SYNTHESIS, CHARACTERIZATION AND EVALUATION OF EXPANDABLE GRAPHITE BASED INTUMESCENT FIRE RETARDANT COATING FOR STEEL STRUCTURES

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ABSTRACT

Structural steel is an integral part of any construction such as bridges, buildings, ships, cars and off shore structures. The integrity of structural steel has pivotal role in safety of structures and human. In the case of fire, the steel starts losing its load bearing ability above 500°C and in the case of fire, the temperature of unprotected steel rises to 800°C within 10 minutes. Intumescent fire retarding coatings are designed to insulate the structural steel under the action of heat, flames or fire thus protecting their integrity.

The main objectives of this research project are to synthesis and characterization of an expandable graphite (EG) based intumescent coating formulation (ICF). An intumescent coating with considerable char expansion and flaky morphology can provide good heat shielding to the steel structures. A high residual weight of intumescent coating on exposure to fire forms a protective passive layer of char which can minimize the flow of heat to steel substrate. A range of formulations were synthesized by varying the concentration of intumescent ingredients. One formulation containing 8.5wt% expandable graphite was identified with char expansion 13.4 times. The performance of the ICF was optimized using a various particle size of EG. An ICF with 300μm particle size improved char expansion, morphology, residual weight and reduced steel substrate temperature to 367°C after 60 minutes fire test. IFC formulation containing 300μm was further studied for reinforcing inorganic fillers, Multi-walled carbon nanotubes (MWCNTs), Kaolin clay (KC) and Zirconium silicate (ZS). One formulation containing 5wt% ZS showed 24 times char expansion and residual weight was increased to 38% with respect to IF5-BA-Mel. The substrate temperature was reduced to 213°C and char was hard and adherent with substrate.

Carbolite furnace was used to study the char expansion of intumescent coating formulations at 500°C and 800°C. Heat shielding test was performed according to ASTM E119 standard test. The test was conducted for 60 minutes and the temperature

of the steel substrate was recorded at an interval of one minute. Scanning Electron Microscopy (SEM) and Field Emission Scanning Electron Microscopy (FESEM) were used to study the char morphology. Thermal stability of IFCs was analysed using Thermogravimetric analysis (TGA) and Differential thermal analysis (DTA). The chemical composition of residual char was determined using X-Ray Diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and X-Ray Photoelectron spectroscopy (XPS). The weather resistance of IFCs was measured using Q-Sun Xenon Test Chambers. The gaseous products during burning of coating samples were analyzed by Pyrolysis Gas Chromatography (Py-GC).

The examination of char morphology showed that flaky and multiporous type of char is most suitable to reduce the flow of heat to steel substrate. It was also noted that addition of ZS 5wt% in ICF modified the char morphology from flaky to multiporous and this was very helpful to minimize substrate temperature. XRD analysis of char of IFCs showed that the presence of high temperature boron based compounds i.e. borophosphate, boron oxide and borophosphate oxide which are stable at high temperature and helped to reduce the flow of heat to substrate. The presence of these compounds in the char was also confirmed by functional groups analysis using FTIR. The elemental analysis and carbon contents of selected ICFs showed high carbon contents compared to oxygen. This type of char is suitable for formation of carboneous layer on the substrate surface. TGA analysis showed a considerable increase in residual weight of IF5-BA-Mel reinforced with inorganic fillers. Py-GC analysis of gaseous products released during burning of selected ICFs showed less concentration compared to IF5-BA-Mel formulation. The weathering test of selected ICFs showed approximately 2% decrease in char expansion, however no change in char morphology was observed. Based on the results it was concluded that a ICF containing 5wt% ZS is more suitable for long term application due to high char expansion, lower substrate temperature, high residual weight and environment friendly properties.