ABS Plastic Coupling Cracking

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Summary

• Acrylonitrile Butadiene Styrene (ABS) plastic couplings installed as part of a water closet carrier system were found to be leaking in many of the rooms of a local hotel. The installer was blamed for his alleged use of certain thread sealing compounds that were incompatible with ABS. Our examination found that the leaks resulted from cracks through the coupling walls that exhibited features common to creep rupture or environmental stress cracking (ESC).

• We conducted a lifetime prediction analysis including mechanical testing, residual stress measurements, strength and strain to failure measurements, and finite element analysis, and determined that the failures could not have occurred as a result of the incompatible material alone.

• Manufacturing and design defects existed in the ABS couplings that made them particularly sensitive to installation tolerances as well as relatively low applied stresses.
Lifetime Prediction Analysis

- Environmental Stress Cracking
- Environments Selected for Analysis
  - Air
  - Thread Sealing Compound (diacetone alcohol)
- Stress
  - Residual
    - Manufacturing
  - Applied
    - Concentricity
      - Contact force at tip of coupling during installation
Subject ABS Plastic Coupling

Cracked

0.298 Thick

0.400 Thick
OD and ID Not Concentric

New Unused Coupling

0.424 in

0.248 in
Coupling Data for Finite Element Model

- OD = 4.607 in
- ID = 3.933 in
- T = 0.340 in
- L = 6 in from tip to end of threads
- ID not concentric with OD
  - Thinnest section = 0.298 in
  - Thickest section = 0.400 in
  - Offset from average = 0.06 in
    - Causes contact force at tip of coupling
- E = 289,000 psi
Displacement applied over 2.4 in of circumference; necessary load to produce this displacement at bottom is 280 lb (117 lb/in)
Resulting Lateral Displacement

0.03 in 0.03 in
Resulting Max Stress = 3.66 ksi
Resulting Applied Stress Distribution

Two Locations

3.66 ksi
2.13 ksi
2.10 ksi
Residual Stress Distribution

Compression, C  Tension, T

Crossover depth, d

Thickness, t

Force Balance Through Cross Section

\[ C \ d = T \ (t/2 - d) \]

\[ T = \frac{(C \ d)}{(t/2 - d)} \]
Average Residual Stress

- Average measured compressive stress to crossover depth
  - Cracked Specimens: -5.6 ksi
  - Uncracked Specimens: -3.3 ksi
- Crossover depth: 0.01 to 0.02 in
- Average d = 0.014 in
- Average t = 0.338 in
- Average Tensile Residual Stress
  - Cracked Specimens: 0.51 ksi
  - Uncracked Specimens: 0.30 ksi
Material Strength Curves

Creep Rupture of ABS

In Air: Stress = 5.405 Time^{-0.0676}

With Thread Sealant: Stress = 4.8481 Time^{-0.0676}

Time to Failure (hours)

1.14 years to 11.4 years
Life Prediction

• In Air
  – Cracked  $2.13+0.51=2.64$ ksi – 4.6 yr
  – Uncracked $2.13+0.30=2.43$ ksi – 15.6 yr

• In Thread Sealing Compound
  – Cracked  $2.13+0.51=2.64$ ksi – 0.9 yr
  – Uncracked $2.13+0.30=2.43$ ksi – 3.1 yr
Results

• Effect of Environment
  – Shortens life from avg of 10.1 yr to 2.0 yr

• Effect of Residual Stress
  – Shortens life from avg of 9.4 yr to 2.8 yr

• Effect of Applied Stress
  – Shortens life from >100 yr to average of 6.1 yr depending on residual stress and environment
  – Proper design stress of 1.24 ksi achieved if Y displacement reduced from 0.060 in down to 0.035 in