Environmental Stress Cracking (ESC) is a decades-old problem in the polymer industry that causes failure of polymers. Buehler has experienced ESC in its Poly(ethylene terephthalate)-Glycol (PETG) safety windows for its abrasive cutting machines due to its interaction with coolant. Accelerated ESC propagation testing was utilized to determine the compounds most responsible for ESC and in what concentrations said compounds initiate ESC. Alternative coolants and chemical compounds that reduce the ESC growth rate were identified and suggested to Buehler.

Environmental Stress Cracking

- Environmental Stress Cracking (ESC) is the premature crazing, cracking, and embrittlement of plastics due to a combination of associated stress/strain in the presence of secondary plasticizing agents like adhesives, coolants, etc.
- ESC is responsible for the failure of ~25% of polymer products
- Buehler’s Cool 3 coolant has 4 components in it:
  - Component 1 – Methyldiethanolamine
  - Component 2 – Butoxydiglycol
  - Component 3 – Glycerol poly(oxyethylene) poly(oxypropylene) ether
  - Component 4 – Butoxydiglycol
- Area measurements were done by assuming the samples were rectangles. Three areas were calculated for each. ESC area was calculated by calculating the area of polygon drawn around the ESC region using ImageJ software and percentages were calculated.
- Corrosion Resistance Experimentation
  - Components 2 and 3 were identified as ones responsible for ESC.
  - Optical Microscopy Procedure
  - Samples were inspected at 4, 7, 11 and 14 days.

Experimental Procedure

- Buehler reports ESC appears after about 6-months of heavy usage on PETG.
- An accelerated testing regimen was developed to simulate rapid ESC growth and propagation.
- ESC Growth Experimentation
  - Three samples of 5/64 inch thick PETG inserted into tensile jigs (fig. 2) and strain of 0.5.
  - Samples then submerged in coolant solution
  - A sample was withdrawn from coolant at 15-30- and 60-minutes for analysis
  - Experiment was designed to give clear indication of ESC propagation through the polymer.
- Buehler’s Cool 3 coolant has 4 components in it:
  - Component 1 – Water
  - Component 2 – Methyldiethanolamine
  - Component 3 – Butoxydiglycol
  - Component 4 – Glycerol poly(oxyethylene) poly(oxypropylene) ether
- Tests were run by varying concentrations of each component individually within the range specified in the MSDS. This was done to identify which component(s) was/were the main cause of ESC.

Results and Discussion

Area Quantification:

- Components 2 and 3 were identified as ones responsible for ESC.
- An alternate to component 2 in Cool 3 was identified and tests were done with both of them to see if any difference in ESC was observed. Fig. 4 shows 60 minute test results for the two component 2 options tested in a water solution.

Integrity Quantification:

- Even though fig. 5 shows that the current component 2 was better, ESC observed in its case was much more intense suggesting that the new component gave less intense ESC on a wider area whereas the current option gave more intense ESC on a smaller region. These are supported by the blind test results plotted in fig. 7.

Corrosion Resistance:

- Since component 2 is the corrosion inhibitor in the Cool 3 system, corrosion resistance tests proved that the new alkanol amine was just as effective as the current one over a period of 11 days as shown below. TC-1 was also comparable to Cool 3.

Recommendations

We recommend the continued use of PETG polymer material but with a change in machine coolant. With current coolant, a change in components 2 (as suggested) and 3 is necessary. TC-1 also provides a good alternative for coolant that is already commercially available.