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Effect of Dolomite Clay on Thermal Performance and Char Morphology of Expandable Graphite Based Intumescent Fire Retardant Coatings

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Abstract

Dolomite Clay was introduced in a traditional intumescent flame retardant system which contains ammonium polyphosphate/expandable graphite/melamine (APP–EG–MEL) to evaluate its effects on char morphology and fire performance. The effect of dolomite clay on the fire-resistance and thermal properties of expandable graphite based Intumescent fire retardant coatings has been investigated by using Bunsen burner fire test and thermal gravimetric (TG) techniques. The current study describes the effects of Dolomite Clay on the heat shielding performance of intumescent passive fireproofing coatings during fire testing. The fire performance of dolomite clay reinforced intumescent coating formulations were evaluated by Bunsen burner fire test according to ASTM E-119. Results showed that the dolomite reinforcement in IFRC formulation significantly reduced the steel substrate temperature up to 180 °C after 1 hour of fire exposure. The coating degradation was studied using thermogravimetric analysis (TGA). The physical morphology and alignment of intumescent char residue were studied by field emission scanning electron microscopy (FESEM). TGA analysis revealed that IFD (8) containing 8 wt. % of dolomite clay enhanced residual weight by 37.30%. It is suggested that Dolomite clay can enhance the fire performance and can significantly affect the formation of dense and continuous char if incorporated as a filler in conventional intumescent fire resistive systems.

Keywords: Intumescent coatings; dolomite clay; char morphology; thermal gravimetric; and field emission scanning electron microscopy

1. Introduction

Lately, fire safety has become an essential requirement of construction legislation in many countries. The strength and load-bearing ability of the steel structures decrease quickly with rising temperature, therefore, any fire accident in steel based buildings may lead to collapse, and causing huge economic losses as a consequence. Avoiding these accidents the protection of steel against fire is crucial. Intumescent coatings are extensively used for ensuring effective fire safety of structural units. To explore its potentials as highly effective fireproofing techniques, various clays additives and filler has been extensively used [1].

Clay integration in polymer for fire retardancy purposes have drawn a great improvement in solvent based Intumescent fire retardants systems. Clays due to their structure can improve mechanically and obstruction properties of polymer/ intumescent coating even at very low loading rate [2, 3] Numerous studies described also the fire resistance action of different clays in solvent based intumescent fire retardant coatings, but the role of dolomite clay in intumescent coatings has not been adequately clarified yet.[4].

Dolomite is carbonate mineral composed of calcium magnesium carbonate $CaMg(CO_3)_2$. Dolomite clay which is known by the local as 'batu reput', is a primary sediment mineral and abundantly available in Malaysia. Dolomite chemical composition consist of 70% of calcium oxide CaO, 20% of magnesium oxide MgO and others in form of carbon and silicon oxide which are already being recognize globally as good fillers of all the time in intumescent fire retardant coatings[5].

The performance of the intumescent coating depends on the choice of the ingredients and their appropriate combinations[6]. Currently, this conventional formulation of the intumescent fire retardant system (APP-EG-MEL) is not adequate due to its low fire performance and thermal stability [7, 8]. Nowadays, extensive research had been done to increase the efficiency of intumescent fire resistive coatings. Recently inorganic fillers were incorporated in the intumescent coating to have improvement in the thermal insulation properties and char strength[9] . One of the solutions is an amalgamation of a mineral based clay dolomite as filler in the intumescent coating.

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2. Experimental

2.1 Materials and methods

In this research, five formulations of intumescent fire retardant coating were developed while using bisphenol A BE-188 as epoxy resin with tetra ethylene tetraamine H-2310 as a curing agent. This formulation contained an acid source (APP), a carbon source (EG), a blowing agent (Melamine-MEL), an additive (Boric acid-BA), alone with Bisphenol based binder system and Dolomite filler with the difference in weight percentage (0-8 wt.%) .All materials were purchased from Sigma–Aldrich (M) Sdn Bhd. Malaysia. . IFD (0) is the controlled formulation while IFD (2) - IFR (8) are added with Dolomite filler with the difference in weight percentage.

For all IFR coating formulations, selected weight percentage of APP, MEL, BA and Dolomite filler were grounded for 1 min by using a grinder. This was followed by mixing with epoxy and hardener with all ground material and expandable graphite (EG) using shear mixture at 40 rpm for 20 min. After 20 minutes, hardener was added and been mixed for another 10 minutes. The total process is 30 minutes for each sample. The formulation then coated on steel substrate having a cross-sectional area of 10 cm^2. The coating was applied using a brush on the steel substrate .The coated steel substrates were cured at ambient temperature for 24 hours. Coating thickness was maintained at 1.5 mm it was ensured by digital Vernier caliper measurement. Table 1 showed five intumescent coating formulations (ICF) designed to study the effects of dolomite clay on fire performance and thermal shielding of the IFRC. The char was characterized by FESEM. The residual weight was investigated using Thermogravimetric Analysis (TGA).

Table 1: The weight percentage of dolomite clay reinforced intumescent coating formulations

Sample No.	Component (wt. %)						
	APP	EG	BA	MEL	Dolomite	Epoxy	Hardener
IFD(0)	11.76	5.5	11.76	5.5	0	43.42	21.71
IFD (2)	11.76	5.5	11.76	5.5	2	42.10	21.05
IFD (4)	11.76	5.5	11.76	5.5	4	40.78	20.39
IFD (6)	11.76	5.5	11.76	5.5	6	39.46	19.73
IFD (8)	11.76	5.5	11.76	5.5	8	38.14	19.07

3. Characterization of intumescent coating and char

3.1 Heat shielding effect

Five different types of formulations were determined and tested for this analysis including the controlled coating sample IFD (0). The samples used for this analysis are IFD(0) ,IFD (2), IFD (4), IFD (6) and IFD (8). In order to evaluate the heat penetration pattern from source to the steel substrate, the fire test was performed for each coating formulation. A methane gas Bunsen burner was used to conduct the fire test of the intumescent fire resistive coating formulations on the steel substrate according to ASTM E-119. A direct fire by Bunsen burner can reach up to 1350˚C in just a few minutes. To measure the continuous increase in steel substrate temperature, three thermocouples of type K were attached at the back of the steel substrate during bunsen burner test. The temperature was recorded with the help of Anarittsu Data logger, Input Channel 6 Model AM- 8000K .The temperature-time curve was documented for one hour of Bunsen burner fire test. Figure 1 shows the Bunsen burner fire test arrangements for heat shielding analysis of dolomite reinforced intumescent fire retardant coatings.

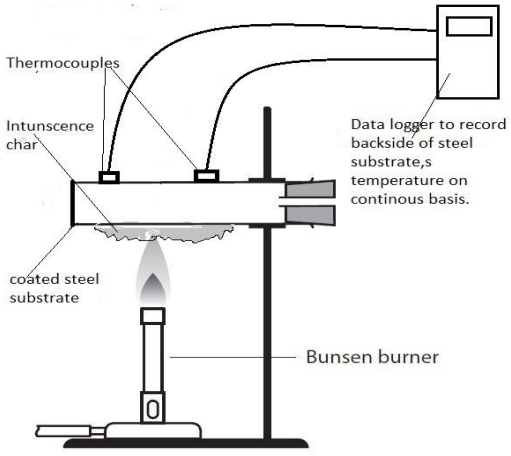

Figure 1: Bunsen burner Fire Test arrangements