The Influence of Flame Retardants on the Combustion of Glass Fiber-Reinforced Epoxy Resin

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Glass fiber-reinforced polymers (GFRP) have good mechanical properties, making them a promising material for construction and aviation. In order to improve the epoxy resin based GFRP fire resistance, the samples with addition of DDM-DOPO (9,10-dihydro-9-hydroxy-10-phosphaphenantrene-10-oxide-4,4`-diaminodiphenylmethane), CBz (phosphorus-containing cardanol-based benzoxazine) and graphene were prepared. Traditional flammability and thermal stability tests along with the experimental investigation and numerical modeling of flame spread over GFRPs were carried out. Graphene and DDM-DOPO exhibited comparable effectiveness in reducing the flame spread rate (ROS) at the same loading. 6wt% of DDM-DOPO addition in GFRP led to increasing limiting oxygen index (LOI) from 22.4 to 26.5 and self-extinguishing in UL94 test. The coupled numerical model of flame spread over the polymers has satisfactorily predicted DDM-DOPO gas-phase effect on decrease of ROS for glass fiber-reinforced epoxy resin. Also, the numerical model based on the decrease of combustible fuel and increase of noncombustible volatile pyrolysis products has predicted effect of graphene on decrease of ROS with a good precision. GFRP with the addition of phosphorus-containing CBz has shown a significant improvement in fire resistance (LOI=28.1) and achieved self-extinguishing in the UL94 test. Moreover, addition of CBz has not deteriorated mechanical properties of the samples. One more advantage of CBz, that it is fully bio-based, that makes it environmentally friendly for industrial use. GFRPs based on phosphorus-containing methacrylate ester binders were synthesized to prepare glass fiber reinforced samples. The samples had high LOI values (>31%), which were achieved due to chemically bound phosphorus in the molecules of the initial oligomers. The fire resistance test results according to FAR-25 (clause 867 (a)) showed that the samples (dimensions 140x150 mm) retained their integrity for 5 minutes under direct flame exposure with a temperature of 1100 °C. Furthermore, glass fiber reinforced polyimide resins have also been tested in flammability tests, demonstrating very high LOI values over 80 and low smoke production. As a result of this research, new fire-resistant GFRPs based on epoxy resin, phosphorus-containing methacrylate ester, and polyimide binder have been developed. These materials can meet modern requirements for safety, manufacturability, and economic efficiency, and can be used as structural materials in construction and aviation.

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