CHAPTER 1
INTRODUCTION

1.1 PROJECT BACKGROUND

Basically, intumescent coating has been used for over twenty years to protect steel which is usually used at buildings to avoid fire-induced structural collapse. An intumescent is a substance which swells as a result of heat exposure, thus increasing in volume, and decreasing in density. Intumescent are typically used in passive fire protection. It applied to structural steel members. Intumescent coatings contain a carbonic, viz. a polyhydric, source of carbon such as starch or penta erythritol, which is rich in carbon and tends to form charred foam on heating. Intumescents are typically used in passive fire protection [1].

Intumescent materials are typically coatings that respond to impingement of a fire by swelling and possibly forming a protective char, to physically and thermally protect the coated steel structure from deteriorating. [2]. Char is the solid material that remains after light gases (e.g. coal gas) and tar (e.g. coal tar) have been driven-out or released from a carbonaceous material, during the initial stage of combustion, which is known as carbonization, charring, devolatilization or pyrolysis. A char with enhanced strength can help to protect the steel structure that exposed to heat or fire. It is believed that reinforcement of the fibre in intumescent coating will strengthen the char and can protect the structure from fire [3].

The “intumescence concept” allows a balance between the fire properties and the level of additives in the material. Generally, three intumescent ingredients are used: an acid source, a carbon source and a blowing agent. The formulation of these coatings has to be adapted in terms of their physical and chemical properties to form an efficient protective char. The mechanism of intumescence is usually described as follows; first, the acid source breaks down to yield a mineral acid, then it takes part in the dehydration of the carbonization agent to yield the carbon char, and finally the blowing agent decomposes to yield gaseous products. The latter causes the char to swell and hence provides an insulating multi-cellular protective layer. This shield limits at the same time the heat transfer from the heat source to the substrate and the mass transfer from the substrate to the heat source resulting in a conservation of the underlying material. Additional, it is learned thay by adding some suitable filler or additives, the properties of the intumescent coating will be change [3].

In this project, the author will add ceramic fibre as additive in ingredients of intumescent coating. Basically, ceramic fibers comprise a wide range of amorphous or crystalline, synthetic mineral fibers characterized by their refractory properties (i.e.,stability at high temperatures). Most ceramic fibers are composed of alumina and silica in an approximate 50/50 mixture. Ceramic fibers are used as insulation materials and are a significant replacement for asbestos [4].

1.2 PROBLEM STATEMENT

Basically, current intumescent coating are lacking of strength when exposed to fire burning. Adding the ceramic fibre to coating is is expecting to give the effect of strength and composition of char coating due to its application on thermal insulation to improve the intumescent coating. It is because the bondings in ceramics structure give ceramic great hardness which is high elastic moduli and great resistance to heat. So, the author believe it will give the char more strengthen when the coating expose to fire. As well, it will increase the protection of steel substrate. However, the effect of adding ceramic fibre to intumescent coating has never been study.

1.3 OBJECTIVE AND SCOPE OF STUDY

The main objectives of the project are:

1) To develop intumescent formulations.
2) To study the reinforcing ceramic fibre into intumescent coating.
3) To study the effect of char strength when reinforce ceramic fibre into intumsecent coating which varied with percentage and length of fibre.

The scope of study of this project is to develop intumescent formulations and fibre reinforcement in intumescent coating to improve the char strength. Before the experiments start, all information and data gathering has been research for a better understanding. All information was gained from the journals, text books, web-sites and articles.

CHAPTER 2
LITERATURE REVIEW

2.1 LITERATURE REVIEW

Basically, objective of the project is to study the effect of char strength when reinforce ceramic fibre into intumsecent coating which varied with percentage and length of fibre. In this project, author also needs to develop intumescent formulations and to study the reinforcement ceramic fibre into intumescent coating.

Nowadays, intumescent coating is important and mainly used in all industry which is need of protecting the steel equipment in high temperature. However, current intumescent coating mostly lacking of strength when exposed to fired burnings so that, it easily to collapsed. Further optional additives may be optionally included as part of the intumescent ingredients to aid char formation and to strengthen the char and prevent char degradation. Such additives include solids such as zinc borate, zinc stannate, zinc hydroxystannate, glass flake, glass spheres, polymeric spheres, fibres (ceramic, mineral, glass/silica based), aluminium hydroxide, antimony oxide, boron phosphate, fumed silica [5].

By reinforce ceramic fibre to the intumescent system; it believed that the char of the coating will more strengthen. It is because of it ionic bonding give ceramics great hardness with high elastic moduli and great resistance to heat. Basically, ceramic fibre is similar to carbon fibre and glass fibre which is also widely used in formulation of intumescent coating because it has good thermo insulating. Others, ceramics also applied on insulation industry. Ceramic fibre that will use in the project is Alumino Silicate.

2.2 CITATION AND CROSS REFERENCING

2.2.1 Intumescent Coating

Intumescent materials respond to impingement of a fire by swelling and forming a protective char that physically and thermally protects the structure. Intumescent concept allows a balance between the fire properties and the level of additives in the material. Generally, three main intumescent ingredients used are; an acid source, carbon source and a blowing agent. However, it is learned that by adding some suitable fillers and additives, the properties of the intumescent system can be increased, for example by reinforce fibre into the system. The mechanism of intumescences is usually described as follow: first, the acid source break down to yield a mineral acid, then it takes part in the dehydration of the carbonization agent to yield the carbon char and finally the blowing agent decomposes to yield gaseous product [6,7].

Intumescents are typically used in passive fire protection. The aim for passive fire protection systems is typically demonstrated in fire testing the ability to maintain the item or the side to be protected at or below either 140 °C (for walls, floors and electrical circuits required to have a fire-resistance rating) or ca. 550 °C, which is considered the critical temperature for structural steel, above which it is in jeopardy of losing its strength, leading to collapse [6].

2.2.2 Char

A char with enhance strength can help to protect steel structure that exposed to fire. It is believe that reinforcement of fiber in intumescent coating will strengthen the char and can protect the structure from fire. This formulation of the coating has to be adapted in term of their physical and chemical properties to form an efficient protective char [8].

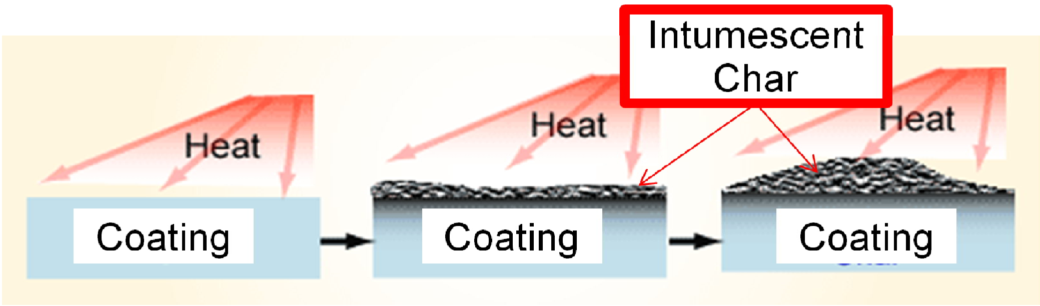

Figure 1: Illustration of char

2.2.3 Ceramic Fibre

Ceramic fibres comprise a wide range of amorphous or crystalline synthetic minerals fibers characterize by their refractory (i.e., stability at high temperatures). It poses some remarkable properties not found in organic or metal materials due to the atomic bonds which make up their structures. These bonds are ionic and covalent with an absence of other types of bonds, gives ceramics great hardness which is coupled with high elastic moduli, great resistance to heat and chemical resistance. They are typically made of alumina, silica and other metal oxides or less commonly of monoxides materials such as silicon carbide (SiC). Most ceramic fibres are composed of alumina and silica. Alumina is inherently resistant to oxidation and has been successful in reinforcing light metal alloys [9].

Aluminum silicate, also known as aluminium silicate, is a mixture of aluminum, silica, and oxygen that can be either a mineral, or combined with water to form a clay. It can also combine with other elements to form various other minerals or clays. Some of these forms are used medicinally and industrially. They retain their strength at high temperatures — a property known as being *refractory*. Some of the minerals are used as gemstones [10].

CHAPTER 3
METHODOLOGY

3.1 SPECIFIC PROJECT ACTIVITIES

3.1.1 Collected data for material used.

3.1.1.1 Ammonium Polyphosphate (APP)

Ammonium Polyphosphate act as acid source in the intumescent system. APP is an inorganic salt of polyphosphoric acid and ammonia containing both chains and possibly branching. It used as a flame retardant for polyolefines and polyurethanes and as a fertilizer.

Emperical Formula: $(NH_4PO_3)_n$

Melting Point: > 270°C

3.1.1.2 Pentaerythritol (PER)

Pentaerythritol is a tetrahydric neopentyl alcohol. It is an odourless white, crystalline, solid compound. It acts as carbon source in intumscent system. PER is used in the surface coating industries. It widely used in compositions of coating to form surface coatings with high gloss, excellent water and alkali resistance and good ageing characteristics.

Empirical Formula: $C_5H_{12}O_4$

Melting Point: 260.5 °C

3.1.1.3 Melamine (MEL)

Melamine based flame retardants represent a small but fast growing segment in the flame retardant market. These products offer particular advantages over existing flame retardants:

- Cost effectiveness
- Low smoke density and toxicity
- Low corrosion
- Safe handling
- Environmental friendliness

Melamine shows excellent flame retardant properties because its ability to interfere with the combustion process in all stages in many different ways.

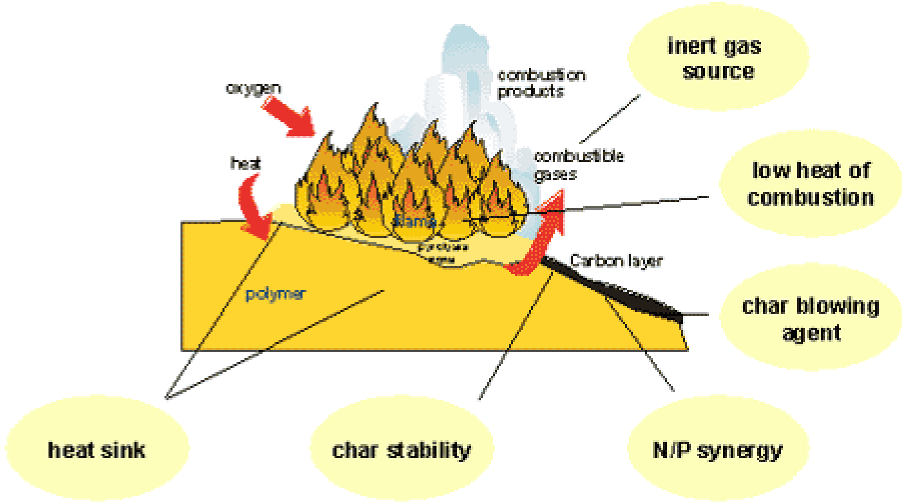

Figure 2: Combustion process of intumescent coating

Melamine can retard ignition by causing a heat sink through endothermic dissociation in case of a melamine salt followed by endothermic sublimation of the melamine itself at roughly 350°C. Another, even larger, heat sink effect is generated by the subsequent decomposition of the melamine vapours.

Melamine can be regarded as a "poor fuel" having a heat of combustion of only 40% of that of hydrocarbons. Furthermore, the nitrogen produced by combustion will act as inert dilluent. Another source of inert dilluent is the ammonia which is released during breakdown of the melamine or self-condensation of the melamine fraction which does not sublimate.

Melamine can also show considerable contribution to the formation of a char layer in the intumescent process. Char stability is enhanced by multi-ring structures like melem and melon, formed during self-condensation of melamine. In combination with phosphorous synergists melamine can further increase char stability through formation nitrogen-phosphorous substances. Besides, melamine also acts as blowing agent for the char, enhancing the heat barrier functionality of the char layer.

3.1.1.4 Boric Acid

Boric acid also called boracic acid or othoborica acid or acidum boricum is a weak acid often used as an antiseptic, insecticide, flame retardant, in nuclear power plants to control the fission rate of uranium, and as a precursor of other chemical compounds.

Empirical Formula: H_3BO_3

Melting Point: 170.9 °C, 444 K, 340 °F

3.1.1.5 Triethylenetetramine

Triethylenetetramine, abbreviated TETA and trien, is an organic compound. This oily liquid is colourless but, like many amines, assumes a yellowish color due to impurities resulting from air-oxidation. It was primarily used as a crosslinker (hardener) in epoxy curing.

Empirical Formula: $C_6H_{18}N_4$

Melting Point: 12 °C, 285 K, 54 °F

3.1.1.6 Epoxy

Epoxy or polyepoxide is a thermosetting polymer formed from reaction of an epoxide with polyamine "hardener". Epoxy has a wide range of applications, including fiber-reinforced plastic materials and general purpose adhesives. In general, epoxies are known for their excellent adhesion, chemical and heat resistance, good-to-excellent mechanical properties and very good electrical insulating properties.

3.1.1.7 Ceramic Fibre

It has been discuss in Chapter 2.2.3. For the project, ceramic fibre that will use is made of high purity of Alumino Silicate. (Refer to APPENDIX 1)

3.1.2 Design Formulation for Intumescent Coating

Basically, at this stage, the formulation of the intumescent coating is developed.The formulation consists of the type of the materials used in the intumescent coating. For this research, author done with two (2) experiments which are first experiment more focus to find out the better formulation with used the basic ingredients. While for second experiment, author used the chosen formulation from first experiment with adding ceramic fibre into the formulation.

3.1.3 Analyze the samples

After the samples have been swelling, the analysis of the sample can be done using the Scanning Electron Microscopin (SEM).

3.2 PROCEDURES

1. Sample Preparation

The main components of the intumescent coating used in this project are:

- Acid source – Ammonium Polyphosphate (APP)
- Carbon source – Pentaerythritol (PER)
- Blowing agent – Melamine
- Acid Boric
- Epoxy
- Hardener – Triethylene Tetramine
- Ceramic Fibre

Experiment 1

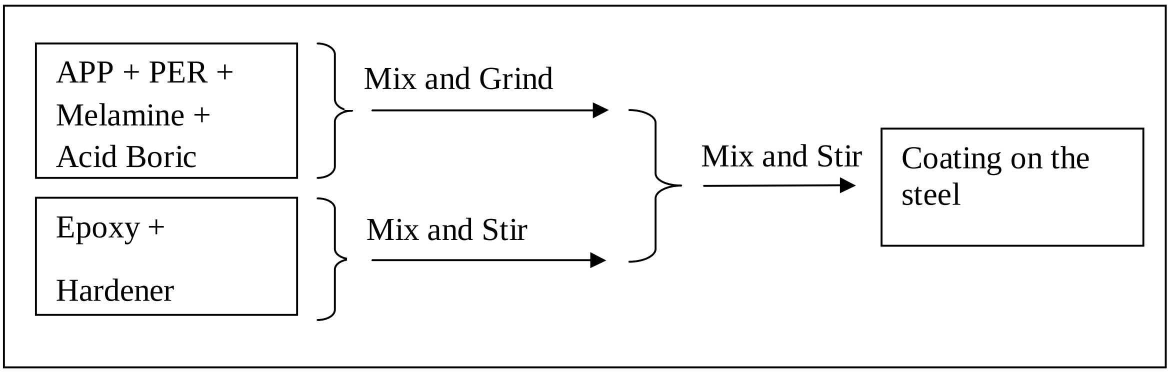

Figure 3: Schematic diagram of simplified process for preparation of the intumescent coating

13 samples have been produced with different formulation. The following tables are the formulation for all samples given by the weight percent (wt%) of the main components.

Table 1: Formulation of intumescent coating

Formulation	PER, wt%	APP, wt %	MEL, wt%	BA, wt%	Epoxy, wt%	Hardener, wt%
N1	5.88	11.76	5.88	5.88	47.06	23.53
N2	5.56	11.11	8.33	8.33	44.44	22.22
N3	5.56	11.11	5.56	11.11	44.44	22.22
N4	5.56	8.33	11.11	8.33	44.44	22.22
N5	5.56	5.56	11.11	11.11	44.44	22.22
N6	8.33	11.11	8.33	5.56	44.44	22.22
N7	11.11	11.11	5.56	5.56	44.44	22.22
N8	8.33	8.33	11.11	5.56	44.44	22.22
N9	11.11	5.56	11.11	5.56	44.44	22.22
N10	8.33	8.33	8.33	8.33	44.44	22.22
N11	5.56	8.33	8.33	11.11	44.44	22.22
N12	11.11	8.33	8.33	5.56	44.44	22.22
N13	8.33	11.11	5.56	8.33	44.44	22.22

Experiment 2

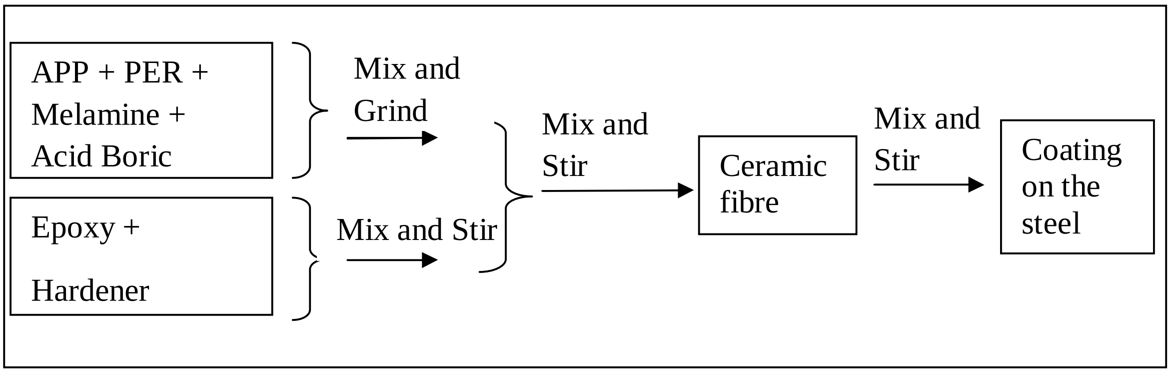

Figure 4: Schematic diagram of simplified process for preparation of the intumescent coating with adding fibre

6 samples have been produced with different formulation which is 2 different formulation will be varied with 3 length of fibre. The following tables are the formulation for all samples given by the weight percent (wt%) of the main components.

Table 2: Formulation of intumescent coating with adding ceramic fibre

Formulation	PER, wt%	APP, wt %	MEL, wt%	BA, wt%	Epoxy, wt%	Hardener, wt%	Fibre, wt%	Length Fibre, mm
C1	8.31	8.31	11.07	5.54	44.30	22.15	0.33	5
C2	8.25	8.25	11.00	5.50	44.00	22.00	0.99	
C3	8.31	8.31	11.07	5.54	44.30	22.15	0.33	10
C4	8.25	8.25	11.00	5.50	44.00	22.00	0.99	
C5	8.31	8.31	11.07	5.54	44.30	22.15	0.33	15
C6	8.25	8.25	11.00	5.50	44.00	22.00	0.99	

2. Mixing Procedure

1. All materials/powders (APP, PER, Boric Acid and Melamine) have been weight using the digital weighting by following the formulation that has been developed before.
2. All powder has been mixed together and grinded it using grinder.
3. Weight epoxy and hardener and mix it together using digital weighting.
4. Mixture of hardener and epoxy has been mixed using liquid mixing equipment and the RPM of the equipment was set from 12rpm until 40rpm.
5. Mixture of powder and mixture of hardener and epoxy has been mixed and stir using the liquid mixing equipment. (RPM was set 12rpm-40rpm)
6. Ceramic fibre has been added during the stirred process for step 5. (Only for experiment 2)

3. Coating Procedure

1. After all components were mixed, the coating has been applied to the surface of metal (5cm x 5cm steel plate).
2. The samples have been dried 1-2weeks in temperature room.
3. The thickness of the samples has been measured and recorded.

4. Fire/ Heat Treatment Procedure

1. Fire/ heat treatment for the samples has been done using the furnace.
2. The temperature of the furnace has been set to the 400^oC.
3. The fire/heat treatment process has been done around 1 hour and 40 minutes.
4. The thickness of the samples has been measured and recorded after the fire/heat treatment process for measures the increment of the swelling.

3.3 RAW MATERIALS AND TOOLS

1. Raw Materials

1. Acid source – Ammonium Polyphosphate (APP)
2. Carbon source – Pentaerythritol (PER)
3. Blowing agent – Melamine
4. Acid Boric
5. Epoxy
6. Hardener – Triethylene Tetramine
7. Ceramic Fibre
8. Plate – steel

2. Tools

1. Digital weighting – to measure each component of the intumescent formulation accurately.
2. Grinder – to mix the all powders
3. Liquid mixing equipment – to mix the all ingredients'
4. Furnace – to supply the heat to the intumescent coating

Refer APPENDIX 2 for figure of each tool.

CHAPTER 4
RESULTS AND DISCUSSION

4.3 RESULTS EXPERIMENT 1 (WITHOUT FIBRE)

4.1.1 Expansion ratio of the coating

When the coating is exposed to the heat or fire, the intumescent coating is started to swell. As a result, the thickness of the coating is expanding, sometimes up to several times of its original thickness. This expansion coating also known as char. The result expansion ratios of the samples are as follow:

Table 3: Expansion ratio of the samples

Formulation	Height before (mm)	Height after (mm)	Expansian ratio
N1	2.28	15.00	6.58
N2	2.87	10.50	3.66
N3	4.93	22.33	4.53
N4	2.83	9.83	3.47
N5	2.48	9.67	3.90
N6	2.72	22.67	8.33
N7	2.26	19.17	8.48
N8	2.66	18.50	6.95
N9	2.70	13.00	4.81
N10	2.62	12.00	4.58
N11	2.40	11.83	4.93
N12	2.97	15.83	5.33
N13	2.33	13.83	5.94

4.1.2 Samples Observation

Table 4: Observation of the samples

Samples			
Formulation	Before	After	Observation
N1			- Sample expands to 6.56 times after burning process. - Small bubbles exist on char.
N2			- Sample expands to 3.66 times after burning process.
N3			- Sample expands to 4.53 times after burning process. - Big bubbles exist on char
N4			- Sample expands to 3.47 times after burning process. - Less bubbles exist on char.

Samples			
Formulation	Before	After	Observation
N5			- Sample expands to 3.90 times after burning process. - Big and small bubbles exist on char.
N6			- Sample expands to 8.33 times after burning process. - Less bubbles exist on char.
N7			- Sample expands to 8.48 times after burning process.
N8			- Sample expands to 6.95 times after burning process. - Big bubbles (like worm) exist on char.

Samples			
Formulation	Before	After	Observation
N9			- Sample expands to 4.81 times after burning process. - Big and small bubbles exist on char.
N10			- Sample expands to 4.58 times after burning process. - Big and small bubbles exist on char.
N11			- Sample expands to 4.93 times after burning process.
N12			- Sample expands to 5.32 times after burning process. - Small bubbles exist on char.

Samples			
Formulation	Before	After	Observation
N13			- Sample expands to 5.94 times after burning process.

4.1.3 Analysis

After burning process, the author needs to choose the better formulation because it will use for the next experiment which is adding the ceramic fibre into that formulation.

For choosing the best formulation and sample, the author must consider the:

- Coating is not detached from the steel.
- Expansion of the coating – better expansion is good.
- Strength of the char by doing the cross-section.
- Structure of the coating which is internal coating not too empty. It's done by doing cross-sectional for the sample.

As the result, the author decides to choose formulation 8 (N8) as a better formulation because the sample expands well. The sample is not greater in expansion of char, but inside of the coating is not empty and the char is hard when doing cross-sectional using cutter.

4.2 RESULTS EXPERIMENT 2 (WITH FIBRE)

4.2.1 Expansion ratio of the coating

Table 5: Expansion ratio of the samples

Formulation	Height before (mm)	Height after (mm)	Expansion (mm)	Expansian ratio
C1	3.75	20.12	16.37	5.37
C2	3.69	18.14	14.45	4.92
C3	3.01	8.45	5.44	2.81
C4	3.42	12.13	8.71	3.55
C5	3.69	11.32	7.63	3.07
C6	3.03	11.55	8.52	3.81

4.2.2 Samples Observation

Table 6: Observation of the samples

Samples			
Formulation	Before	After	Observation
C1			- Sample expands to 5.37 times after burning process. - Big bubbles exist on char.
C2			- Sample expands to 4.92 times after burning process. - Small bubbles exist on char.

Samples			
Formulation	Before	After	Observation
C3			- Sample expands to 2.81 times after burning process. - Small bubbles exist on char.
C4			- Sample expands to 3.55 times after burning process.
C5			- Sample expands to 3.07 times after burning process. - Big bubbles exist on char.
C6			- Sample expands to 3.81 times after burning process. - Big bubbles exist on char.

4.2.3 Analysis

Similar with the experiment 1, for choosing the better formulation and sample, the author must judge the samples based on:

- Coating is not detached from the steel.
- Expansion of the coating – better expansion is good.
- Strength of the char by doing the cross-section.
- Structure of the coating which is internal coating not too empty. It's done by doing cross-sectional for the sample.

As the result, samples of C1 and C4 have been decided as the better formulation based on above activities. For further information, SEM test has been done for two samples to examine the structure of the coating.

4.2.4 SEM Analysis

The charring layer protects the matrix materials, and its protective property depends on the physical and chemical structure of the charring layer. Researches indicate that there are other elements in the charring-layer structure. But the non-charring layer element is easy to be oxygenated and very unstable on chemistry aspects. There are two ideal types of charring structures namely uniformity and asymmetry. For uniformity type of structure, there are great deals of integrated closed honeycomb pores. That type of structure can form adequate temperature gradients in the charring layer and protect the molten mass and matrix below. The other structure which is asymmetry has many channels and apertures and the gas and molten mass of polymers can overflow to the entry of the flame-region. Therefore, the isolation effect of heat transfer is inferior. This type of structure is non-ideal [11].

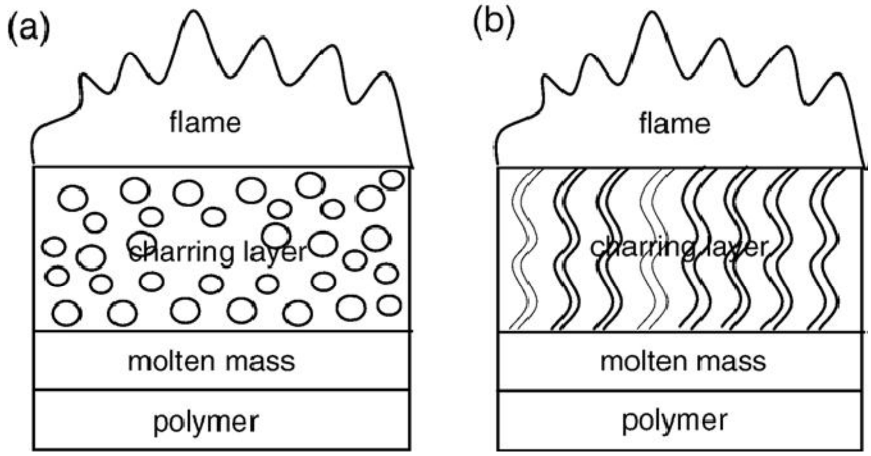

Figure 5: Structures of charring layer: (a) uniformity and (b) asymmetry.

SEM analysis has been done for both samples which is C1 and C4 to see the structure of the char. Results from SEM analysis area as follow:

a) Sample C1

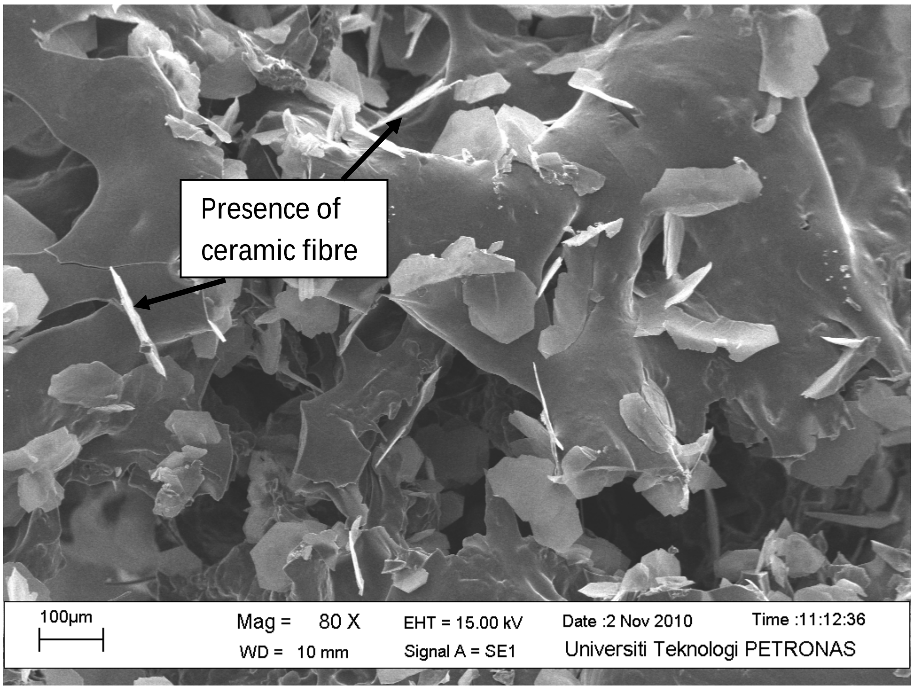

Figure 6: SEM image for sample C1 in Mag= 80 X

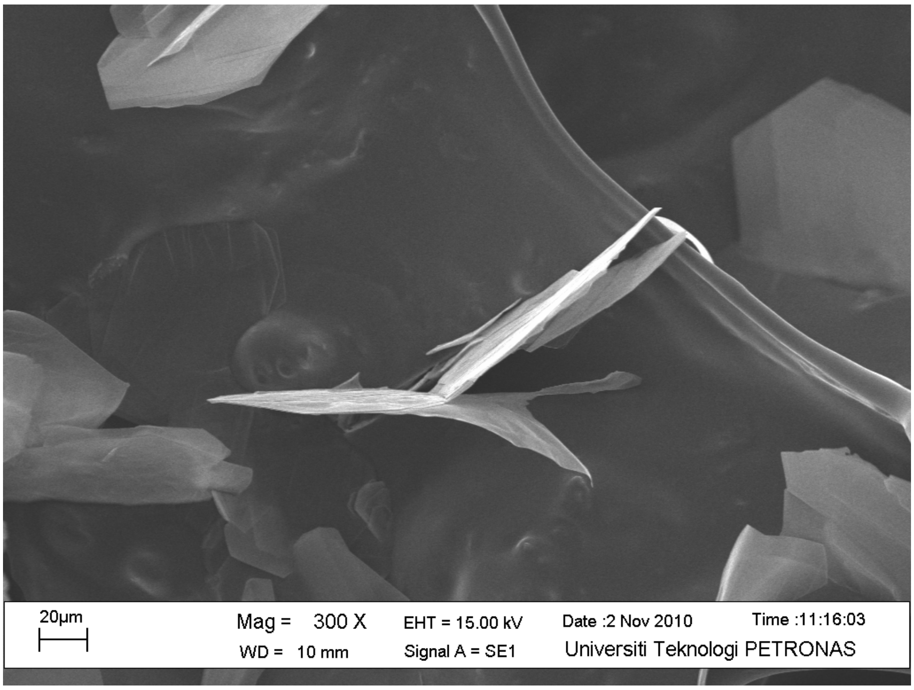

Figure 7: SEM image for sample C1 in Mag= 300 X

b) Sample C4

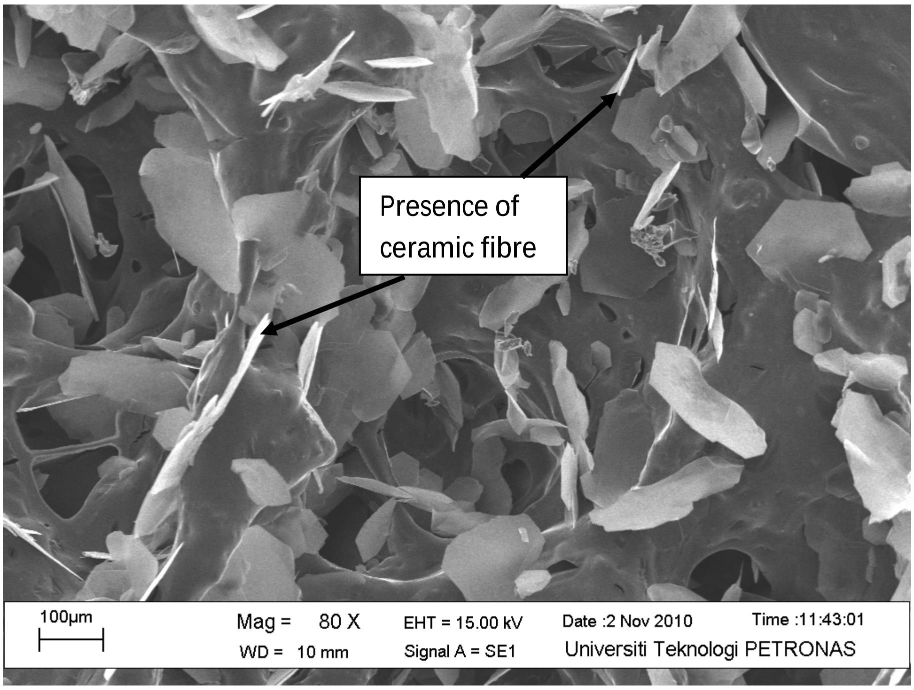

Figure 8: SEM image for sample C4 in Mag= 80 X

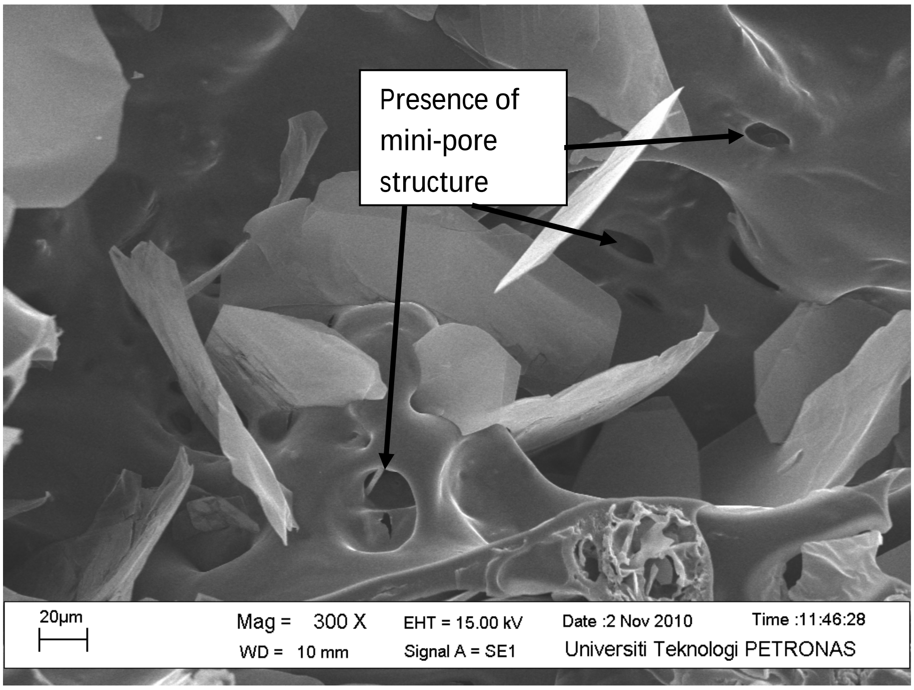

Figure 9: SEM image for sample C4 in Mag= 300 X

From all figures shown earlier, the structure of the charring layer of sample C4 is to be more compact than C1. Image from C4 also shown distribution of fibre is too many in samples C4. These images prove that the C4 structure is better than C1. Others, image of C4 shown the irregular mini-pores structure in the char layer is existed.

4.3 DISCUSSIONS

As the result for experiment 1, the formulation 8 (N8) has been choose as a better formulation.

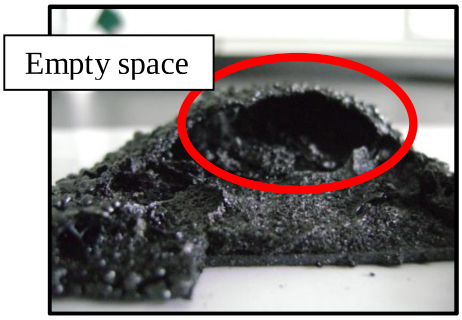

Figure 10: Cross-sectional of sample N7

Figure11: Cross-sectional of sample N8

Based on the figure above, there is comparison of cross-sectional between the sample N7 and sample N8. Cross-sectional activity basically to see the inside structure of the coating. Based on the figure, sample N7 has empty space compared to the sample N8. It shown that sample N8 has a good composition even it not greater in expansion of char, but inside of the char is has not empty space. Further, the char is hard when doing cross-sectional using cutter.

In experiment 2, sample C4 has been choose as a better composition. It is followed by the SEM analysis which is shown that the distribution fibre is too many in samples C4. These images prove that the C4 structure is better than C1. Others, image of C4 shown the irregular mini-pores structure in the char layer is existed. These criteria are good for heat insulation properties. The intumescent charring layer with many mini-pores acts as the effect of the flame retardant, heat insulation and protecting inner matrix materials.

Presence of ceramic fibers in the coating for both sample C1 and C4 improves the heat insulation effect. In this project, a blanket ceramic fiber is cutting about 5mm – 10mm long were used. The fiber did not degrade during exposure time instead buried in the coating structure thus increase its strength.

CHAPTER 5
CONCLUSSION AND RECOMMENDATIONS

5.1 CONCLUSION

Intumescent formulation basically consists of acid source, carbon source, and blowing agent,. In this project, the developed intumescent formulation is using Ammonium Polyphosphate (APP) as acid source, Pentraerythritol (PER) as carbon source, Melamine as blowing agent and other ingredients are epoxy, triethylenetetramine as hardener. When exposed to fire, acid source breaks down to mineral acid, which will dehydrate the carbon source to produce carbonaceous char. Meanwhile the blowing agent releases gas and expands or swells the intumescent coating. These combinations of processes produce a heat insulating protective char layer. Further optional additives may be optionally included as part of the intumescent ingredients to aid char formation and to strengthen the char and prevent char degradation. Such additives include solids such as zinc borate, zinc stannate, zinc hydroxystannate, glass flake, glass spheres, polymeric spheres, fibres (ceramic, mineral, glass/silica based), aluminium hydroxide, antimony oxide, boron phosphate, fumed silica.

2 set of experiments had been developed to achieve the objective. In experiment 1, 13 formulations have been developed. Basic ingredients have been used with different composition to choose the better formulation which must use in experiment 2. Formulation N8 has been chosen to use in experiment 2 which is 6 formulations has been developed with different weight and length of fibre. This experiment basically to observe the structure of the char layer whether the fibre gives for strength or not to the intumescent system. It has been proven that by reinforce the ceramic fibre has change the structure of the char layer through the SEM analysis. It showed that mini-pore existed in char layer which is mini-pores acts as the effect of the flame retardant, heat insulation and protecting inner matrix materials.

5.2 RECOMMENDATIONS

In the end of this project, there are some aspects that can be improved for better project accomplishment that can be involved in the future. The recommendations for future works of this project are:

i. Conduct experiment in an appropriate place and equipments where the results are not affected by the surrounding.

ii. Conduct more tests to approve the char strength such as rheometer or any suitable equipment.

iii. Refer to available standards and manuals for each of the testing procedure to make sure experiment run smoothly and safely.

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APPENDICES

APPENDIX 1:

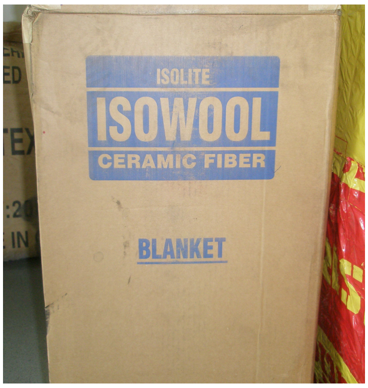

Figure 12: Ceramic Fibre Blanket

Figure 13: Ceramic Fibre Blanket

Figure 14: Ceramic Fibre Blanket after cutting process

APPENDIX 2:

Figure 15: Digital Weighting

Figure 16: Grinder

Figure 17: Liquid Mixing Equipment

Figure 18: Furnace