Time-Dependent Mechancial and Structural Response of Polymer-Matrix Composites under Elevated Temperatures

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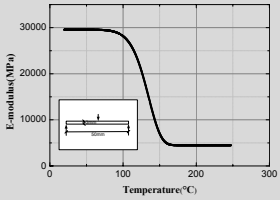
Introduction

- Fibre-reinforced polymer, mainly thermosets, are widely used in public buildings, bridges and vehicles.
- Compared with steel and concrete, the mechanical properties of polymers are much more sensitive to temperature and thermal histories.
- The glass transition temperature is an important parameter in polymer studies.

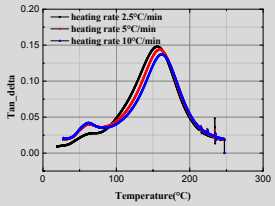


MOTIVATION

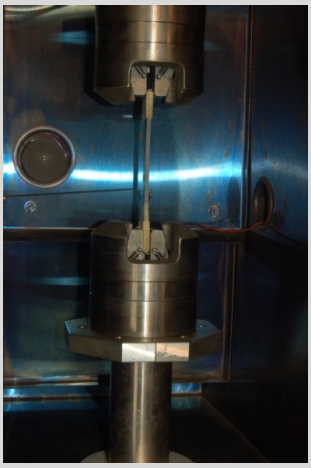
- When thermosets are exposed to high temperatures, the E-modulus and other mechanical properties drop significantly. This happens in a temperature range that is called glass transition stage.
- Under different heating rates and thermal histories, the glass transition temperature of polymers will be different.

OBJECTIVES

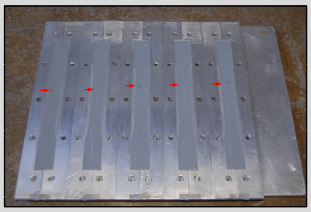
- Find the relationship between E-modulus and temperature during glass transition stage.
- Study the influence of elevated temperature and thermal history on glass transition temperature.
- Find the reversibility of mechanical property after different thermal conditions.



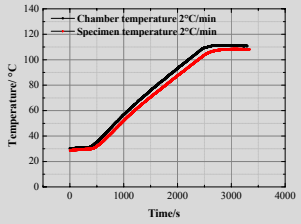
EXPERIMENTAL

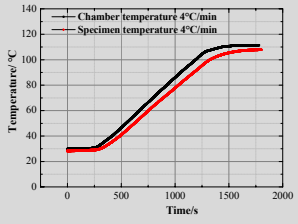


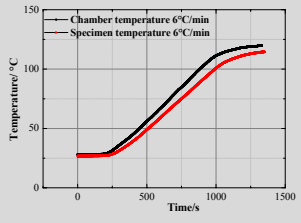
- DMA machine is usually used in the experiments studying the relationship between E-modulus and temperature under different heating rates and thermal histories.
- A preliminary experiment was designed to find the influence of heating rates, or the temperature difference between specimens and the environment under different heating rates.
- The temperature curves showed that the temperature difference between specimens and environment always increased with time and heating rates.

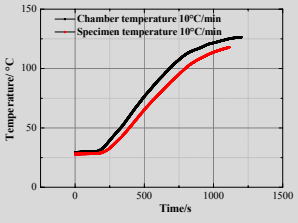


- It is possible that during DMA experiments, the shift of glass transition temperature with increasing heating rates is not the real specimen glass transition temperature shift, but measurement errors.





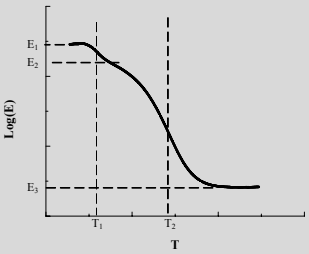


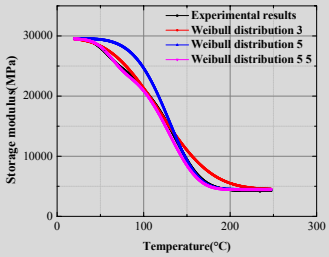


MODELING

- The probability of bonds breakage is described by Weibull distribution, which is much more precise than the commonly used Arrhenius Law to describe the behavior of polymer during temperature elevation .
- $$E = (E_1 - E_2)\exp(-(\frac{T}{T_1})^{m_1}) + (E_2 - E_3)\exp(-(\frac{T}{T_2})^{m_2}) + E_3\exp(-(\frac{T}{T_3})^{m_3})$$
- m_1, m_2 and m_3 can include the influence of thermal history, heating rates, and they are different between primary relaxation and secondary relaxation because of the different probability of bonds breakage during these two stages.

Weibull parameters ⇩ **Simulation** ⇩





CONCLUSION

- E-modulus and other mechanical properties change significantly during the glass transition stage, and glass transition temperature is an important parameter for polymers.
- Weibull distribution can be a much better choice for describing of the relationship between E-modulus and temperature than Arrhenius Law.
- The shift of glass transition temperature under different heating rates maybe caused by the temperature difference between specimens and environment.

FUTURE DEVELOPMENTS

- DMA mechanical and thermal experiments to determine the temperature difference in DMA furnace.
- Specify the relationship between Weibull parameters and thermal history as well as heating rates.
- Find the method for the calculation of the glass transition temperature and compare results with experimental data.
- Find the time-dependent properties of the examined polymer.