Department of Civil, Environmental and Natural resources engineering
Division of Structural and Construction Engineering

Laboratory work - 1.

Cone Calorimeter.

S0003B

Fire Dynamics I

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Important information/Reporting

- Laboratory date. Estimated time for the lab is about 1 hour for each group.
  - 2nd of October.
    - Group 1 - 13.00
    - Group 2 – 14.00
    - Group 3– 15.00
  - 3rd of October.
    - Group 4 – 10.00
    - Group 5– 11.00
    - Group 6– 13.00
    - Group 7– 14.00
    - Group 8– 15.00

- Place – Complab. Fire corner.
- Groups of 3-4 people
- The report should be written in English in groups of 3-4 students.
- Hand in the report at latest Thursday the 10th of October (hand in on the Fronter course page.)
- Each report should include information about group number, name of group members, version of the report (1,2,..) on the form: "S0003B_Lab_1_Group_XX_Name1_Name2_Name3_Version_XX.docx"
- The approved report will award 1.5 points.

Introduction

The purpose of this lab is to introduce the cone calorimeter which can be used to determine the burning rate, Heat Release Rate and time to ignition of building materials, furniture and similar materials.

The aim of the lab is to inform students of how measurements of Heat Release Rate are made and give a rough introduction of the calculation methodology followed during the measurements.

The laboratory experiments are conducted in a standardized devise (a so called the Cone Calorimeter) where the sample is heated with a cone-shaped electrical heater. The gases from pyrolysis are ignited with a spark and the heat release rate is estimated from the reduction of oxygen in the exhaust gases, see Figure 1. In our case a horizontal sample holder will be used.

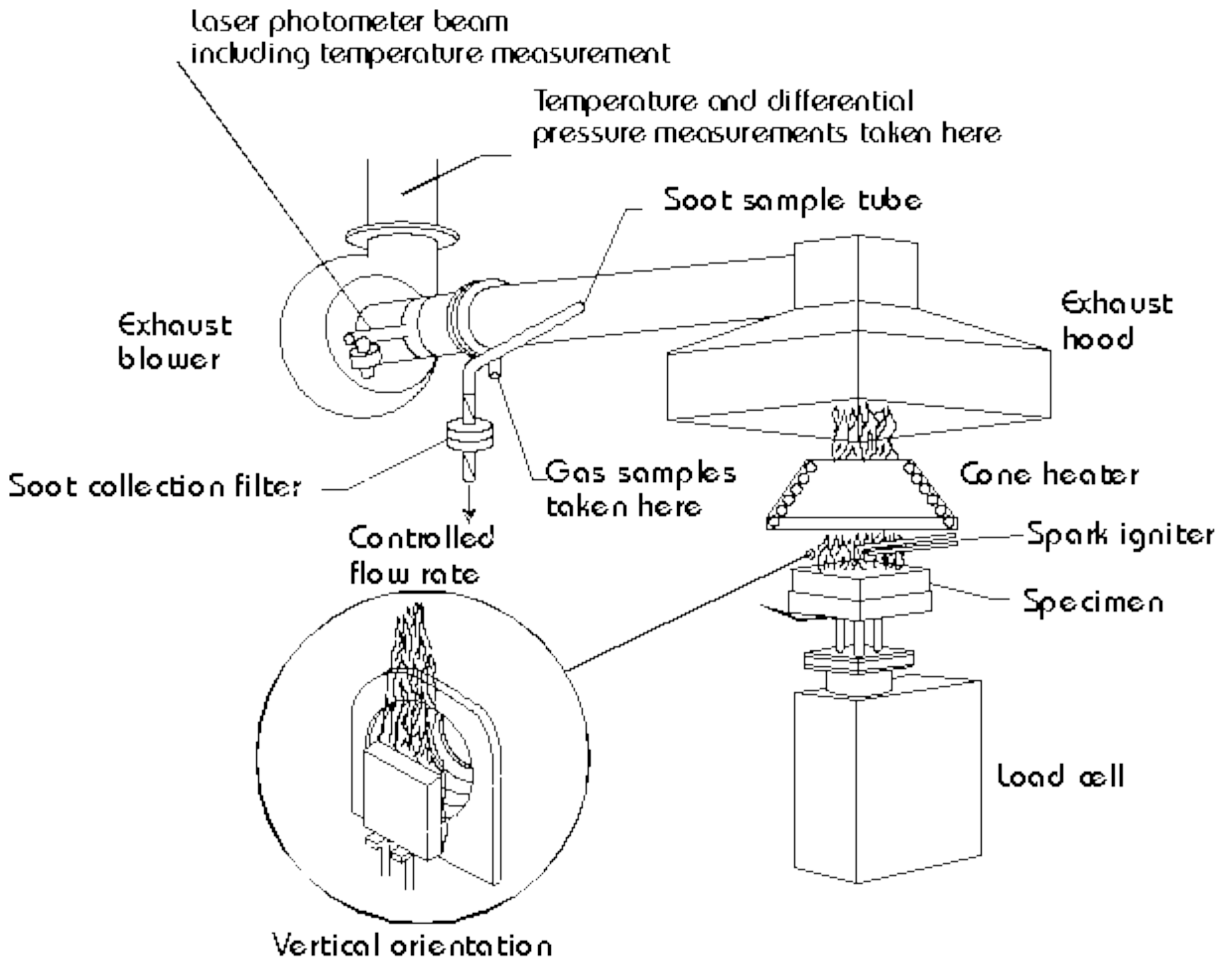

Figure 1. Cone Calorimeter adapted from [1].

Test

Because of the limited time for laboratory work groups 1, 3, 5, 7 will perform tests with an incident radiation level of 20 kW/m^2, and exchange data with groups 2, 4, 6, 8 respectively, who will perform tests with an incident radiation level of 40 kW/m^2:

Group 1 ←→ Group 2
Group 3 ←→ Group 4
Group 5 ←→ Group 6
Group 7 ←→ Group 8

During this test we use two building materials: particle board (PB) and porous fiberboard (PF)) of approximately the same dimension 100 mm by 100 mm, but with different densities. They will be heated until ignition.

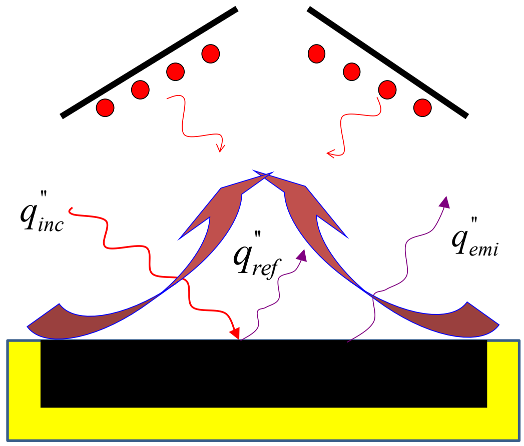

Figure 2. Ignition of the wood samples.

Incident radiation levels to be used are 20 kW/m^2 and 40 kW/m^2. For setting the radiation level, see the calibration curve for cone calorimeter (will be provided during laboratory experiments).

Measuring Heat Release Rate (HRR) as a function of time:

When the material ignites (porous board and chipboard) it starts to burn. We are interested in knowing how much effect is developed as a function of time.

The Cone Calorimeter estimates the HRR of a material by measuring the oxygen concentration in the smoke gases. The energy developed per kilogram used oxygen is approximately the same for all (or nearly all) materials, or 13,1 MJ/kg oxygen. The Cone measures the oxygen concentration of the smoke gas and the volume flow in the smoke channel.

The apparatus measures the volume flow first at a reference temperature and then at the smoke gas temperature. These flows are determined using a “bidirectional probe” to measure velocity. A theormocouple is used to measure the temperature of the gases, allowing the gas density to be determined. The bidirectional probe (pitotrör) measures the dynamic pressure ΔP (difference between the high pressure and low pressure side of the probe) and thereby the velocity in the centre of the channel can be determined. When the gas velocity in the centre of the channel is known, the volume flow can be calculated, since the cross sectional area of the channel is known. The volume flow at a given temperature is calculated as a funtion of area and average velocity.

Knowing the volume flow and the oxygen used for combustion, the HRR can be calculated according to equation (1)

$$\dot{Q} \quad = \quad 17{,}2 \cdot \left(X_{0_2}^{0} - X_{0_2}^{S} \right) \cdot \dot{V}_{298} \cdot \alpha \qquad (1)$$

där

$\dot{Q}$ = effektutveckling i MW

$X_{0_2}^{0}$ = vol% syrgas i den omgivande luften

$X_{0_2}^{S}$ = vol% syrgas i rökgaskanalen

$\dot{V}_{298}$ = volymflödet i rökgaskanalen m^3/s vid 25°C och 1 atm

α = expansionsfaktorn för den luft som förlorat sitt syre ≈ 1,1

Instruction:

1. Set the temperature of the "cone-heater" to obtain the incident radiation effect of 20 or 40 kW/m^2, based on the calibration curve.
2. Weight samples.
3. Measure dimensions of samples: width, length and thickness.
4. Place the sample in the sample holder.
   Preparation of test sample
   a) *Wrap the sample with aluminum foil, with the shiny side of the foil facing the sample.*
   b) *Placed sample holder without sample on the weight device (under cone) and press "Tare" on the instrument panel*
   c) *Placed the sample into the sample holder, make sure there is no gap between the holder and exposed surface of the sample*
5. Start the recording (computer connected to the cone calorimeter).
6. Press 1 on the remote control when the cone is open.
7. Make sure the spark is on.
8. Press 2 when the sample is ignited and record the thermocouple temperature.
9. Remove the spark to the side.
10. Press 4 when the fire is extinguished.
11. Press the left green circle (on the computer) to end the measurement.
12. Take out the sample.
13. Collect the data from the experiment.
14. Repeat the same procedure for the next sample.
15. Collect data from experiments performed by other group
16. Write a lab report.

Recordings and reported information

Time to ignition	$t_{ign\ PB}$ $t_{ign\ PF}$	sec sec
Samples dimensions (PB and FB)	L*B*H	m
Weight of samples	m	kg
Time of extinguished (PB and FB)	$t_{ext,\ PF}$ $t_{ext,\ FB}$	sec
Heat release rate as a function of time	$\dot{Q}$	W/m^2
Peak rates of heat release (PHRR)	$\dot{Q}_{max}$	W/m^2
Time of maximum HRR (PHRR)	$t_{max\ HRR}$	sec
Average effective heat of combustion	$\Delta H_{eff,\ average}$	MJ/kg
Mass burning rate	$\dot{m}$	g/sec

Questions/Calculations:

1. What temperature should be set on the cone to get the incident radiation effect at 20 kW/m^2 and 40 kW/m^2? (According to the calibration data).
2. What is the time to ignition for both materials (at the two different incident radiation conditions, totally four experiments)?
3. Explain the shape of the Heat-release rate curve.
4. How would the Heat-release rate curves look like if the test pieces were considerably thicker? (see [4])
5. Using the value of Peak Heat Release Rate, calculate backwards the remaining mass% oxygen in the duct for that HRR with help from example 3.1 from Enclosure Fire Dynamics. Use data from the cone calorimeter test as input.
6. Examine how the Peak Heat Release Rate, at a given time t_{peak}, is calculated by the apparatus in eq. (1) and give an estimate of the volume flow of gases [l/s] in the channel at this time. Use data from the cone calorimeter test as input.
7. With the measured Peak Heat Release Rate, at a given time t_{peak}, roughly calculate the volume flow rate of gases [l/s] in the channel at that time with help from example 3.1 and eq. (5.10) from Enclosure Fire Dynamics. Use data from the cone calorimeter test as input. Smoke/gas temperature is found under 'TSM' in the data.
8. Compare flow rate from 6. and 7. and discuss why they differ and sources of error.

Report instructions:

In order to be approved, the report must fulfill both the general criteria for report writing and the specific subject/tasks for this laboratory work. Guidance for report writing (in swedish) can be found in the document 'Manual för laborationsrapport' on Fronter.

Literature:

1. Babrauskas, V. The cone calorimeter. SFPE Handbook of Fire Protection Engineering, Third Edition. Section 3/Chapter 3, NFPA.2002.
2. ISO 5660-1. Reaction-to –fire tests – heat release, smoke production and mass loss rate – part 1: heat release rate (cone calorimeter method) 2002.
3. Karlsson, B., Quintiere, J., G. (2000). Enclosure Fire Dynamics
4. Tsantaridis, L. Reaction to the fire performance of wood and other building products. Doctoral thesis. KTH. 2003