THERMOPLASTIC MATERIALS FOR RIGIDIZABLE SPACE SYSTEMS

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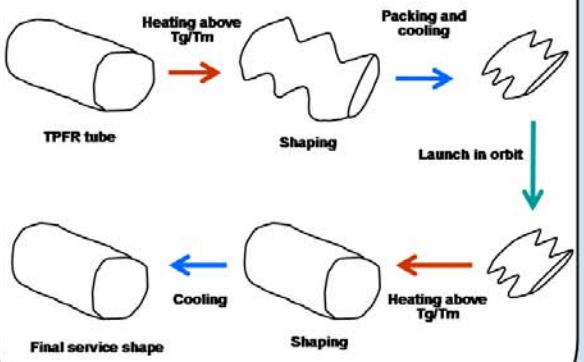
INTRODUCTION: INFLATABLE/RIGIDIZABLE SPACE SYSTEMS



INTRODUCTION: MATERIAL REQUIREMENTS

- Processability: adequate wet-out of the fibers within a tow → minimal void content → maximum mechanical performance.
- High fiber volume fraction: at least 50% Vf → high mechanical performance-to-weight ratio → cost efficiency.
- Formability: capability of:
  - being heated above a softening or melting temperature T_m
  - being formed to shape and cooled without lowering properties or retaining original shape
  - repeating the steps above.
- Glass transition temperature (T_g)/melting temperature: low T_m and/or T_g → minimum energy required for curing and erection.
- Mechanical performance: high Young's and compressive moduli, low deflection under creep.

MATERIALS

Reinforcement: Toraya T300 1k as 24 x 24 plain- weave 125 g/m² fabric.

Matrix	PP60	PP35	HDPE	PETG
Specific Gravity (g/cm³)	0.90	0.90	0.97	1.27
Tensile Stress at Yield (psi)	5100	4600	4430	7700
Tensile Elongation at Yield (%)	8	12	602	4.8
Tensile Modulus (ksi)	NA	NA	156	320
Flexural Modulus (ksi)	220	170	201	310
Deflection Temp. at 66 psi (°C/°F)	108/226	95/203	175/80	164/74
Melt Flow Rate (g/10 min)	60	35	0.70	<1
Supplied in sheets with thickness (mils/mm)	8/0.2	6/0.15	10/0.25	20/0.5
Melting Temp. (°C)	165	165	125-135 (*)	81-91 (**)
Glass Transition Temp. (°C)	-10-0°C	-10-0°C	-10	80

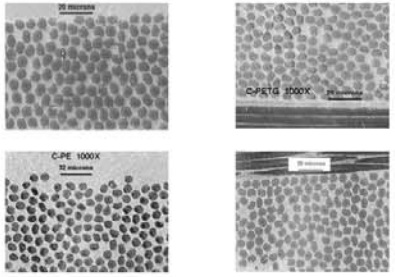
(*) Crystalline polymer. (**) Amorphous polymer.

PROCESSING PARAMETERS

Values of Processing Parameters for Compression Molding of One-Ply Composite Sheets

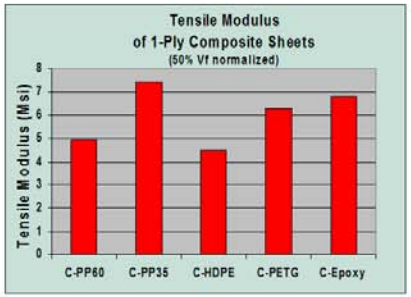
Processing Parameter	Composite			
	C-PP60	C-PP35	C-PETG	C-HDPE
Preheating Time (min)	10	20	10	10
Max Molding Pressure (psi)	2600	2600	19800	4750
Pressing Rate (psi/min)	200	220	220	220
Molding Temp (°C/°F)	190/374	190/374	175/347	190/374
Molding Time (min)	12	12	16	18

PROCESSING: MICROSCOPIC OBSERVATION

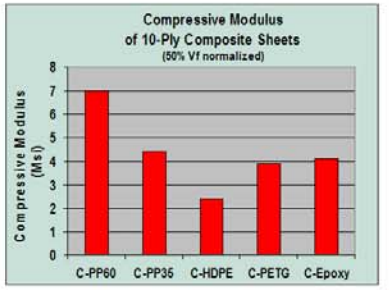


Photomicrograph of one-ply composites: top left C-PP (PP60); top right C-PETG; bottom left C-PE; bottom right C-PP (PP35)

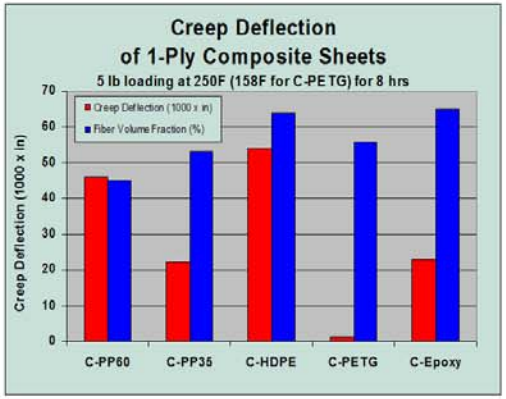
MECHANICAL PERFORMANCE



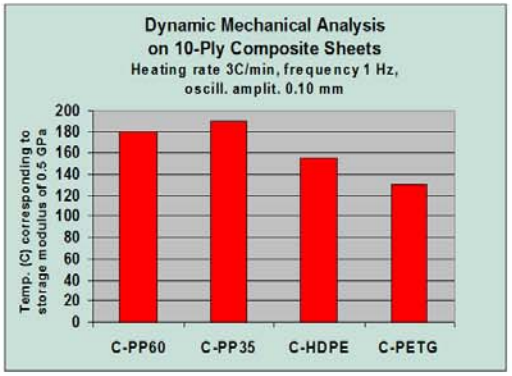
MECHANICAL PERFORMANCE



PROPERTIES: CREEP RESULTS



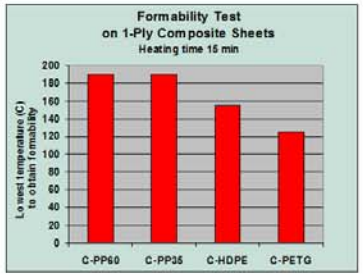
PROPERTIES: DMA RESULTS



PROPERTIES: FORMABILITY TEST

Formability test on one-ply composite in C-PP (PP60). Left: first forming (T=190°C); middle: flattening in oven after first forming (T=190°C); right: forming after flattening in oven (T=190°C).

PROPERTIES: FORMABILITY TEMPERATURE



ENERGY REQUIREMENTS

Parameter	Composite			
	PETG	HDPE	PP60	PP35
Glass Transition Temp. T_g (°C)	78	-27	-10	-10
Melting Temp. T_m (°C)	—	133	157	165
Heat of Fusion ΔH_m (J/g)	—	223	108	85
Forming Temp T_f (°C)	125	155	190	190
Specific Heat C_p (J/g°C) (0°C-T_m)	2.0 (0°C-T_g)	2.0	2.1	2.1
Specific Heat Cp (J/g°C) (T_m-T_f)	2.0 (T_g-T_f)	2.6	2.7	2.7
Energy needed to raise temp. of 50% Vf composites from 0°C to T_f (J/g); (Cp = 0.8 J/g°C for CF)	159	261	263	253

CONCLUSIONS

Candidate C-TP materials evaluated for rigidizable/inflatable space structures in terms of processability, mechanical properties, formability, energy requirements.

Each composite passed all tests, although to varying degrees.

Processability. Excellent inter-tow and intra-tow wet-out in all cases with void content < 1%. Defects limited to rare intra-tow cracks—perhaps related to processing conditions, i.e., rapid cooling—and some inter-tow voids.

CONCLUSIONS

Mechanical behavior.

- Tensile modulus from 5 to 7 Msi (80% of the theoretical limit of 8.3 Msi), compressive modulus from 4 to 7 Msi. Tensile and compressive strengths of all materials 20-40% lower than C-ep.
- Creep deflection: some materials (C-PP35 and C-PETG) performed as well as and better than C-ep

Formability.

- Optimal forming occurs at 20-40C above melting temperature or Tg.
- All candidates can be repeatedly shaped without retaining previous shape.

Energy requirements. C-PETG requires lowest energy input to be formed.