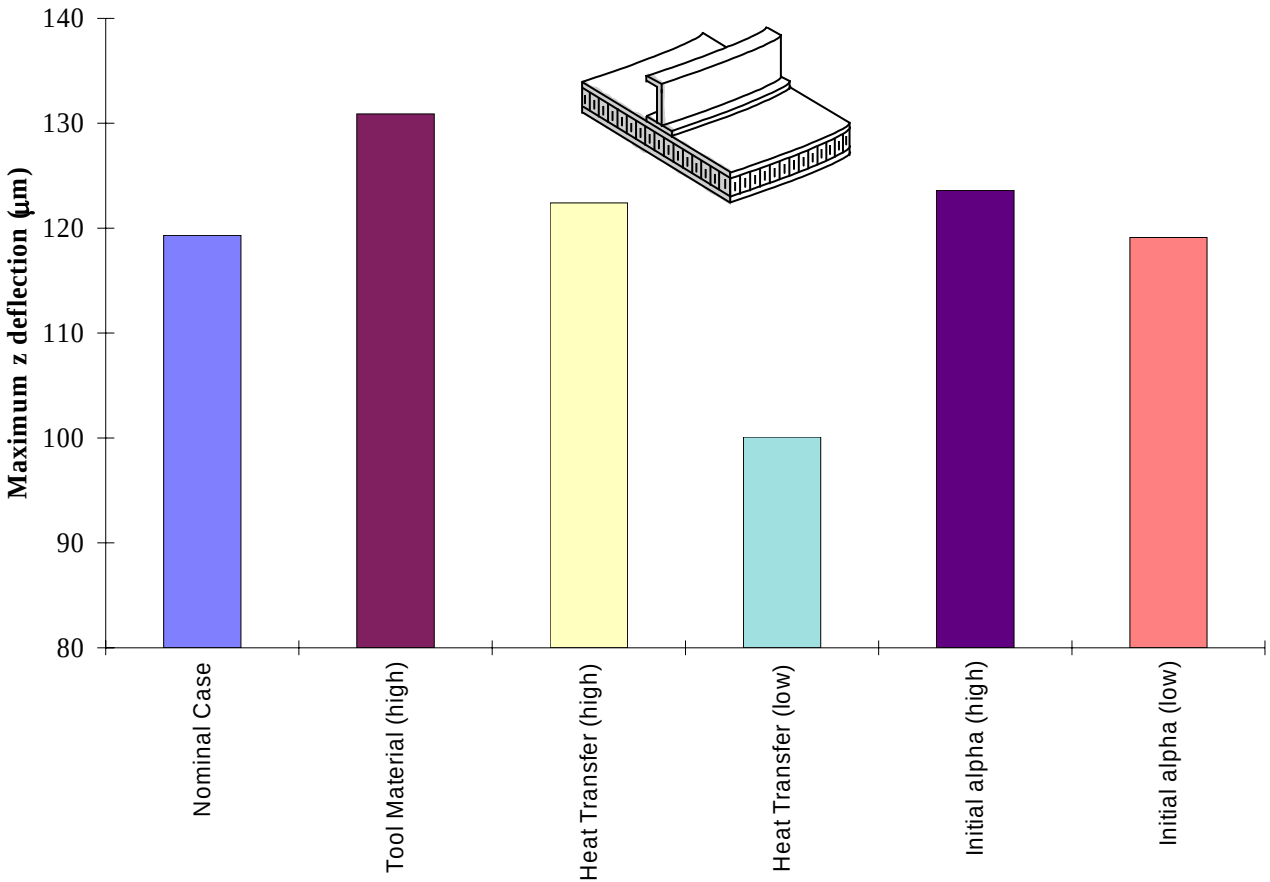
Boundary and Initial

- tool material
- heat transfer coefficient
- initial degree of cure

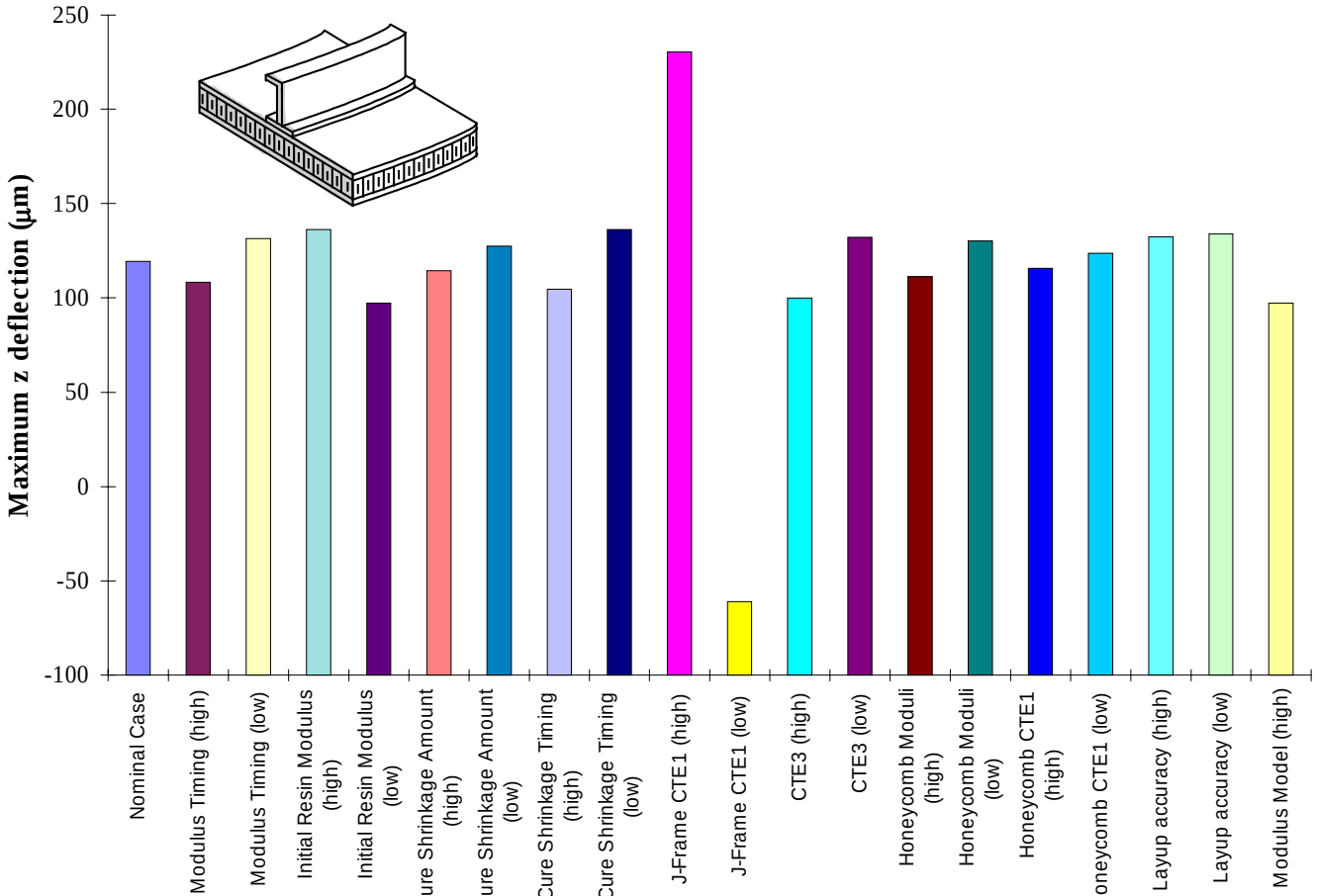
Effect of variations in thermo-physical properties on maximum deflection of panel



Effect of variations in boundary and initial conditions on maximum deflection of panel



Effect of variations in mechanical properties on maximum deflection of panel



Conclusions

- Accurate warpage prediction requires complete and detailed representation of complete structure, tool, autoclave characteristics
- Baseline predictive capability of COMPRO is reasonably good.
- For the stiffened honeycomb structure
  - normal variations in thermo-physical properties had little effect
  - resin cure kinetics are important, through the effect on resin shrinkage and modulus development, rather than temperature distribution
  - J-frame noodle behaviour is very important

Summary:
Some simple case studies are presented to show the value of process modeling in predicting cure cycle lengths, fibre volume fraction distributions in simple shapes, and process and material variations in complex shapes.

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