An Experimental Investigation on Effectiveness of in Tumescent Coating as Thermal Barrier on Wire Netting

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Abstract

This paper investigates the result of an experimental study on thermal resistance performance of intumescent coating on wire netting which exposed to high furnace temperatures. In this investigation the fire resistance test was carried on the intumescent coated wire netting of different materials such as stainless steel, aluminum and galvanized steel. The study variables include double coat and triple coat of intumescent coating on Stainless Steel (SS), Galvanized Steel (GS) and Aluminum wire nettings. One side of wire netting is exposed to a high temperature of about 900 °C developed with the help of muffle furnace. The heat flux was measured on the unexposed side of the wire netting as faraway of 500 mm from the origin of heat. It was observed that the wire mesh of SS, Aluminum and GS allowed the maximum heat flux of about 9.26 W/cm^2, 3.67 W/cm^2 and 8.69 W/cm^2 respectively with double coat whereas heat flux with triple coat of intumescent on SS, Aluminum and GS wire netting were found to be 3.04 W/cm^2, 2.77 W/cm^2 and 5.31 W/cm^2 respectively. It was observed that the intumescent coating is acting as good thermal barrier and able to reduce the heat flux by around 57 %.

Keywords— Intumescent Coating, Radiation Heat, Thermal Barrier, Wire Netting

I. INTRODUCTION

Fire is one of the major problems not only in the developing countries but also in developed countries. The fire is still of great benefit to all of us if it is under control, but when it spreads, it can cause havoc to the mankind. Every year, there is heavy loss of lives and property due to fire incidents. In the absence of fire safety and fire protection measures in buildings, occupants are likely to expose to asphyxiate toxic gases and hot environment [1]. In general active fire protection system and passive fire protection system are the two types of fire protection system available in most of the buildings. Passive fire protection systems are the system which is always present and effectively working whenever there is fire. Passive fire protection works on the principle of containment of fire which results in controlled and slow spread of fire to adjacent bodily spaces and limits the size of the fire by limiting the quantity of fresh air. The passive fire protection is mostly used to curtain the fire spread in the building. These fire spread can be within a room, room to room, floor to floor and one building to another. The fire spread of the fire from one space to another is mostly due to thermal radiation [1] as heat energy from radiation is directly proportional to fourth power of absolute temperature. For an instance, wood is self-ignited spontaneously, if it is exposed to 1.26 W/cm2 of thermal radiation [2]. In order to provide better insulation to thermal radiation intumescent paints are now being most common alternative available in modern buildings. The instrument paints are commonly used as thermal insulation to protect columns and beams of building structure from failure

July – August 2020
ISSN: 0193-4120 Page No. 493 - 497

due to high thermal load during fire [3].

Generally, intumescent coating is blend of an acid source (ammonium phosphate, APP), a carbon source (pentaerythritol, PER) and a puffing agent (melamine, MEL) which are bound together by polymer matrix. When the coating is exposed to thermal radiation it begins to decompose and form a cellular charred layer which ultimately act as thermal insulation and prevent heat transfer to the basic substrate [4] [5].

Intumescent coating insulates the structures from the effects of the elevated temperature that may be generated during fire. The coating behaves best when exposed to a fire condition with quick fire growth and elevated temperature in case of steel structure [6]. Many of these researches were carried out to study the behavior fire spread applying intumescent coating to different members of building [7] - [12].

The purpose of this investigation was to study the effectiveness as thermal insulation of intumescent coating on wire netting of different materials. Wire netting used in the windows of the rooms was investigated for this study as the window flame, projecting from a burning building, is likely to cause radiation exposure to the puppet floor openings and adjoining building and fire can spread to upper floors from the exterior of the building. Due to the elevated temperature of the fire, the intumescent coating forms an insulation in the wire netting and prevent the further spread of fire. The series of experimentation were carried out and the result was analyzed for reducing the spread of fire through thermal radiation.

II. Materials And Method

A. Experimental Setup:

The muffle furnace with maximum temperature is 1450 °C with opening of 750 mm x 750 mm is used. The box of bison sheet with the opening 140 mm × 140 mm and 500 mm in length is designed for the experiment. All the surfaces inside the box is painted with white colure except the surface opposite to opening which is painted black. This combination of surface paint ensures that the all radiation from furnace will incident on black surface. In experimental box, the K-type thermocouple is placed in contact with black surface to measure the incident radiation. The positioning of thermocouples and details of experimental box is shown in figure 1. The size of wire netting with dimension 140 mm × 140 mm, it fixed with the experimental box.

B. Experimental Material:

Wire netting of stainless steel, aluminum and galvanized steel is used in this study. The material composition of stainless steel, aluminum and galvanized steel is mentioned in table I, table II and table III respectively.

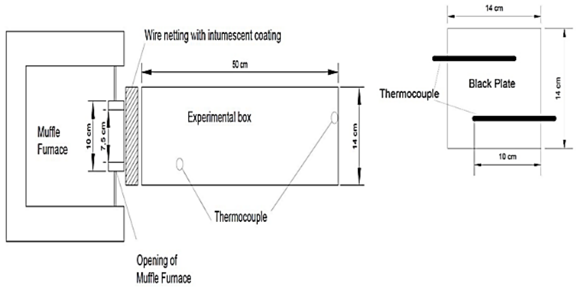


Fig 1. Schematic view of Experimental setup

TABLE I: CHEMICAL COMPOSITION OF STAINLESS-STEEL WIRE NETTING

Sample	C%	Si%	Mn%	P%	S%	Cr%	Mo %	Ni%
SS Wire net	0.23	0.42	0.77	0.04	0.03	7.98	0.2	0.40

TABLE II: CHEMICAL COMPOSITION OF ALUMINUM WIRE NETTING

Sample	Al %	Fe %	Si %
Aluminum Wire net	96.36	1.02	0.69

TABLE III: CHEMICAL COMPOSITION OF GALVANIZED STEEL WIRE NETTING

Sample	C %	P %	S %
Galvanized Steel Wire net	0.253	0.943	0.069

K-Type Thermocouple: The K-type thermocouple wire used in this investigation was grade 0.75 (CA), having a diameter of 1.4 mm. The thermocouple was primarily composed of nickel–chromium and nickel–aluminum wires.

The intumescent coating in this investigation used consist of 22% ammonium polyphosphate,15% polyvinyl acetate resin, 8% heat expandable agent, 6% melamine, 27% solvent, 15% pigment, and 7% additional materials. It had a density of 1.3 ± 0.1 g/cm^3. The coating used in this investigation is a solvent-based intumescent coating having a white color.

C. Experimental Variables and Specimens:

There are two type of variable examined in this experiment; Without Intumescent Coating and With Intumescent Coating. The Intumescent coating was applied with brush on wire netting with double and triple coating. The curing time of each layer was 24 hours. Intumescent coating used applied directly on each sides of the wire netting. This coating was applied directly on the wire netting without applying

July – August 2020
ISSN: 0193-4120 Page No. 493 - 497

any epoxy zinc phosphate primer and epoxy topcoat. The sample of wire netting with intumescent coating were dried up in natural ventilation and then fitted on experimental box and placed in front of muffle furnace to perform the experiment.

D. Muffle Furnace:

An initial understanding of the effect of the wire netting with intumescent coating exposed to high temperatures was studied. This study includes an initial heating trial on wire netting with intumescent coating by high-temperature furnace. Heating curve of muffle furnace displayed in figure 2. The primary heating trial validates that intumescent coating works effectively as thermal barrier on wire netting.

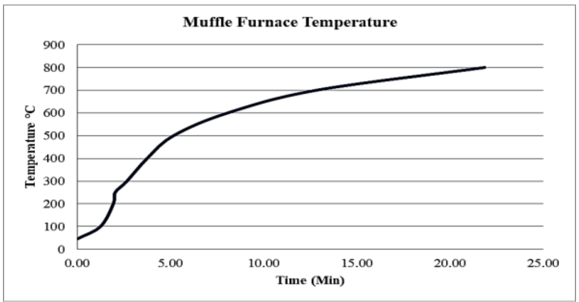


Fig 2. Muffle Furnace Temperature v/s Time

E. Experimental Plan:

The specimen sample of wire netting was installed on experimental box and placed in front of furnace. The muffle furnace is prefixed with temperature of 1000°C for each experiment. The temperature of the thermocouple placed at 500 mm apart from the wire netting on the experimental box is noted with interval of every 5 minutes as shown in figure 3. With help of this temperature the incident radiation is calculated and effectiveness of wire netting as thermal barrier is analyzed.

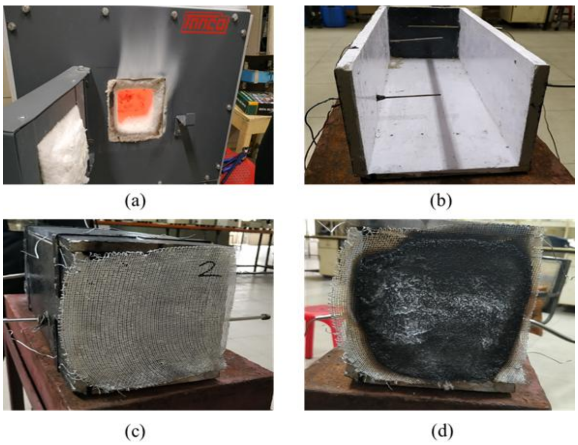


Fig 3. Wire netting with Intumescent Coating. (a) 750 mm x 750 mm Furnace; (b) Prepare of Experimental Box; (c) Fix the wire netting with intumescent coating on Stainless Steel to the experimental box; (d) Wire netting at 900°C char formation

III. RESULTS AND DISCUSSION

When intumescent coating is applied on wire netting, its response is categorized into three phases after being exposed to elevated temperature. During the first phase the surface coating become softer and release incombustible gases. During the second phase, the inner part of coating begins to form bubbles after melting and then expands the carbon layer on the material surface. In the last phase, the bubbles of carbon cover the spaces of wire netting and restrict the thermal radiation to pass across the wire netting.

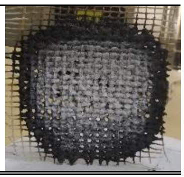
After performing series of experiment, the stainless steel wire netting, without intumescent coating allowed the heat flux of 9.27 W/cm^2 at 500 mm apart with a maximum temperature of 179.25^{o}C is recorded, whereas with double and triple layer of intumescent coating allowed 3.04 W/cm^2 and 2.98 W/cm^2 of thermal radiation with maximum temperature of 69.3^{o}C and 67.7^{o}C respectively. The heat flux of different samples of stainless steel wire netting is shown in figure 4. Aluminum wire netting allowed the radiation of about 3.67 W/cm^2, 3.17 W/cm^2 and 3.00 W/cm^2 with a maximum temperature of 85.9°C, 72.5°C and 68.3°C is recorded on without coating, double coating sample and triple coating sample respectively. The heat flux of different samples of aluminum wire netting is shown in figure 5. Similarly, for Galvanized Steel allowed a thermal radiation of about 8.69 W/cm^2, 5.30 W/cm^2 and 3.17 W/cm^2 with a maximum temperature of about 172.15°C, 120.45°C and 72.9°C is recorded on without coating, double coating sample and triple coating sample respectively as shown in figure 6. The samples of wire netting before and after experimentation are displayed in table VI.

TABLE IV: SAMPLES AFTER MAXIMUM TEMPERATURE 900°C

Material	Double Coating	Triple Coating
Stainless Steel Wire Mesh		
Aluminum Wire Mesh		

TEST Engineering & Management

July – August 2020
ISSN: 0193-4120 Page No. 493 - 497

Galvanized Wire Mesh		

IV. Conclusions

This experiment focused on reduction of the radiation heat, use as thermal barrier. An intumescent coating was applied on wire netting could use at open surface which would continuously in contact with radiation heat. Because of the high temperature, the intumescent coating on the wire netting expands and generates carbon layers that reduces the radiation heat and prevent the fire from spreading. The findings from sets of experiments are as follows:

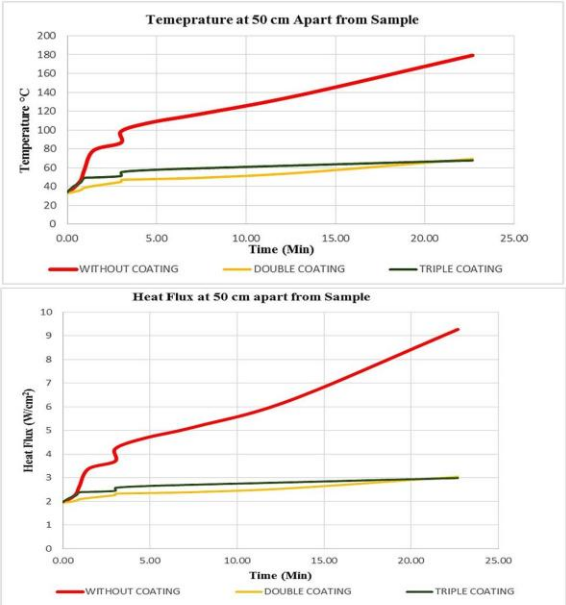


Fig 4. Stainless-steel Samples Temperature and Heat Flux

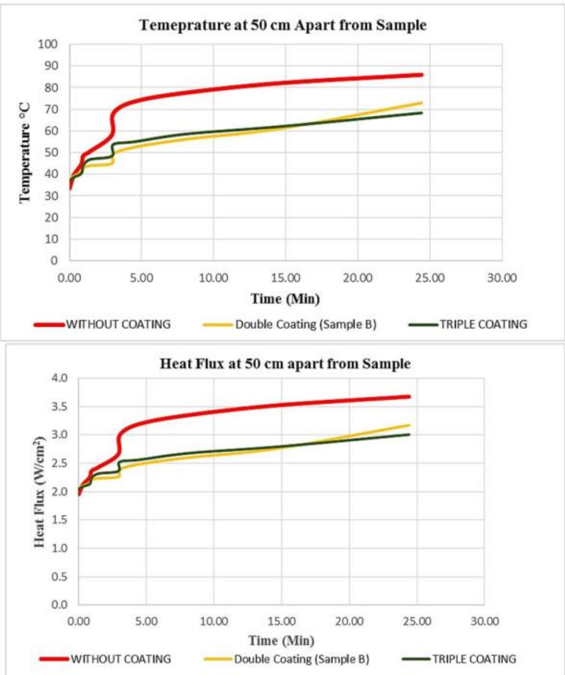


Fig 5. Aluminum Samples Temperature and Heat Flux

- It is observed that the intumescent coating covers the spaces of the wire netting with good integrity with layer of carbon bubbles.

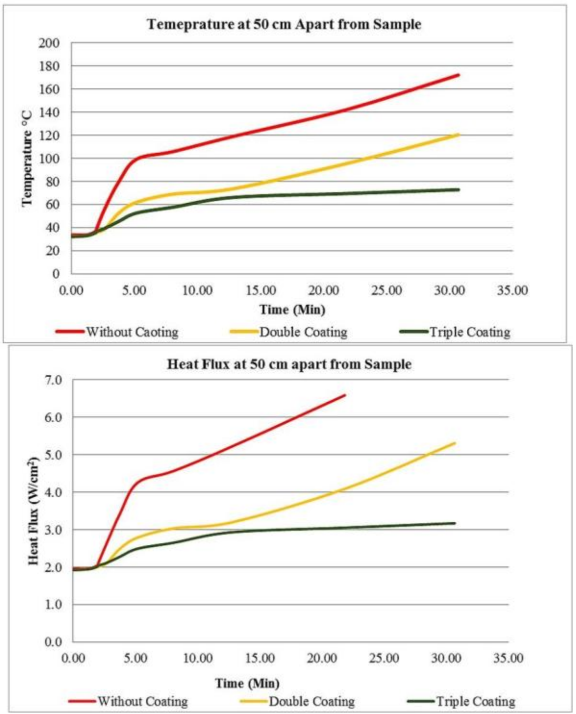


Fig 6. Galvanized Steel Samples Temperature and Heat Flux

- The coating decreases the thermal radiation on the unexposed side of the wire netting with the formation of char coal layer.
- It was observed from the results that, the triple coating was more efficient in insulating the thermal radiation. Meanwhile but double coating with maximum char formation was more effective at initial stage.
- Intumescent coating does not show any remarkable results as thermal barrier in aluminum wire netting. This is due to the low integrity of the aluminum wire netting at high temperatures as aluminum as low melting point of about 630°C.
- It was also observed that the thermal insulation is effective in wire netting of stainless steel and galvanized steel.
- The intumescent coating applied on wire netting is acting as a good thermal barrier and can be able to reduce the radiation by 57%. These outcomes can assist as reference for forthcoming design of fire protection buildings.

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