Why Commercial Epoxy-Phenolic Coatings Can Crack in Service Leading to Costly Failures

By PCN Editor

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Premature cracking is a significant issue in epoxy-phenolic (EP) coatings used for corrosion protection in LNG and Oil & Gas, leading to costly failures. The formation of cracks is primarily attributed to curing-induced internal stress, which results from crosslinking reactions, solvent evaporation, and thermal expansion mismatch between the coating and the metallic substrate.

Role of Fillers

The presence of fillers, such as barium sulphate and talc, can exacerbate the crack susceptibility in epoxy coatings and EP coatings. Fillers can increase the coating's elastic modulus, leading to an earlier development of a large internal stress and a higher crack susceptibility. New research by Qiong Li, Claus Erik Weinell and Søren Kiil (2024) has shown that premature defects and crack formation in filler-containing epoxy coatings occur much earlier than in filler-free epoxy coatings, attributed to stress concentration and magnification around the filler particles.

Factors Influencing Premature Cracking

Several studies have investigated the factors influencing premature cracking in epoxy coatings:

1. Curing-induced shrinkage, thermal coating strain, and substrate strain: Song et al. found that premature cracking results from a combination of thermal stress, substrate-related stress, and curing-induced internal stress, with the latter being highly dependent on the chemical structure of the binders.

2. Thermal-mechanical properties: Lee and Kim observed that the thermal-mechanical properties, such as the coefficient of thermal expansion and the glass transition temperature, rather than curing-induced shrinkage, dominated the cracking resistance in immersion-grade epoxy coatings.

3. Curing temperature and vitrification: Chekanov et al. attributed defect formation to the onset of vitrification, where the glass transition temperature of the coating equals the curing temperature.

Consequences of Premature Cracking

Premature cracks in epoxy coatings can lead to several detrimental effects:

1. Decreased mechanical properties: Defects and cracks decrease the coating's mechanical properties, such as strength, dimensional stability, and stiffness.

2. Accelerated environmental degradation: Cracks can accelerate the environmental degradation of coatings by providing pathways for the ingress of moisture and salts, resulting in de-bonding or coating failure.

3. Blister formation: Oehler et al. found that for coatings with a strong barrier performance, water or electrolyte migration along the coating-substrate interface via initial defects can lead to blister formation within the migration zone.

To mitigate premature cracking and ensure the long-term performance of epoxy-phenolic coatings, it is crucial to consider the factors influencing internal stress development, such as filler content, curing conditions, and thermal-mechanical properties of the coating system.

Conclusions

To protect metallic substrates, such as industrial processes and infrastructures, from corrosive ions, UV-radiation, moisture, dissolved oxygen and carbon dioxide, and mechanical damage, organic coatings. Due to their excellent mechanical properties, barrier performance, and thermal stability, epoxies and EP coatings are amongst the most commonly used binders for protective coatings in LNG and Oil & Gas applications. However, as a result of crosslinking reactions, solvent evaporation, and a thermal expansion mismatch between the coating and the metallic substrate, in-plane internal stress develop over time.

Premature crack formation in epoxy coatings mainly results from curing-induced internal stress. Research has shown that although the measured internal stress is much smaller than the coating strength, cracks still initiate and propagate within the coating as a result of localized stress concentration.

In particular, cracks initiate and propagate within the coating as a result of localized stress concentration provided by the filler particles such as barium sulphate and talc. Such fillers also increase the coating elastic modulus of the coating leading to earlier development of a large internal stress and a high crack susceptibility.

References

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