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The Advantages of Epoxies versus Polyester Resins in Composite Applications

In any high-tech structural applications, where strength, stiffness, adhesion, water and chemical resistance are required, epoxy resins are seen as the minimum standard of performance for the cured product or for the matrix of the composite material. This is why in aircraft and aerospace applications, civil engineering, electrical industry, construction and maintenance repair, epoxies have been the norm for decades.

There are still some applications where polyester resins are used (pleasure boats under 60' long, some non-structural composites, molding applications). The main consideration for material selection for most composite builders is cost, with performance and more importantly, the longterm cost often being a secondary consideration. As a general rule epoxy resins are two times or more expensive than polyesters.

However, when durability and longevity of the higher quality structures made of epoxies are taken into consideration (e.g. epoxy molds can survive 10+ times more de-moldings comparing to polyester fiberglass) the long term gain can be tremendous.

Let us review the main advantages of epoxy resins in more details.

1. Adhesive Properties

Epoxy resins yield far better adhesion than polyesters resins. The superior adhesion of epoxy is due to two facts. The first is at molecular level, where the presence of polar hydroxyl and other groups improves the bond with a substrate. The second is at the physical level – epoxies cure with very low shrinkage (< 2 %), as a result of this the internal stress produced between the resin and the substrate or reinforcement during the curing process are very low.

2. Micro- and Macro-Cracking

Polyesters shrink up to 7-10 % volumetrically. They continue to cure over long periods of time, and the high shrinkage effect may not be immediately obvious.
However, delaminating and cracking will be seen sooner or later.

3. Mechanical Properties

In general, the tensile strength of epoxy is 20-30 % higher than that of polyesters. The ability of epoxy to withstand stress or deformation without structural damage is much better, and creep under load is much lower. Mechanical properties are very important when molding, machining, de-molding, and when handling molds made of polyester which are prone to cracks and delaminate.

4. Fatigue Resistance

The superior ability to withstand cyclic loading is an essential advantage of epoxies over polyester resins. This is a primary reason epoxies are chosen almost exclusively for aircraft structures and other high strength composites.

5. Water Resistance

This is an important property of any resin, particularly in direct contact with moisture. All resins will absorb some moisture, adding to total weight, but what is more significant is how the absorbed water affects the resin and its bond to the substrate, leading to a gradual and long-term loss of mechanical properties. Polyesters are prone to water degradation due to the presence of hydrolyzable ester groups in their molecular structure.

6. Handling Properties

Both epoxies and polyesters have two components to be mixed just before application. A common mix ratio for polyesters 100 parts of resin to 1-5 parts of catalyst. At such a ratio a very reliable metering and mixing procedure is required. Epoxies are more user friendly with non-fractional mix ratios like 1/1, 2/1. Depending on catalyst used, pot life of polyesters varies within 20-40 min. Epoxy may be formulated with a very long pot life (up to 4-6 hrs) which is very convenient for large applications.

Shelf life of epoxies is usually 2-3 time longer than that of polyesters.

7. Safety and Health Issues

Polyesters contain up to 40 % styrene (CAS # 100-42-5) – a monomer with a strong offensive odor. The International Agency for Research on Cancer considers styrene to be "possibly carcinogenic to humans" (Group 2B). Polyester resin components are flammable liquids, catalysts are flammable and explosive. The handling of polyesters in large volumes in particular, requires special training and specific safety measures.

Styrene belongs to a group of volatile organic compounds (VOCs) that are organic chemical compounds with significant vapor pressures. These compounds can negatively affect the environment and human health. The United States Environmental Protection Agency (EPA) regulates VOCs in the air, water, and land. The United States Department of Labor and its Occupational Safety and Health Administration (OSHA) regulate VOC exposure in the workplace. The global regulation of VOC's is becoming more severe and restrictive.

Composites processors that use polyester resins report their emissions of styrene monomer to their state environmental authority. Environmental regulations under Title V of the 1990 Clean Air Act amendments require EPA to certify programs in every state to limit emissions of volatile organic chemicals (VOCs) and hazardous air pollutants. To satisfy EPA, the states must require all major emissions sources to document their emissions and obtain state operating permits (see PT, Feb. '95, p. 83). These regulations will continue to become more stringent under the current federal government.

Properly formulated epoxies do not contain carcinogenic components, are VOC free, non-flammable and most critically, are much more friendly in transportation, handling and in the workplace.