Estimate of the effect of hysteresis on bonded specimen

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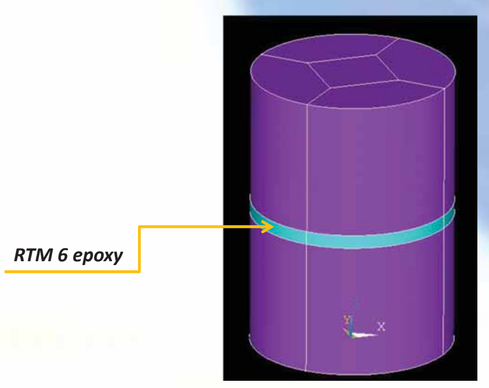
PREFACE

At the origin of this study is the need to make an assessment of the equilibrium temperature of an adhesive meatus in a bonded joint of mechanical components when subject to regimes of cyclic operation.
The same approach could be used to study the behavior of composite material components.
In general a mechanical component is subject to an ***internal damping*** which provides to dissipate the energy due to vibration: this energy dissipation can bring in temperature increase proportional to the degree of internal damping of the material that may induce sensitive alterations of the mechanical properties of the material which could compromise the structural strength of the joint.
The evaluation of this temperature increase on an adhesive meatus constituted by epoxy resin (2 mm in thickness and 15 mm in radius) subjected to a cyclic load, is reported. The internal heat generation is due to inelastic phenomena that are usually measured through rheological tests (e.g. ***DMA,*** Dynamic Mechanical Analysis) through which it is possible to estimate the internal damping as the ratio between the loss modulus ***E''*** and the storage modulus ***E'***.



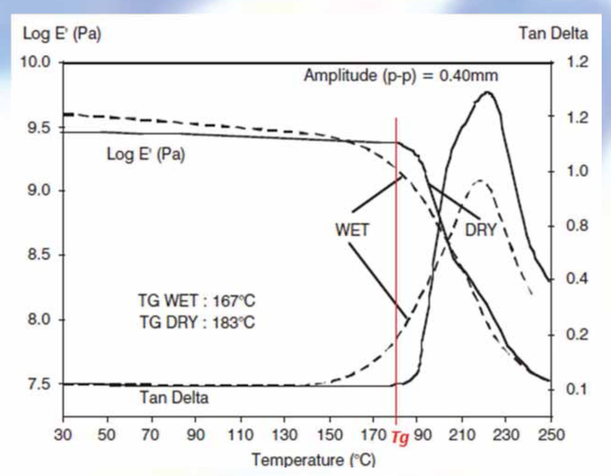
$$E^* = E' + iE'' \rightarrow E^* = \frac{\sigma_0 e^{j\delta}}{\varepsilon_0}$$
$$E' = \frac{\sigma_0}{\varepsilon_0}\cos\delta \;\&\; E'' = \frac{\sigma_0}{\varepsilon_0}\sin\delta$$
$$\tan\delta = \frac{E''}{E'}$$

For the simulation (carried out by ANSYS 14.5) it was considered a typical load profile of alternative machines.

APPROACH TO THE PROBLEM

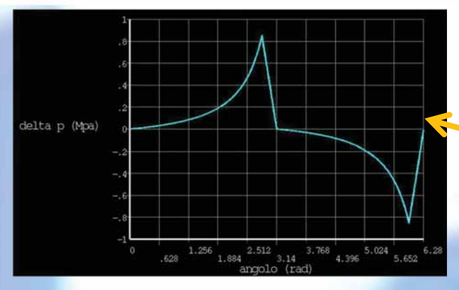
Starting from the load spectrum depicted on the right, the Fourier expansion allowed to select 20 harmonic frequencies assumed acting independently each other. At this point it was set up a iterative procedure consisting of:

1. Harmonic analyses focused on the evaluation of the area of the respective cycle of hysteresis[2] (based on the experimental data of the rheological resin[1], to be noted that the tangent of the phase corresponds to *tan δ* of the complex modulus);
2. Static thermal analyses in which the temperature increase, due to damping effect, was mitigated by natural convection (heat exchange coefficient of $5\ ^{mW}/_{mm^2 °C}$).

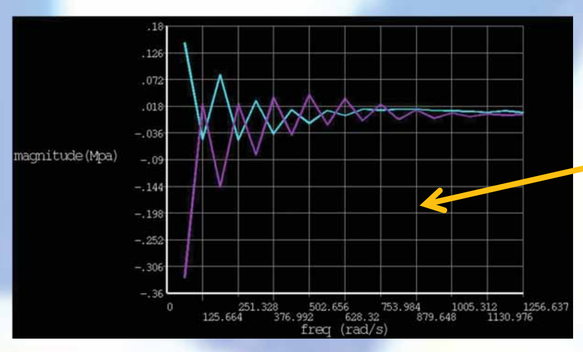


Iterations stopped as soon as the difference in temperature increase is lower than threshold value (ΔT < 3°).
For each iteration temperature dependent material properties were updated.

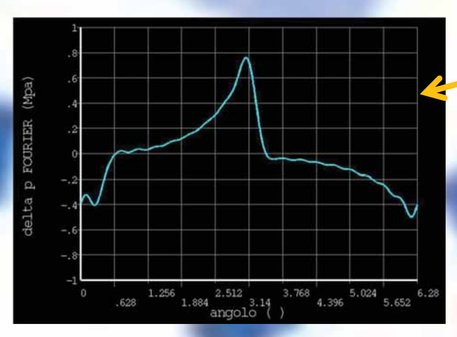
LOAD SPECTRUM



Consider a trend of pressure type that in figure characterized by a frequency of 10 hz

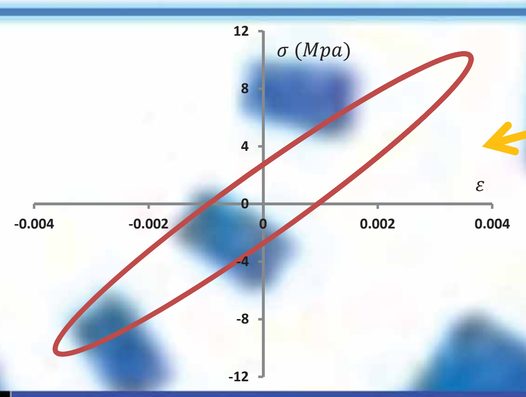


Expansion in Fourier series of order 20



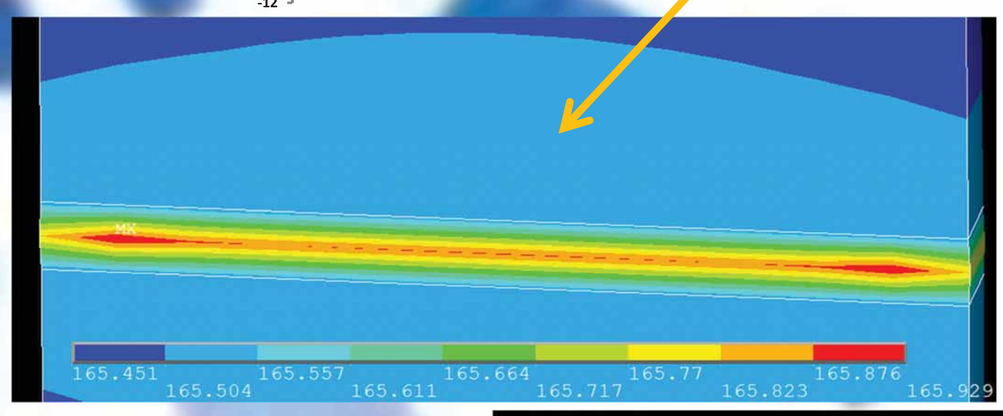
Historical expansion in a period.

RESULTS

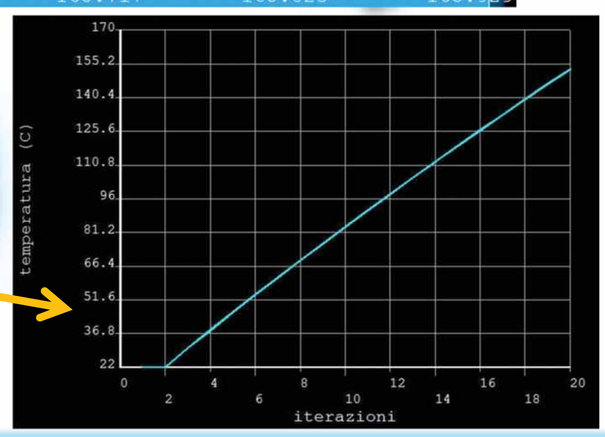


HYSTERESIS CYCLE
FIRST HARMONIC (amplitude factor: 22)

TEMPERATURE RANGE OF SPECIMEN IN STATIONARY CONDITION



FINAL TEMPERATURE FOR EACH ITERATION



CONCLUSION

Simulation results show that the equilibrium temperature of the meatus is close to ***98% T_g*** (cure temperature ***T_c 170°C***); this suggests that damping phenomena could lead to the structural failure of the component in particular in the case of economic cure processes (T_c lowest), therefore, this study suggests an approach that could be useful in the preliminary assessment of the level of *degradation of the mechanical strength* and in the prediction of structural failure caused by the *attainment of the glass transition temperature (T_g)* of the thermoset adhesive as well as the matrix of a composite material.

REFERENCE

- *[1]HEXFLOW RTM 6, «product data»*
- *[2]WENBA L., XIAOLING H., QIFU L., «Frequency and strain-amplitude dependent dynamical mechanical property and hysteresis loss of CB filled vulcanized natural rubber», 2009*
- *[3]MAURO ZARRELLI, «Cure induced property changes and warpage in thermoset resin and composite», 2003*