Thermal-Mechanical Characterization/Selection of a Two-Part Epoxy Cure Profile for Structural Bonding

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Description – Design Constraints:

An off-the-shelf two-part thermoset epoxy, used for structural bonding of commercial jet aircraft interiors, was tested and analyzed to find improved cure profiles over manufacturer-supplied cure specifications. Testing methods include tensile testing, differential scanning calorimetry (DSC), thermogravimetric analysis (TGA). Additionally, fracture surfaces were analyzed via stereo-microscopy and scanning electron microscope to confirm cures failed.

Goal – Problem Statement:

To develop an improved set of cure profiles for a two-part epoxy Loctite Hysol EA9309.3NA over the manufacturer's recommended cures.

Future Experiments/Discussion:

Additional cure profiles should be considered at a wider range of temperatures and cure times. Also, additional DSC testing on proposed cures would provide useful information on cure characteristics.

Conclusion:

Mechanical testing provided data to support the 1-hour @ 250°F cure as having the highest average peak break strength. Additional testing of planned cure profiles, and DSC testing, would have supplied important statistics to determine optimal cure profiles for different situations.

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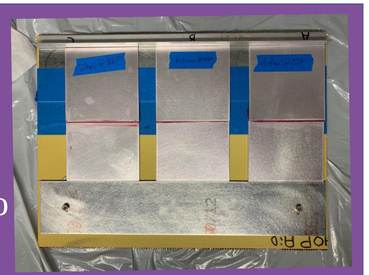
Sample Preparation:

Pre-cut and treated aluminum plates are used as the bond surface for lap-shear testing. A jig was designed using CAD to align and clamp the tensile test sample plates while curing to ensure a complete bond.



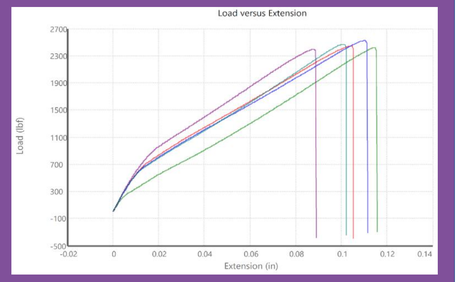
3 different sample plates before curing

Cutting samples from cured plate

CAD assembly of jig

Tensile Testing:

Mechanical lap-shear tensile testing on all cure profiles provided average and peak shear strengths for the epoxy:

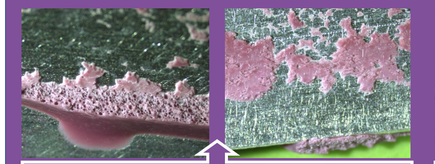


Stress vs strain plot of 1hr @ 250F

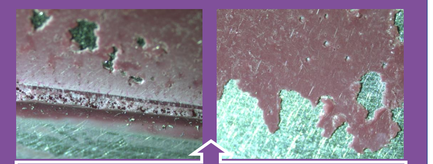
Cure Profile	Constant Area (in²)	Avg Peak Load (lbf)	Standard Deviation	Avg Peak Stress (lbf/in²)	Standard Deviation
5 day (72 F)	0.601	2216.37	24.628	3690.27	41.006
2 hr (180 F)	0.601	2177.10	175.253	3873.40	313.021
1 hr 30 min (226 F)	0.601	2192.44	52.736	3901.14	93.836
1 hr 15 min (226 F)	0.601	2210.237	36.09	3931.81	64.463
1 hr (250 F)	0.601	2450.171	49.257	4079.539	82.012

Stereo-Microscope:

- Air bubbles occur due to the preparation process
- The 1 hour cure samples have a rougher surface
- The 5 day cure samples have a smooth surface
- Scratches are caused by MTS testing or samples handling after the tests

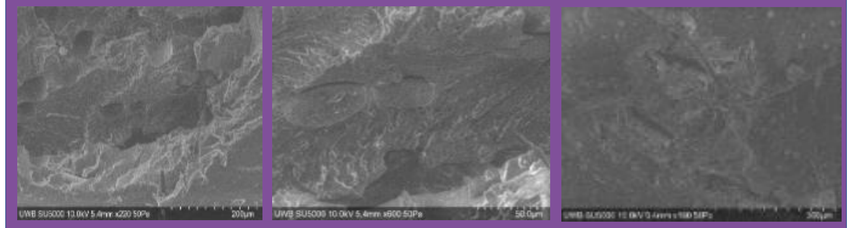


The 1 hour (250°F) epoxy sample
Left: Edge of the shearing surface
Right: Shearing surface



The 5 days (room-temperature) epoxy sample
Left: Edge of the shearing surface
Right: Shearing surface

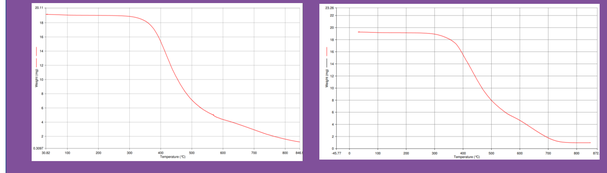
Scanning Electron Microscope (SEM):



SEM pictures of the 5-day room temperature cure. Sample fracture surface was observed to analyze fracture geometry and look for possible contaminants or air bubbles.

Thermogravimetric Analysis (TGA):

Two samples with the same 1 hour cure profile were tested. Both samples quickly began to degrade at about 300°C. This gives a temperature limit for DSC testing.



Epoxy sample completely pyrolyzed and left behind ash by 750°C