Kanazawa Institute of Technology

Influence of Water Absorption on Statistical Life of Unidirectional CFRTP under Creep Loading

Materials System Research Laboratory

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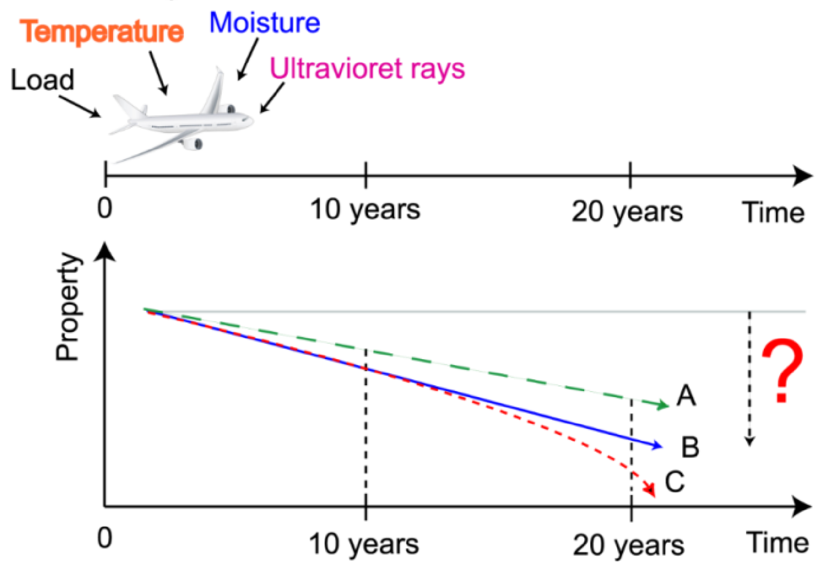
Background



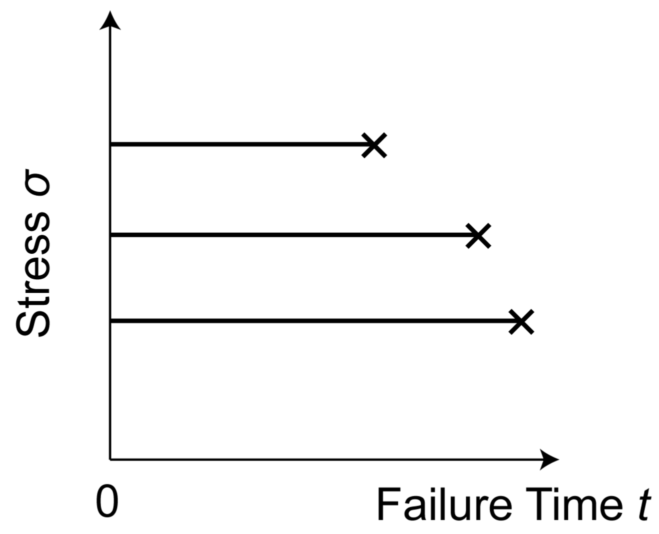
The Accelerated Testing Methodology (ATM) can be used for the prediction of the long-term life of CFRP.

The tensile strength of unidirectional CFRP is important and fundamental data for the reliable design of CFRP structures.

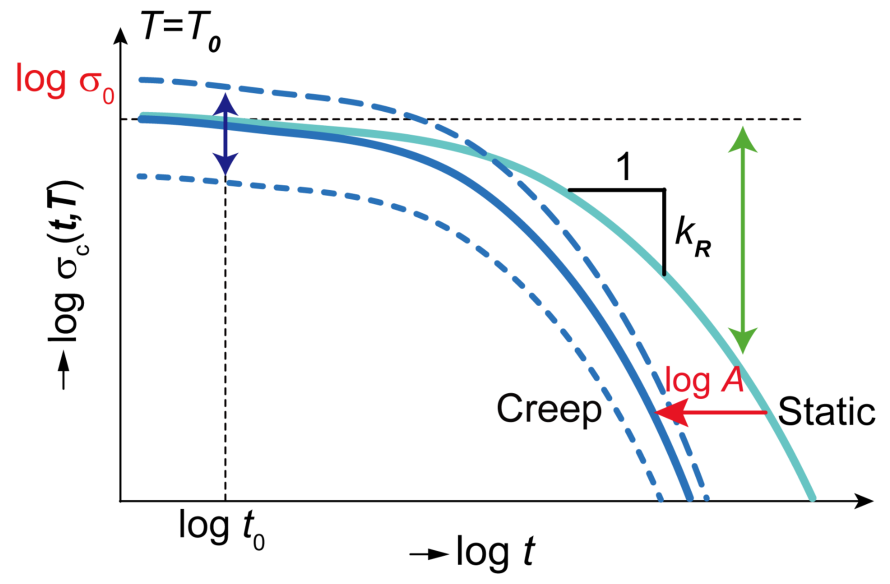
Recently, thermoplastic epoxy resin (TPEP) has been developed and used for CFRP structures.

Objective

In this study, the statistical life of TPEP resin impregnated carbon fiber strand (CFRTP strand) under creep tension loading was evaluated under dry and wet conditions using the ATM we developed.



Formulation of statistical creep strength



Static strength

$$\log\sigma_s(t,T)=\log\sigma_0(t_0,T_0)+\frac{1}{\alpha}\log[-\ln(1-P_f)]+n_R\log\left[\frac{E_s(t,T)}{E_s(t_0,T_0)}\right]$$

Creep strength

$$\log\sigma_c(t,T)=\log\sigma_0(t_0,T_0)+\frac{1}{\alpha}\log[-\ln(1-P_f)]+n_R\log\left[\frac{E_c(t,T)}{E_c(t_0,T_0)}\right]$$

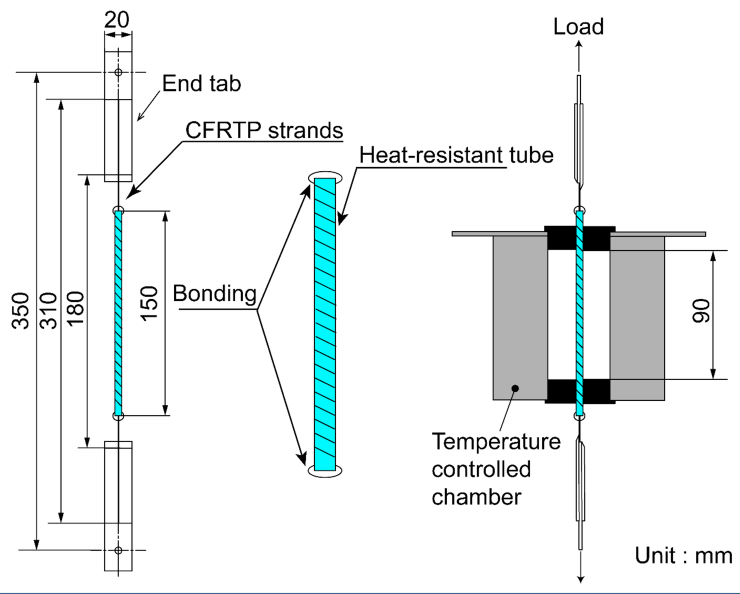
$$E_c(t,T)=E_s(At,T)=E_r\ (At/2\,,T) \qquad \log A=\log(1+1/k_R)$$

- t : Failure time
- t_0 : Reference time
- T : Temperature
- T_0 : Reference temperature
- P_f : Failure probability
- σ_0 and α: Scale and shape parameters of static strength at t_0 and T_0
- n_R: Viscoelastic parameter determined by failure mode
- E_s: Viscoelastic modulus of matrix resin under static tensile
- E_c: Viscoelastic modulus of matrix resin under constant loading

Testing method

Test material

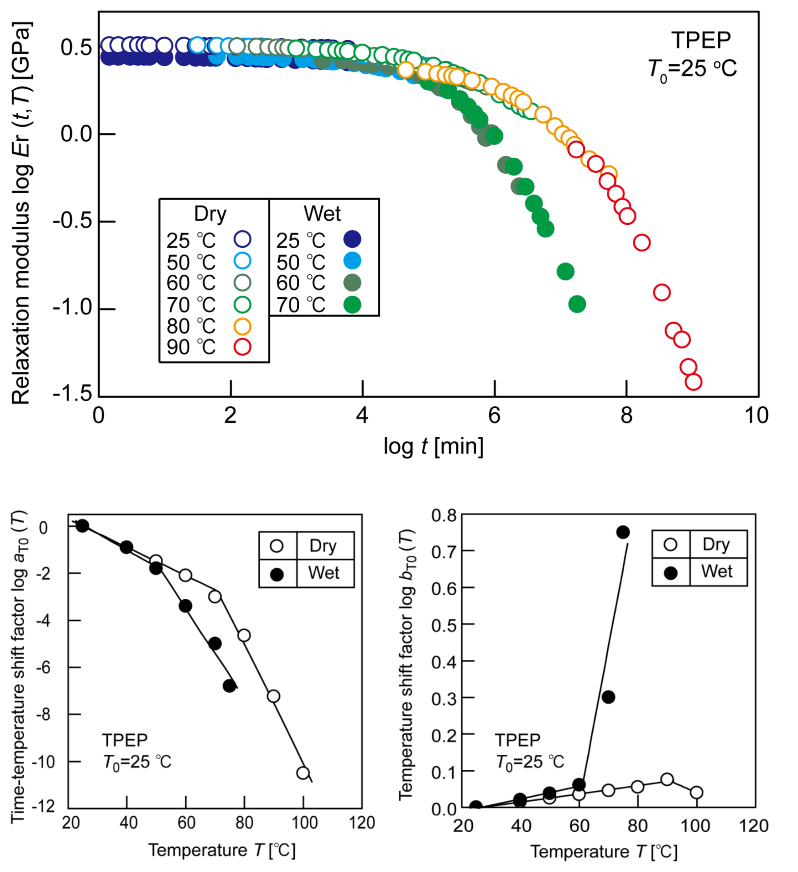
CFRTP strand	Carbon fiber	Resin
T700/TPEP T300/TPEP	T700SC-6000 T300-3000	Thermoplastic epoxy (TPEP)



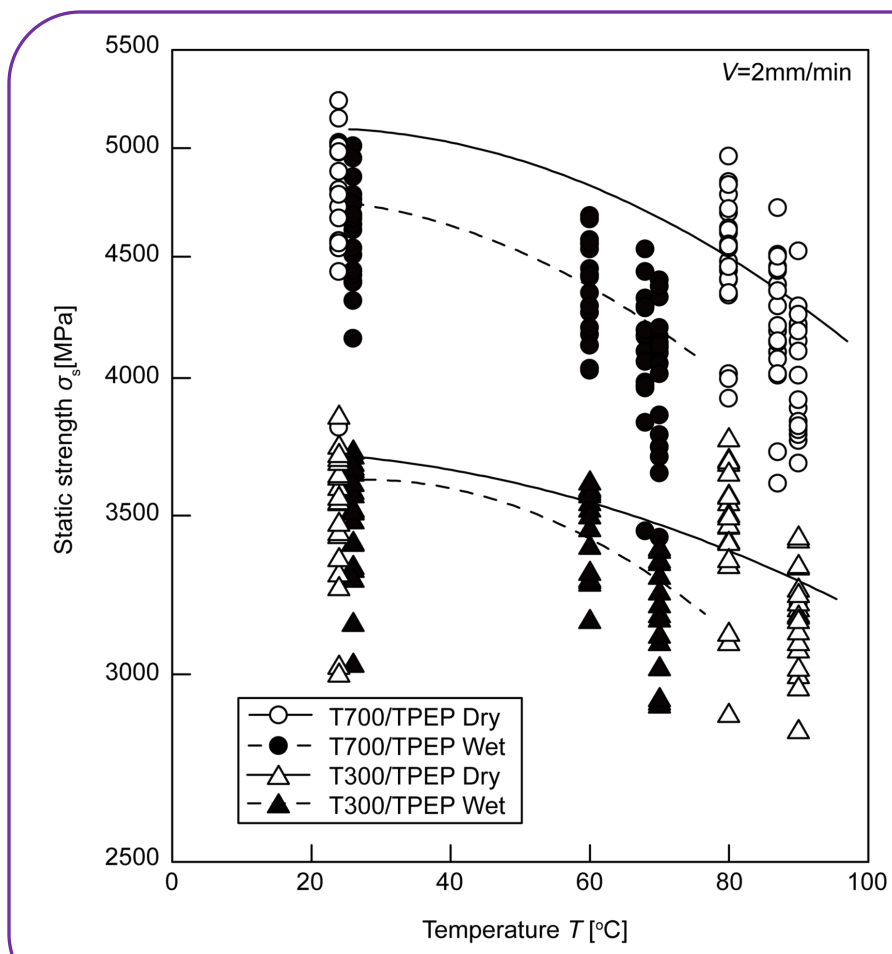
Viscoelastic test for matrix resin → E_r: Relaxation modulus of matrix resin; n_R: Viscoelastic parameter determined by failure mode

Static strength test for CFRTP strands → σ_0 : Scale parameters of static strength at t_0 and T_0; α : Shape parameters of static strength at t_0 and T_0; n_R : Viscoelastic parameter determined by failure mode

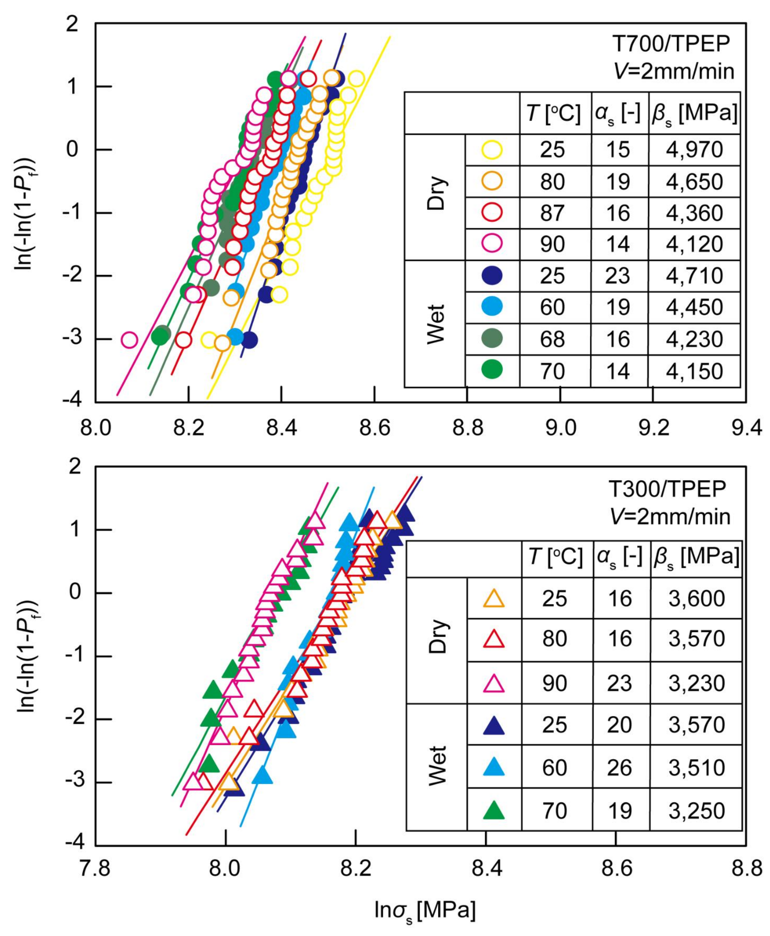
Results and Discussion



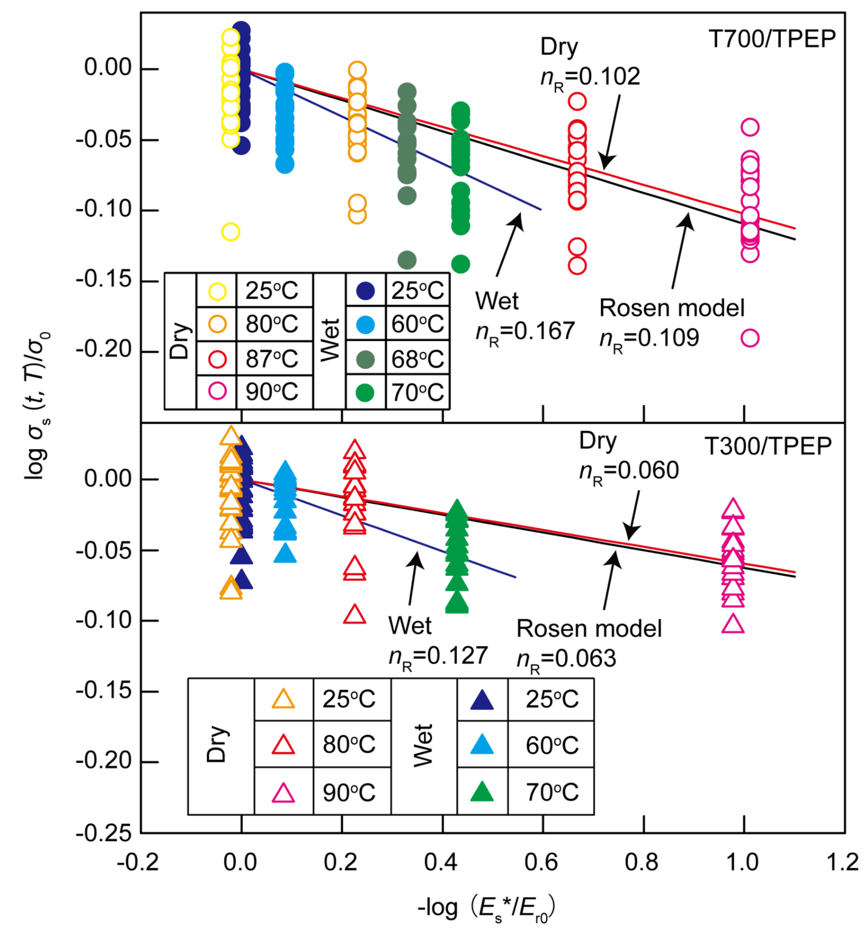
Relaxation modulus of matrix resin



Static tensile strength of CFRTP strand



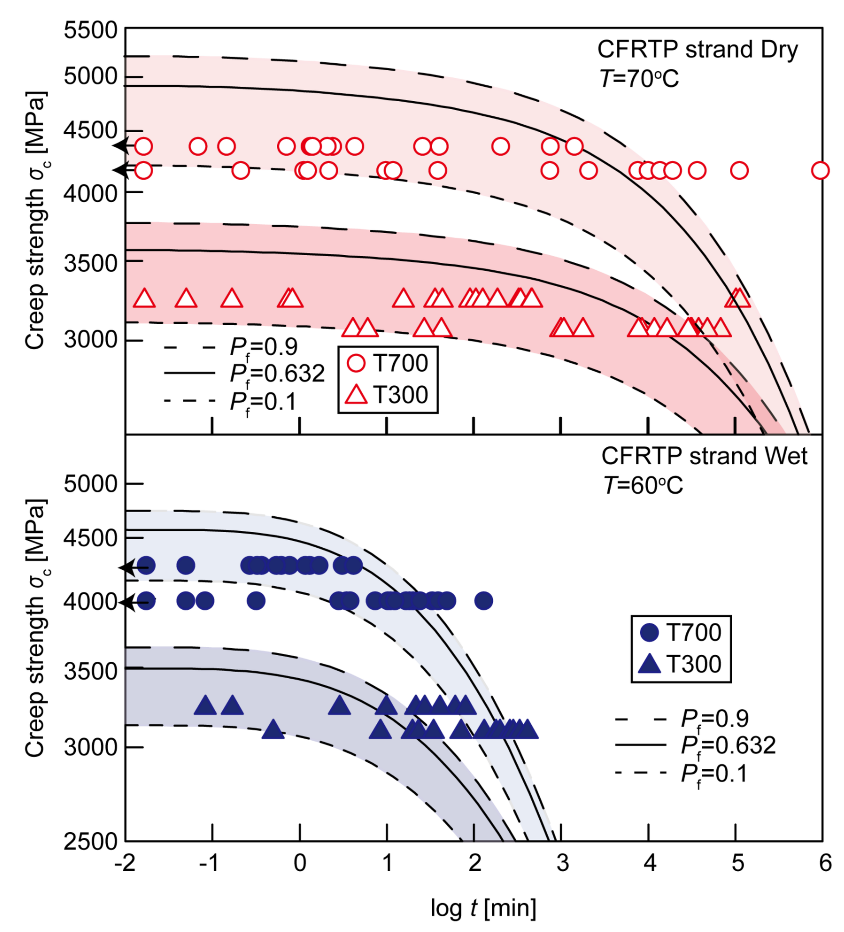
Weibull distribution of static tensile strength for CFRTP strand



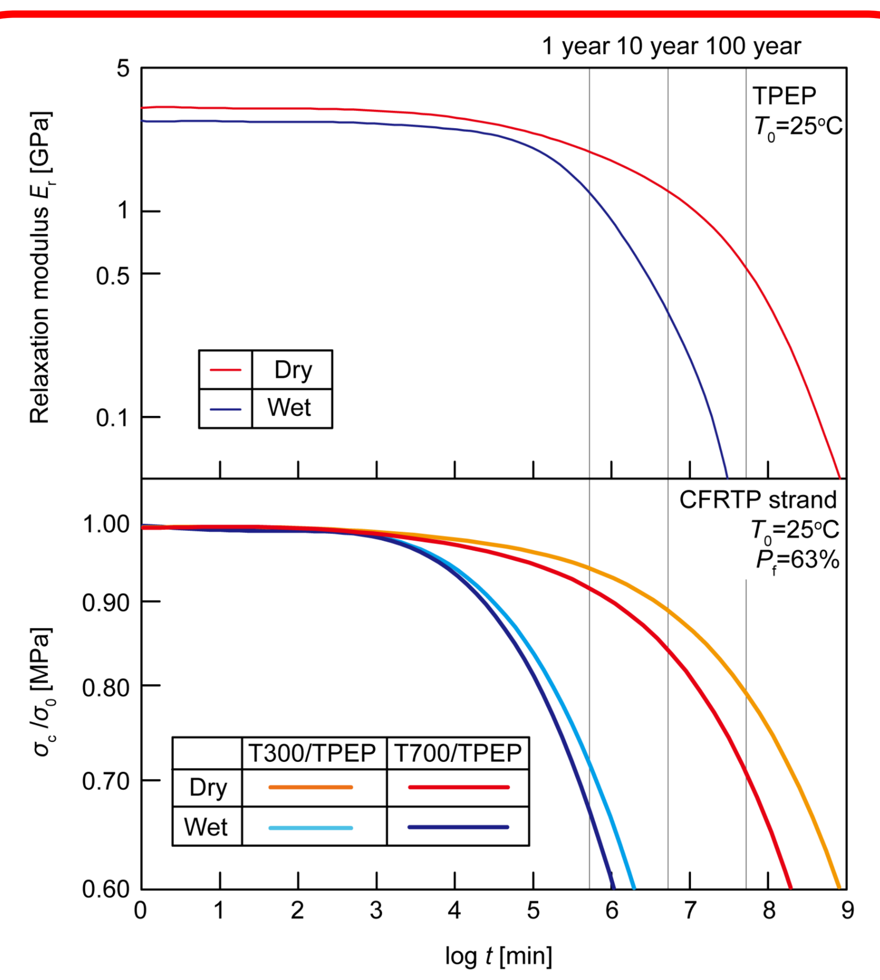
Static tensile strength of CFRTP strand versus viscoelastic modulus of matrix resin

Parameters in formulation

		σ_0 [MPa]	α [-]	n_R [-]
T700/TPEP	Dry	4,970	15	0.102
	Wet	4,710	23	0.167
T300/TPEP	Dry	3,600	16	0.060
	Wet	3,570	20	0.127



Comparison of predictions and experiments



Long-term creep life prediction at reference temperature of 25°C

Conclusion

- Statistical creep strength of unidirectional CFRTP under tensile loading in the fiber direction can be predicted using ATM not only in dry but also in wet conditions.
- There is no difference in creep strength reduction with time and temperature for two kinds of unidirectional CFRTP.
- This reduction in creep strength is accelerated by water absorption.

Acknowledgements

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