PF (Phenol Formaldehyde)

General information

Overview

Considered to be the first truly synthetic polymer to be exploited commercially. Formed by combining phenol and formaldehyde in the presence of a catalyst. PF resins are used for bonding, coating, and as molding compounds. Molding compounds usually contain fillers as the unfilled resin is extremely brittle. As molding compound resins are up to 60% filled, the properties are significantly dependent on filler type.

Strengths

Low cost unfilled resin. High temperature resistant grades available (with appropriate fillers), very low smoke emission, high oxygen index (dependent on catalyst used in reaction) and self-extinguishing (though flammable fillers can reduce this), very low toxicity of combustion products compared with e.g. PUR. Very good UV resistance in terms of mechanical, dimensional, and electrical properties though significant darkening will occur. Similar compressive strength to UF, good dimensional stability over a wide temperature range. Long-term and wide ranging application experience. Easily molded into intricate shapes.

Limitations

Only subdued/dark colors available. Worse scratch resistance than MF, lower water and heat resistance than MF. Tends to be brittle with low cost fillers (e.g. cellulose) and very brittle when unfilled (wall thicknesses less than 1.1mm not recommended for any grade). Some grades are attacked by alkalis. Humidity significantly affects tracking resistance, surface finish adversely affected by hot, wet conditions (particularly wood-filled grades). High molding pressures, releases volatile compounds during cure, requires high curing pressures for use as adhesives.

Tradenames

Bakelite, Catalin, Tufnol

Typical uses

Distributor caps, the nose cone on the space shuttle's external fuel tank (CF reinforced), in two component adhesive systems (resin and hardener) for the bonding of wood and in plywood and MDF fabrication. Approximately 49% of PF is used in the production of plywood with a further ~16% being used for MDF/fiberboard. Around 12% of PF is used for thermal insulation. 2.5% is used for friction materials, e.g. cut-off/grinding wheels (containing alumina or silicon carbide abrasive grain), the matrix for brake linings (the part of the brake pad which contacts the brake disc/drum, often filled with glass, rubber, aramid or metal), and clutch facings. Around 5.5% of production is used for molding parts and products, 5.5% is used for laminated (e.g. Formica), and only around 0.5% is used for coatings.

Composition overview

Compositional summary

(-CH2-C6H3(OH)-)n, approximate formula

Material family	Plastic (thermoset)
Base material	PF (Phenol formaldehyde resin)

Effect of composition

Cellulose, wood flour, and rag filled grades are cheaper but have higher mold shrinkage. Glass filled grades have higher tensile strength, flexural modulus, impact strength, heat distortion temperature, and surface hardness. Mica filled grades have high oxygen indexes, low mold shrinkage, and the best combination of electrical characteristics of phenolic grades at the expense of impact strength. Mineral filled grades have the highest maximum operating temperatures. Ammonia-free and so odor-free grades are also available for use as bottle tops and cosmetic containers. Toughness and impact resistance can be improved with rubber or PA modification. Metallic fillers can produce magnetic compounds or x-ray/microwave shielding parts. Graphite filler reduces coefficient of friction.

Processing properties

Feedstocks & production

Cumene from propylene and benzene. Phenol from cumene, O2, and acid. Methanol from CO and H2 (from natural gas) which is then used to produce formaldehyde with a silver catalyst. In general, a phenolic resin is the condensation of a phenol with an aldehyde.

First commercial production	1909

Available forms

Flake, powder, liquid, and filled grades as granules, nodules, pellets or flakes.

Forming

Very suitable for compression molding (especially wood and cellulose filled grades) and transfer molding, suitable for foam casting and injection molding (or RIM), extrusion is also possible. Injection and transfer molding gives the highest tensile and flexural strength for grades except those with long fibers (e.g. glass). For non-insert molding, transfer molding has been largely replaced by injection molding. Advances in injection molding mean that there is little economic disadvantage in injection mold processing compared with thermoplastics.

Machining
Generally easy to machine though fabric, mineral, long glass fiber, and mica filled grades are more difficult.

Joining
Suitable for bonding. Epoxies produce strong bonds. Polyurethanes produce weaker though still significant bonds.

Surface treatment
Very difficult to paint, though glass, and mineral filled grades slightly easier (still difficult).

Geo-economic data for principal component

Annual world production	4.04e6	ton/yr