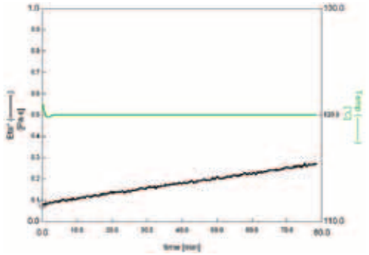
Properties of Resins

Isothermal Viscosity

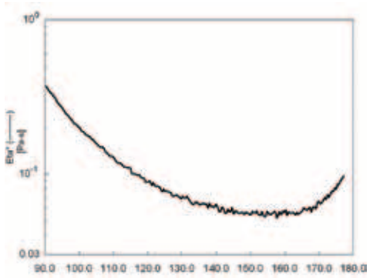
RTM-PYCO3 resin shows good isothermal stability (more than 1 hour) at temperatures below 120°C, which allows injection for large structural applications.



10 *Isothermal Viscosity of new RTM-PYCO3 resin at 120 °C (1 Hz at 100% strain)*

Dynamic Viscosity

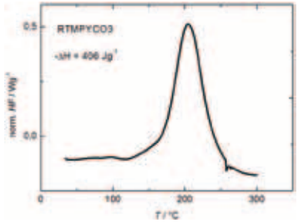
The new RTM-PYCO3 resin development demonstrates its potential to be used as low viscosity resins for RTM process. Dynamic viscosity of new RTM-PYCO3 resin is about 90 mPa·s at the processing temperature of 120 °C (for RTM6, η = 33 mPa·s).



11 *Dynamic Viscosity of new RTM-PYCO3 resin (1 Hz at heating rate of 3 K/min)*

Curing Enthalpy

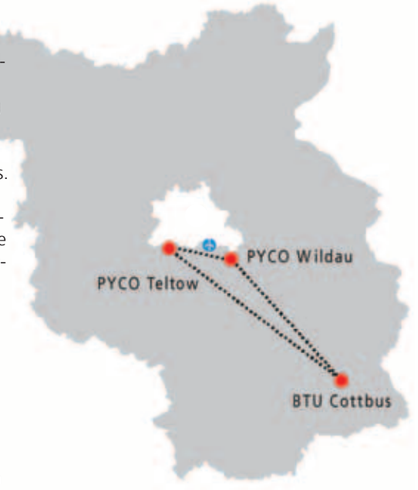
The curing enthalpy for new RTM-PYCO3 resin lies in the region of about -406 J/g (determined by DSC at 5K/min) and it is similar to common epoxies, e.g. enthalpy of cure for RTM6 is -413 J/g (via DSC at 5 K/min).



12 *Differential Scanning Calorimetry (DSC) of new RTM-PYCO3 resin at 5 K/min*

Location Berlin-Brandenburg

New solutions require new approaches: The locations of the research institute in Teltow and Wildau where the metropolis of Berlin and the federal state of Brandenburg meet, offer optimal conditions for innovative scientific research. Here, the products of tomorrow emerge from ideas and visions. Therefore, the institute's scientists have formed a creative research network with renowned universities, well-known large-scale enterprises, and various innovative medium-sized companies.
Additionally, new synergy arises from the integration in the third largest location of aerospace industry in Germany.



Acknowledgement

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Clariant

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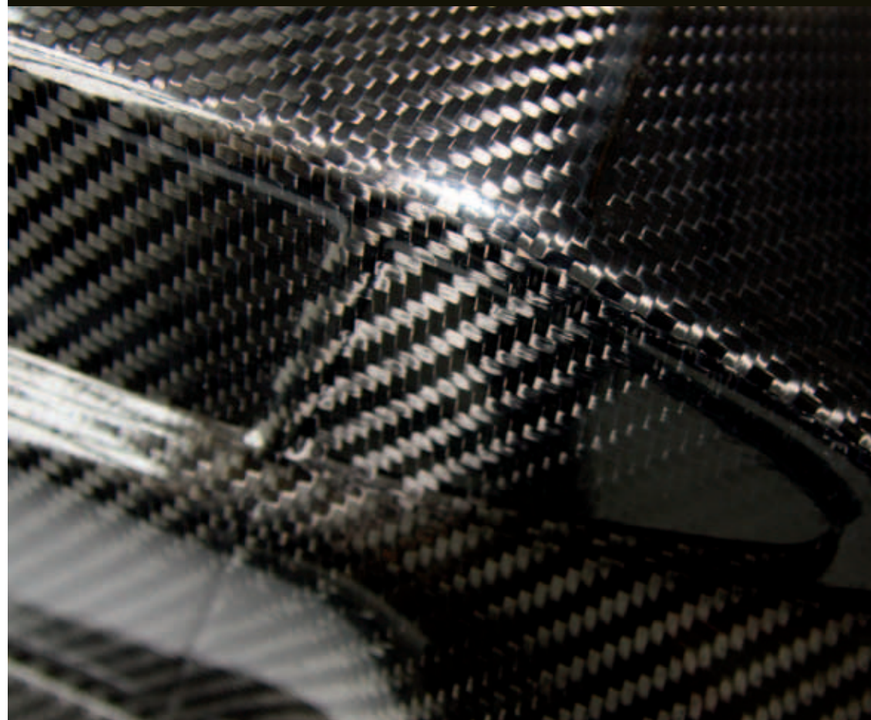
Fraunhofer PYCO

FRAUNHOFER RESEARCH INSTITUTION FOR POLYMERIC MATERIALS AND COMPOSITES PYCO

New Flame-retardant RTM Resins - RTM6 Benchmark



ORGANIC-INORGANIC THERMOSETTING HYBRID RESINS FOR RESIN TRANSFER MOLDING (RTM)

Motivation

The novel organic-inorganic thermosetting hybrid resins are manufactured from well established thermoset resins and inorganic polymers by chemical bonding. The resulting materials have become quite popular and practical because they exhibit positive characteristics of both of their components, i.e. processability, toughness and flame retardance.

The aim of this work was the development of new hybrid resins for RTM (Resin Transfer Molding), based on cyanates with silazane comonomers, which have excellent FST (Fire Smoke Toxicity) behavior, good moisture stability and mechanical properties. The commercially available RTM6 epoxy resin, which is the aerospace industry standard for RTM, served as a benchmark for neat resin property comparison.

Applications at a Glance

- Adhesives
- Coatings
- Varnishes
- Binders
- Inmolds and gelcoats
- Castings
- Foams
- Prepregs
- Pultrusion
- Resin Transfer Molding (RTM)

Properties at a Glance

- Fast curing
- Curing enthalpy comparable with epoxy resins and much lower than cyanates
- High T_g and high fracture toughness
- Improved flame retardancy with low smoke emission and high yield of char residue
- Good moisture stability
- Low viscosity, suitable for RTM
- Recyclable, repairable

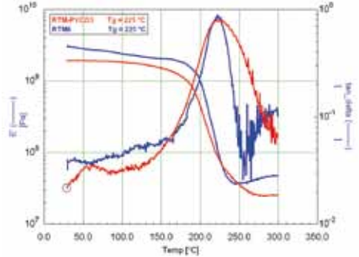
Now a fire resistant RTM-resin for aircraft application is available.

1 *RTM unit*

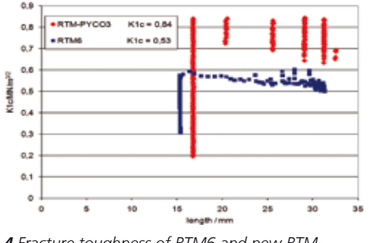
Properties of Cured Neat Resins

Resin	T_g (DMApeak) [°C]	K_{1c} [MN/m$^{3/2}$]	HRRpeak [1)] [kW/m²]	MARHE [2)] [kW/m²]	THR [3)] [MJ/m²]	TSR [4)] [m²/m²]	CR [5)] [%]
RTM-PYCO3	225	0,84	229/131	94	139	3739	45
RTM6	225	0,53	382/478	292	164	9978	8

2 *Properties at a glance in comparison with the reference RTM6: [1)] HRRpeak: Heat Release Rate peak, [2)] MARHE: Maximum Average Rate of Heat Emission, [3)] THR: Total Heat Release, [4)] TSR: Total Smoke Release, [5)] CR: Char Residue, Cone calorimetry test at a heat flux of 50 kW/m²*



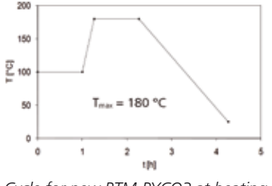
3 *Dynamic Mechanical Analysis (DMA) of RTM6 and new RTM-PYCO3 resin (1 Hz at heating rate of 4 K/min)*



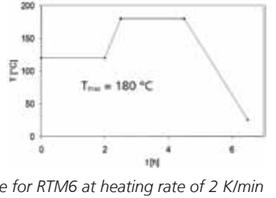
4 *Fracture toughness of RTM6 and new RTM-PYCO3 resin (determined by OCT)*

Cure Cycles for Neat Resins

The comparison of the curing profiles of both resins shows that for the hardening of the new RTM-PYCO3 resins shorter cycle times are needed.



5 *Cure Cycle for new RTM-PYCO3 at heating rate of 5 K/min*



6 *Cycle for RTM6 at heating rate of 2 K/min*

Water Uptake

The moisture stability of both resin systems was investigated according to the RTM6 data sheet (samples were stored in water for at least 14 days at room temperature and 70 °C). The analysis of water uptake of cured resin samples illustrates good moisture stablility of these new materials. The influence of water absorption on the mechanical properties of the materials at elevated temperature was studied by DMA measurements. The results show that the new resins exhibit a high glass transition temperature of about 200 °C whilst maintaining low water uptake.

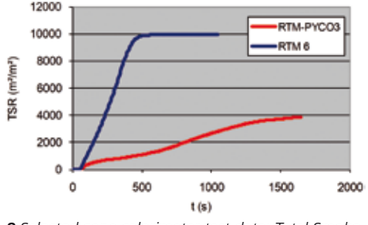
Resin	Water uptake at 70 °C		at RT
	[%]	T_g [°C]	[%]
RTM-PYCO3	1,26	193/wet	0,66
RTM6	2,01	219/wet	2,28

7 *Water uptake of cured neat resins after 384h*

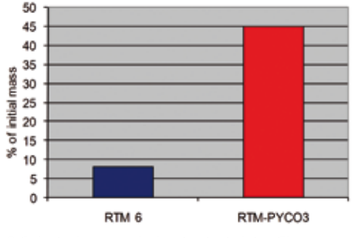
Flame Retardance

Cone Calorimetry

To investigate the fire characteristics of the samples, the cone calorimeter was used. During the testing, resin samples were exposed to a 50 kW/m² radiant heat flux. Heat Release Rate peak (HRRpeak), Maximum Average Rate of Heat Emission (MARHE), Total Heat Release (THR), Total Smoke Release (TSR) and mass loss - here given as Char Residue (CR) - were determined. The new RTM-PYCO3 resin shows very good fire performance compared to RTM6. Especially the TSR values of the new resins are significantly lower. Additionally, considerable char residue yields were obtained after burning.



8 *Selected cone calorimeter test data: Total Smoke Release (TSR) at heat flux of 50 kW/m²*



9 *Selected cone calorimeter test data: Char Residue (CR) at heat flux of 50 kW/m²*