A NUMERICAL STUDY ON THE RATE OF BURNING OF PMMA

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ABSTRACT

Now-a-days, plastics is being widely used as consumer products, building materials and for many others purposes. As a result, it has raised the concern on fire hazard in resedential and commercial buildings, and as well as in industries. Polymethyl methacrylate (PMMA) is one of the plastic materials widely used for these purposes. Therefore, the understanding of the burning behaviour of PMMA fire would help in designing suitable fire control systems. The use of computational fluid dynamics (CFD) based model can be tools to study the behaviour of plastic fires. However, it is also essential to understand the capabilities any CFD based tool in modelling the growth of fires. Therefore, the objective of this work is to study the burning rates of PMMA slab using a CFD based tool and compare the predicted results with a reference data for the purpose of investigating the accuracy of the model. In this study, we have used fire dynamic simulator (FDS), version 6, as a CFD based tool and the published experimental data has been used for the purpose of validation. The numerical results of steady-state burning rates have been compared with experimental data. The calculated steady-state burning rates of the specimen by FDS has reasonably agreed with the experimental measurements.

Keywords: *Fire dynamic simulator (FDS), PMMA, burning rate.*

1. INTRODUCTION

Plastic is one of the building materials that are being used for the construction of different components of buildings (Ede, 2015; Gerard, 2014). Nowadays, the doors, windows, partition walls etc of a building are prepared from plastic materials. Plastic pipe is also used for the water supply network and electric line network in a building. Not only as a building materials, the use of plastic in furniture are being popular in our country as they are lighter in weight and cheaper in cost compared to wood or metal. However, plastic is more susceptible to fire. Hence, it is essential to understand the behaviour of fires produced by plastic.

Computational fluid dynamics (CFD) based models are tools that can be used for the simulation of fires. In the recent years, fire dynamic simulator (FDS) is being widely used for studying the behaviour of fires. However, it is essential to validate the model of FDS before using it for detail study. Therefore, the objective of this study is to validate the FDS model in burning of a plastic fire. In this study, we have used polymethyl methacrylate (PMMA) to simulate the burning rate of fire, as it is one of the widely used plastic materials in buildings. The burning rate of a PMMA slab has been predicted in the simulation and compared with the published experimental data by Magee and Reitz (1974).

2. NUMERICAL SIMULAITON

2.1 Computational Domain

A computational domain was created using FDS (version 6) for the simulation of burning of a PMMA slab (McGrattan et al., 2014). The rate of burning of the material was predicted in the model. The dimension of the computational domain was 1 m × 1 m × 2 m. All sides of the domain were kept open to be consistent with the conditions associated with the experiment.

A PMMA specimen of size 17.8 cm wide × 17.8 cm high × 5 cm thick was placed horizontally at a height of 0.5 cm from the floor. Two inclined steel plates were used as a heating source (radiant heaters) to the specimens. The heaters were mounted 17.8 cm apart, positioned 25 cm above of the specimen and inclined 45^o to the plane normal to the centreline of the specimen. The set-up for the specimen in the FDS model is shown in Figures 1. In this study, a grid size of 5 mm was used for the discretisation of the domain based on a study by Abu-Bakar and Moinuddin (2015). A supercomputer was used to meet the computational requirement of the simulation.

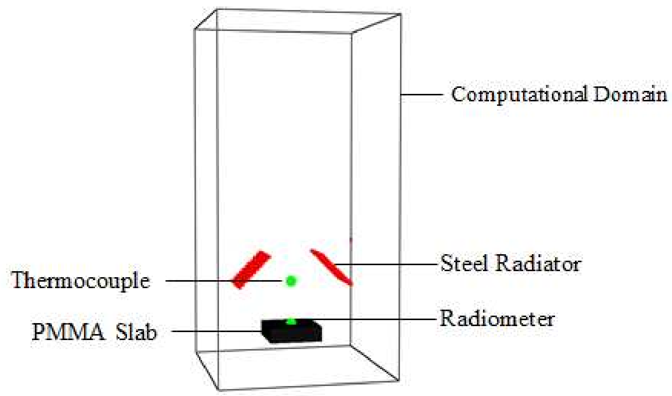


Figure 1: Set-up of the computational domain for the simulations of fires produced by a PMMA slab.

2.2 Thermo-physical Properties

The thermos-physical properties of the material are listed in Table 1. These properties are taken from the literature by Abu-Bakar and Moinuddin (2015). The specimen was heated up by radiation emitted from the two steel plates for the burning of the PMMA slab. The radiation flux on the PMMA slab surface was 12.55 kW/m^2.

Table 1: Thermo-physical properties of PMMA (Abu-Bakar and Moinuddin, 2015)

Material Property	Value	Unit
Density	1210	kg/m^3
Conductivity	1.9 at T = 20^{o}C 1.13 at T = 100^{o}C	W/m/K
Specific heat	1.55 at T = 20^{o}C 1.96 at T = 100^{o}C 2.36 at T = 280^{o}C	kJ/kg/K

3. RESULTS AND DISCUSSION

The rate of burning of the PMMA specimen was calculated in the numerical simulation until the steady-state condition was observed. The results of the rate of burning are presented in Figure 2. The radiation flux rate on the specimen was 12.55 kW/m^2. In the simulation, it was observed that the specimen was ignited after 1400 seconds and reached the steady state burning rate at around 4000 seconds.

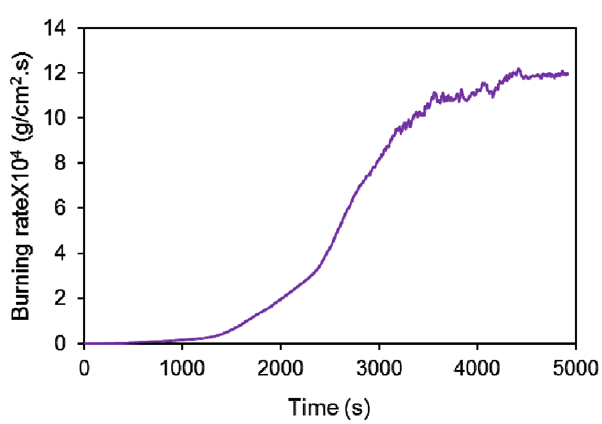


Figure 2: The rate of burning rate of the PMMA slab at a radiation rate of 12.55 kW/m^2.

In the study by Magee and Reitz (1974), the authors measured the steady state burning rate of the sample; however, they did not show the growth or variation of the burning rate with respect to time before reaching to the steady-state burning rate of the sample. The predicted steady state burning rates of the specimen is 12.0 $g/cm^2.s$, whereas this value in the experimental study is 15.0 $g/cm^2.s$. The numerical result has under predicted the burning rate by 20% compared to that of the experimental data. The experimental and numerical values of the steady state burning rates of the PMMA slab and the differences between them are presented in Table 2 and also presented graphically in Figure 3.

Table 2: The experimental and numerical values of steady state burning rates of the PMMA slab

Radiation flux (kW/m^2)	**Experimental values ($g/cm^2.s$)**	**Numerical values ($g/cm^2.s$)**	**% difference**
12.55	15.0	12.0	20%

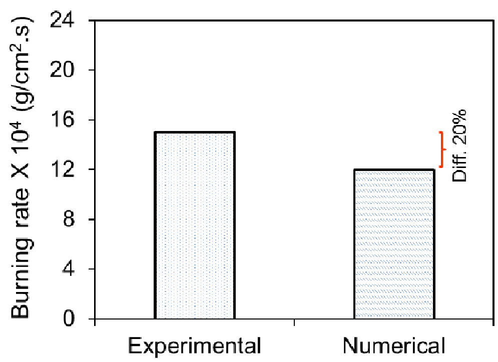
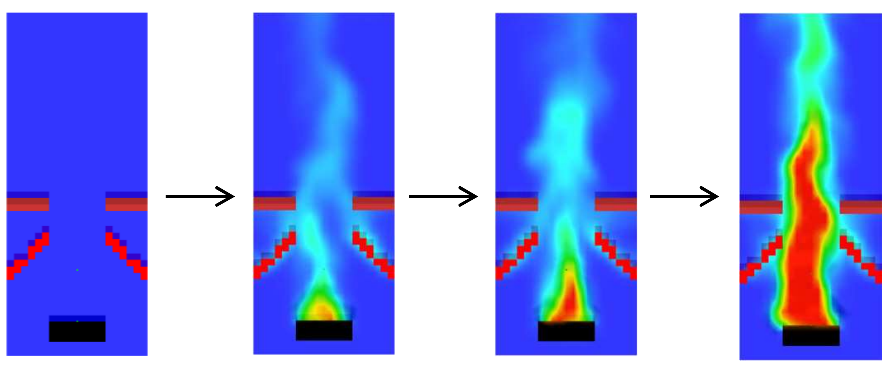


Figure 3: Comparison between the experimental and numerical steady state burning rates of PMMA slab.

The ignition of the sample, development of the fire and the steady state burning of the specimen in the simulation at different levels of time are demonstrated sequentially in Figure 4.



(a) Start of simulation (0 sec) (b) Ignition of sample (1400 sec) (c) Fire in growth (1500 sec) (d) Fire in steady state (4000 sec)

Figure 4: Burning of fire at different stages produced by the PMMA slab.

4. CONCLUSIONS

In this study, the results of the burning of a PMMA specimen using FDS (version 6) has been presented. The steady state burning rate of the specimen were predicted in the simulation and compared with the published experimental data. The results show that the steady state burning rate of the specimen by FDS is in reasonable agreement with the experimental measurement. The prediction of FDS of the burning rate of the PMMA slab is in a reasonable agreement with the experimental data. The difference in between them is 20%. A further study varying the heating rate on the specimen will be worthwhile to access the capability of FDS in wider range in simulating the plastic fires.

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