

CLEANING LABORATORY EVALUATION SUMMARY

SCL #: 2019

DateRun: 11/25/2019

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ClientType: Additive Manufacturing

ProjectNumber: Project #1

Substrates: Stainless Steel, Liquid

PartType: Part

Contaminants: Resins/Rosins

Cleaning Methods: Immersion/Soak

Analytical Methods: HSPiP

Purpose: To identify the Hansen solubility parameters of grey, grey pro, high temp, elastic, and tough resins.

Experimental Procedure: Twenty-four standardized solvents for HSPiP testing were placed into individual 22ml vials per resin. The resin was poured into a ¼ teaspoon, 1.25ml, and added to a vial; this process was repeated for each of the 24 solvents. Visual observations and ratings were taken after 15 minutes of unheated immersion. The following rating key was based on how the resin dissolved in the solvents.

Chemistries Evaluated:

(1) Toluene; (2) Dimethyl carbonate; (3) Xylenes; (4) Benzyl alcohol; (5) Ethylene glycol; (6) Methyl acetate; (7) Undecane; (8) Ethyl acetate; (9) Methanol; (10) Ethanol; (11) 1,3- Dioxolane; (12) Diethyl carbonate; (13) 1- propanol; (14) 2- propanol; (15) Propylene carbonate; (16) Thiophene; (17) 1-methoxy2-propanol; (18) Dimethyl sulfoxide; (19) Acetone; (20) 1-butanol; (21) Dimethyl glutarate; (22) Anisole; (23) 2-butoxy ethyl acetate; (24) Ethyl lactate

Results:

| Solvent | Rating | | | | |
|---------|--------|-------|------------|---------|----------|
| | Grey | Tough | High Temp. | Elastic | Grey Pro |
| 1 | 1 | 2 | 2 | 0 | 1 |
| 2 | 2 | 2 | 1 | 2 | 2 |
| 3 | 1 | 2 | 2 | 0 | 1 |
| 4 | 0 | 0 | 1 | 2 | 1 |
| 5 | 0 | 0 | 0 | 2 | 0 |
| 6 | 1 | 2 | 1 | 2 | 1 |
| 7 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 2 | 1 | 1 | 1 |
| 9 | 2 | 2 | 1 | 0 | 1 |
| 10 | 1 | 0 | 1 | 1 | 1 |
| 11 | 2 | 2 | 1 | 2 | 1 |
| 12 | 2 | 0 | 1 | 2 | 1 |
| 13 | 2 | 0 | 1 | 1 | 0 |
| 14 | 2 | 0 | 1 | 2 | 0 |
| 15 | 1 | 2 | 1 | 2 | 1 |
| 16 | 2 | 2 | 1 | 1 | 1 |
| 17 | 1 | 0 | 1 | 2 | 1 |
| 18 | 2 | 0 | 2 | 1 | 0 |
| 19 | 2 | 2 | 2 | 0 | 1 |
| 20 | 1 | 0 | 1 | 1 | 0 |
| 21 | 2 | 0 | 2 | 2 | 1 |
| 22 | 1 | 2 | 2 | 2 | 1 |
| 23 | 1 | 0 | 2 | 1 | 0 |
| 24 | 1 | 2 | 0 | 2 | 1 |

Observations from Testing:

The two hardest resins to dissolve were the High Temp. Resin and the Grey Pro resin within the 10-minute cleaning time. There was no change in ratings even after a full 20 minutes of immersion. Isopropanol (#14) was not effective at dissolving the Tough and Grey Pro resin. Most of the resins settled on the bottom of the vial and agitation after rating did improve solubility with some of the solvents.

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HSPIP Program Sphere Results:

A core value for D, P, and or H value of 0.25 or less is considered good, and 0.75 or higher is considered a bad.

| Resin | D Value | P Value | H Value | Core Values |
|------------|---------|---------|---------|---------------------|
| Grey | 16.49 | 0.84 | 10.97 | ±[0.30, 0.65, 0.90] |
| Tough | 18.72 | 10.35 | 15.49 | ±[0.35, 1.95, 0.75] |
| High Temp. | 18.61 | 15.76 | 14.87 | ±[1.45, 1.15, 1.15] |
| Elastic | 20.83 | 11.82 | 13.87 | ±[0.20, 0.65, 0.45] |
| Grey Pro. | 16.51 | 16.67 | 12.86 | ±[0.25, 0.15, 0.30] |

Summary:

| Substrates: | | Stainless Steel, Liquid | | | |
|----------------------|---|-------------------------|-------------|--------------------------|---------------|
| Contaminants: | | Resins/Rosins | | | |
| Company Name: | Product Name: | Conc.: | Efficiency: | Effective: | Observations: |
| Fisher Scientific | Dimethyl glutarate (CAS:1119-40-0) | | | <input type="checkbox"/> | |
| EM Science | Toluene | | | <input type="checkbox"/> | |
| Alfa Aesar | Dimethyl Carbonate 99% | | | <input type="checkbox"/> | |
| Alfa Aesar | Methyl Acetate | | | <input type="checkbox"/> | |
| TCI America | Undecane | | | <input type="checkbox"/> | |
| Fisher Scientific | Methanol (CAS: 67-56-1) | | | <input type="checkbox"/> | |
| Fisher Scientific | Propylene carbonate 99.5% (CAS: 108-32-7) | | | <input type="checkbox"/> | |
| Alfa Aesar | Thiophene | | | <input type="checkbox"/> | |
| Fisher Scientific | Dimethyl Sulfoxide - DMSO (CAS: 67-68-5) | | | <input type="checkbox"/> | |
| Fisher Scientific | Acetone (CAS: 67-64-1) | | | <input type="checkbox"/> | |
| Alfa Aesar | 1-Butanol 99.4%+ | | | <input type="checkbox"/> | |

Conclusion:

Additional solvents will be needed for testing to create a better sphere of solubility for each resin. It would also be helpful going forward to get coupons made of the resins so we can test cured and uncured at the same time. Once the spheres are considered "good", the D, P, and H values will be plugged into the software to create a junction value of all of the resins. This junction value will be used to identify the safer solvent options.