

CONE CALORIMETER STUDIES: EFFECT OF RADIATIVE HEAT FLUX AND SAMPLE THICKNESS ON BURNING OF PLYWOOD SAMPLES

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ABSTRACT

It is necessary to study the fire behaviour of plywood as the material is widely used for partitioning places into rooms. For example, most of the karaoke boxes built six years ago are made of plywood boards. In this paper, studies on burning behaviour of plywood samples by a cone calorimeter are reported. From the results, ignition time and time to first peak for different incident heat fluxes and samples thickness are discussed.

It is observed from this study that shorter ignition time was found under higher heat flux, even for thicker plywood samples. For example, by increasing the heat flux from 20 kWm^{-2} to 50 kWm^{-2} on plywood of 6 mm thick under ambient condition, the ignition time reduced from 191 s to 13 s. The ignition time decreased from 191 s to 152 s when the thickness of plywood sample was increased from 6 mm to 18 mm.

1. INTRODUCTION

As reviewed before [e.g. 1], timber products including plywood, are commonly used as partition materials. Many places, including karaoke establishments opened six years ago, might have boxes made of plywood boards. By that time, using gypsum as plaster board with adequate fire protection were not yet popular. Therefore, studying the burning behaviour of plywood is important for safety assessment.

Cone calorimeter is now an "essential tool" in studying transient heat release rate for materials of products and assemblies [2,3] using the oxygen consumption method. In addition, optical smoke density, mass loss rate, concentrations of carbon monoxide and carbon dioxide, and amount of soot produced can also be measured with optional equipment provisions. This has led to a number of studies aimed at identifying the factors responsible for the heat release rate of different materials and assessing their suitability for use in the constructions, textiles and furniture industries [2-5]. There are other bench-scale testing methods to give heat release rate which are suitable for studying wood-plastic composites [e.g. 6]. An example is the Ohio State University (OSU) test apparatus [7].

The objective of this paper is to study the fire behaviour of plywood with a cone calorimeter. Correlations between ignition time, time to first peak, and peak value of HRR with the incident heat flux and sample thickness are derived. Experiments isolating the effects due to individual factors on the heat release rate curves of plywood product were performed. Incident heat flux is an

obvious influence factor. In addition, the effect of the sample thickness cannot be ignored. Measured results would provide information for better understanding on the fire behaviour of materials. Factors which are important in the development of fire codes can then be identified.

A series of experimental measurements were conducted with the cone calorimeter. Key operational parameters such as input heat flux and thickness of specimen or curve were varied independently. Unpainted plywood samples were cut into squares of 10 cm by 10 cm and tested under incident heat flux R_f from 20 kWm^{-2} to 50 kWm^{-2} . The sample thickness of specimen D_s varied from 6 mm to 18 mm.

2. IGNITION TIME

How R_f in the cone calorimeter can be adjusted was described clearly in the literature [2,8]. R_f acting on the sample depends on:

- Temperature of the cone heater
- Distance between the cone and the sample
- Humidity and temperature of the environment

The distance between the cone and the sample was fixed in the tests. Temperature of the electric conical heater was determined by the temperature controller. Incident heat flux was calibrated by the cone temperature. The apparatus and samples were kept under ambient environment of similar humidity and room temperature. Therefore, the above three points can be kept to give consistent value of R_f .

Effect of flux R_f on the ignition time t_{ig} is illustrated in Fig. 1. Shorter ignition time was found for higher incident heat flux. With specimen of 6 mm thick, the ignition time reduced from 191 s to 13 s when the input heat flux was increased from 20 kWm^{-2} to 50 kWm^{-2} . Similar results were observed for samples of thickness 12 mm and 18 mm, although shorter t_{ig} were recorded.

The effect of sample thickness D_s on t_{ig} at different R_f is shown in Fig. 2. Shorter ignition times were

observed for thicker plywood. For R_f at 20 kWm^{-2} and sample thickness increased from 6 mm to 18 mm, the required ignition time decreased from 191 s to 152 s. Similar sets of results were obtained for R_f of 30, 40 and 50 kWm^{-2} .

Therefore, ignition time for combustible materials would be decreased if its thickness is increased. A thicker sample would have a longer ignition time.

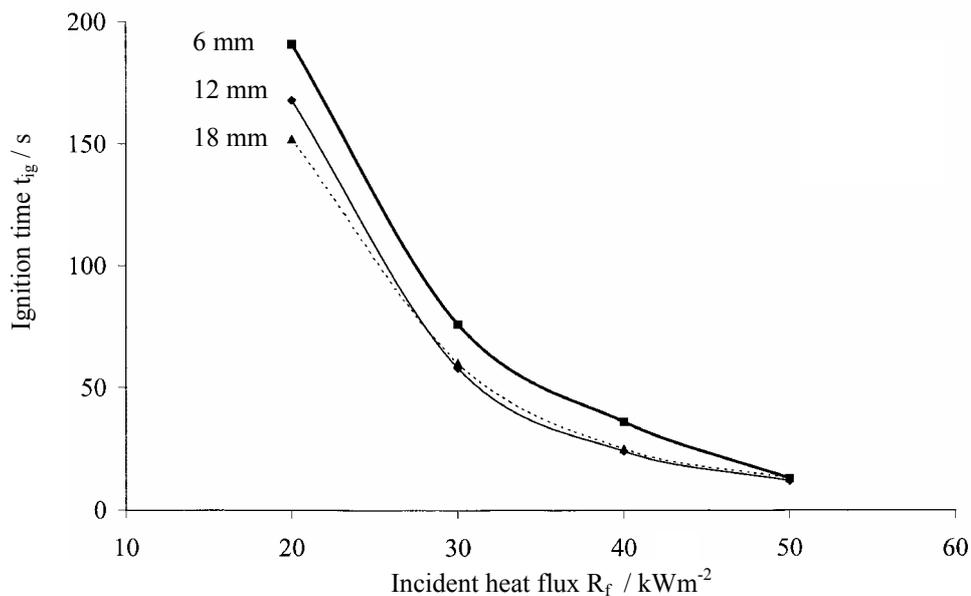


Fig. 1: Effect of incident heat flux on ignition time

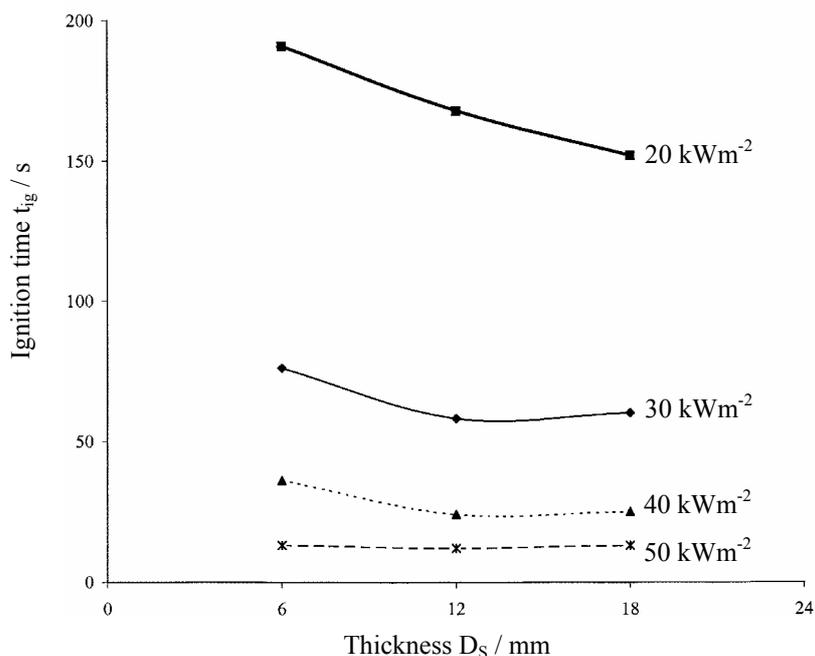


Fig. 2: Effect of sample thickness on ignition time

3. TIME TO FIRST PEAK OF HEAT RELEASE RATE

Measured times t_{fp} required to reach the first peak of heat release rate are plotted against R_f in Fig. 3. It is observed that values of t_{fp} were fairly constant over a range of R_f . For the 6 mm thick plywood sample, t_{fp} for R_f of 20 kWm^{-2} and 50 kWm^{-2} were 29 s and 18 s respectively.

It is reported [5,8,9] that t_{fp} is related to the rate of fire growth. Results indicated that the transition of a typical room fire resulted by burning this plywood sample to flashover would not depend on R_f .

Similar patterns were observed for sample thickness from 12 mm to 18 mm. However, a longer t_p was obtained with thicker samples as shown in Fig. 4.

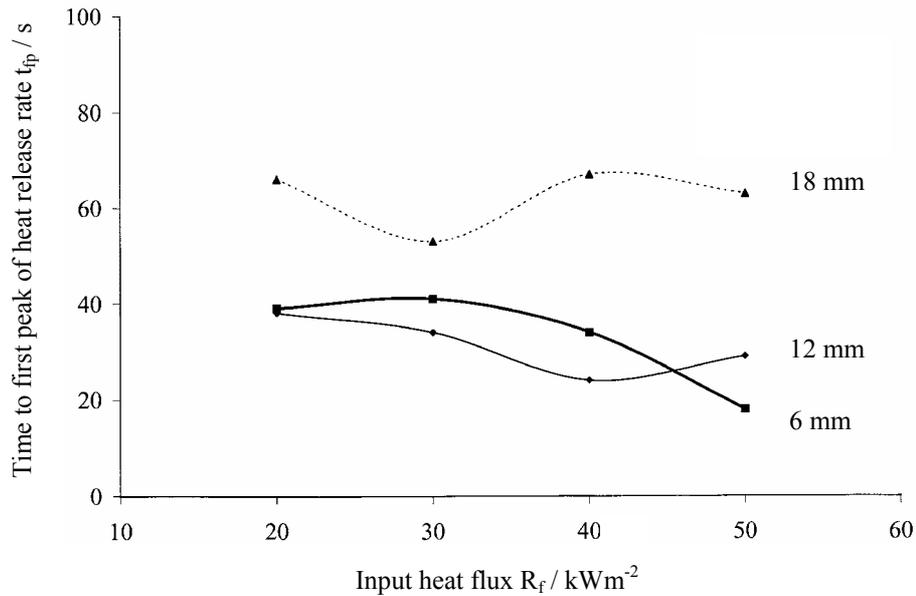


Fig. 3: Effect of incident heat flux on time to first peak of heat release rate

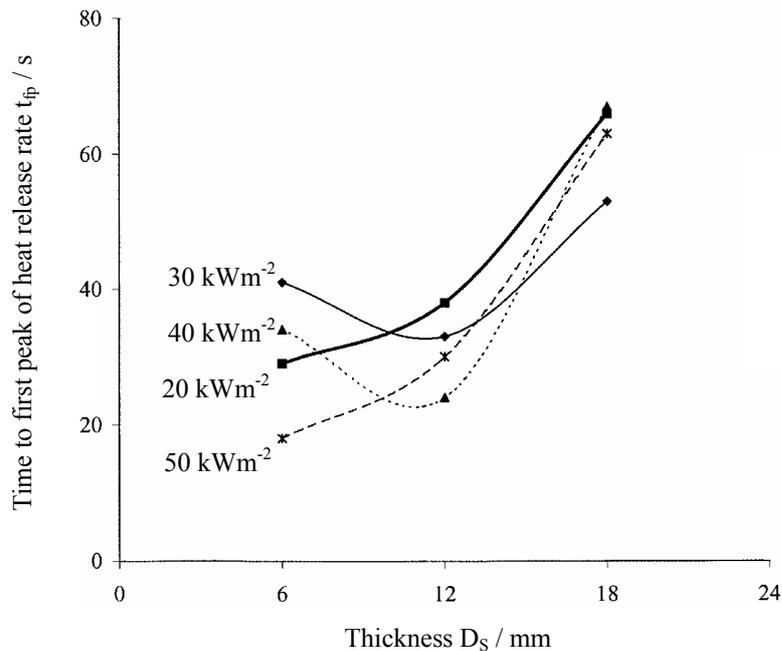


Fig. 4: Effect of sample thickness on time to first peak of heat release rate

4. CONCLUSIONS

Within the range of this study, the experimental measurements on the plywood sample illustrated that:

- Higher the incident heat flux, shorter the ignition time.
- Thicker the sample, shorter the ignition time.
- The time to first peak of heat release rate does not depend on the incident heat flux. However, a longer time is required to reach the first peak of heat release rate with thicker plywood samples.

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NOMENCLATURE

- R_f Incident radiative heat flux, kWm^{-2}
 D_s Sample thickness, mm
 t_{ig} Ignition time, s
 t_{fp} Time to first peak value, s

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