Flame attached plastic dripping

Peng-Jin Lin(林鵬晉),Jia-Wei Chang(張家維),Han-Tsung Lee(李漢琮）
TA: Lu-Hsin Lee (李律昕), Advisor:Meng-Fan Luo（羅夢凡）
Department of Physics, National Central University

I. Introduction

Overheated wire catching fire is a common cause of fire hazard. Once ignited , the plastic material of the wire will be melted, accumulating as drips and fall down due to gravity. Chances are that flame is attached to drips and falls on other objects with them , thus resulting in spreading of fire. We try to investigate the dripping phenomenon by direct ignition of horizontally-placed PE tubes with cylindrical copper rod as the core using the torch gun. In our experiment , we hope to find the probability to ignite other objects for drips generated by different diameter of PE tubes and falling from various heights.

II. Apparatus for Experiment

Two rods of maximum length 3m with adjustable holders on each are placed vertically between the ceiling and a table. A metal platform bearing PE tube which wrapping the cylindrical copper core is clenched by the holders. The core and PE tube are locked by screws on the platform and are able to be replaced to those of different sizes by loosening screws. Tissue paper is used as the object to be burned.

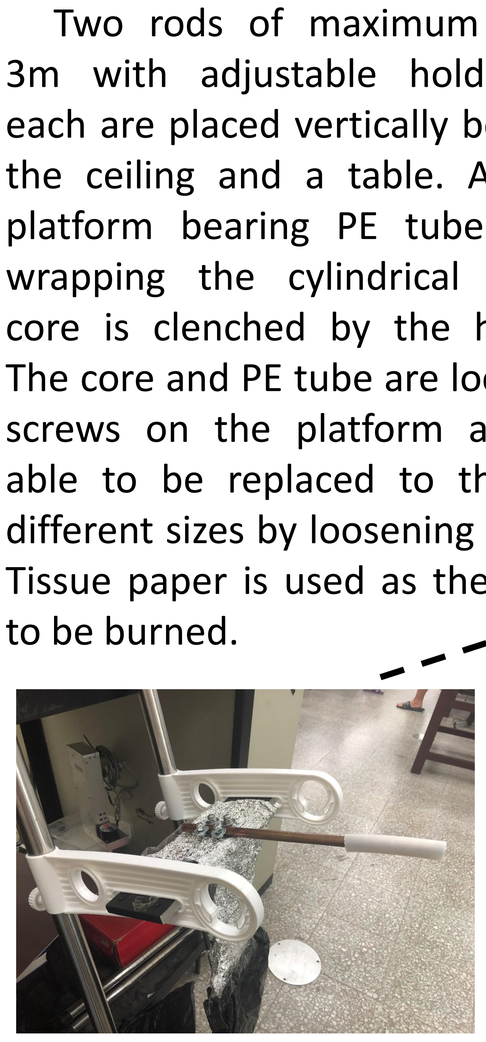

Fig.2 Holders , platform and copper core

Fig. 1 Rods

Fig. 3 metal shelf covered with trash bag to block wind

III. Experimental Results

Velocity

The velocity curve of drips is found to correspond to the simulation curve applying the following equation:

$$Ma = Mg - \frac{1}{2} Cd\rho v^2 \frac{\pi}{4} D^2$$

except for an inconsistency in a time interval between 0.2s and 0.4s.

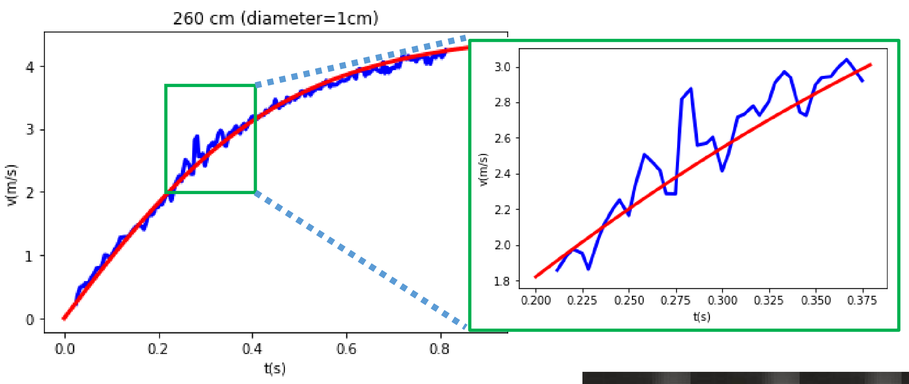

Fig 4. velocity curve for drips from 1cm tube falling from 260cm

The video recording the falling process is examined, and it is discovered that, in the time interval, flame on drips experiences a sudden “explosion”.

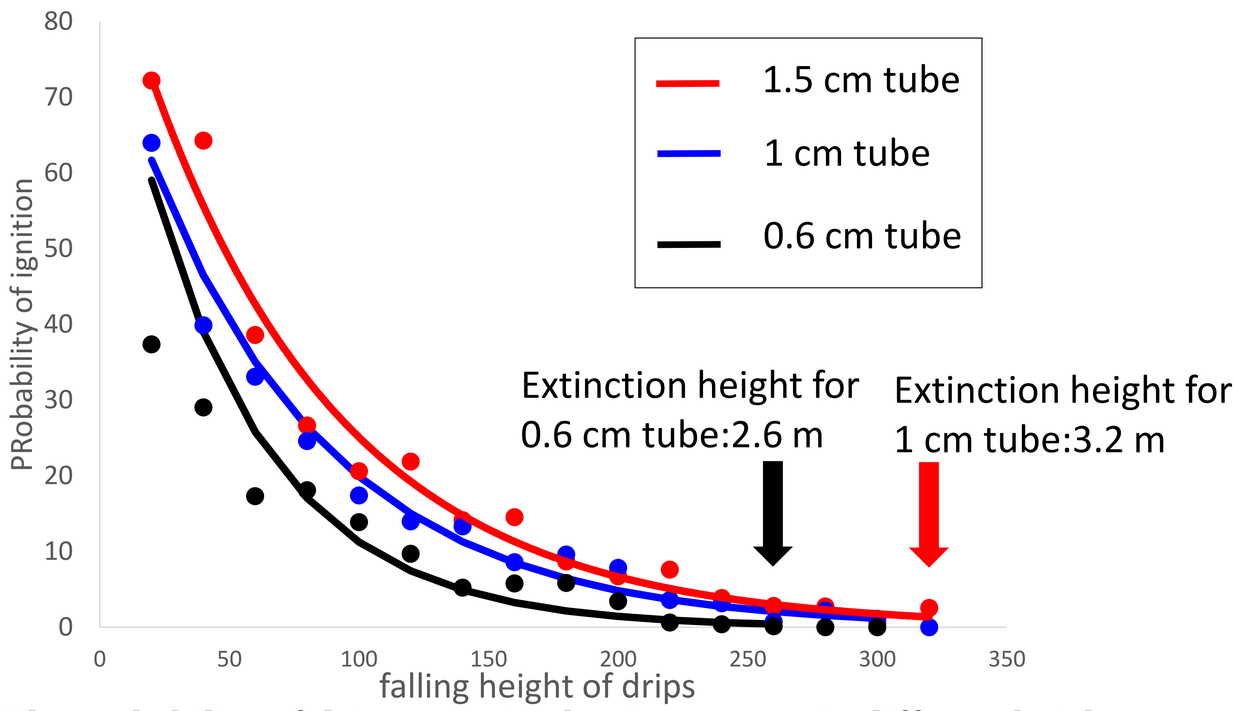

Fig.5 The probability of drips to ignite the tissue paper in different height

The probability of ignition decreases as the falling height of drips increases. In addition, the probability of ignition for drips from larger diameter of tube is higher than that of small diameter tube. Extinction heights , at which all drips cannot ignite tissue paper , are discovered for different sizes of tubes.

Environmental cooling effect

The temperature change rate for falling drips is express as :

$$\frac{dm}{dt}\,\Delta Hc - hA(T - T_\infty) = \rho V c\,\frac{dT}{dt}$$

where the first term of left side is the generation rate of heat of combustion from flame on drips , and the second term is the environmental cooling rate. Combining with the velocity , the simulated curve of drip temperature versus falling distance can be obtained.

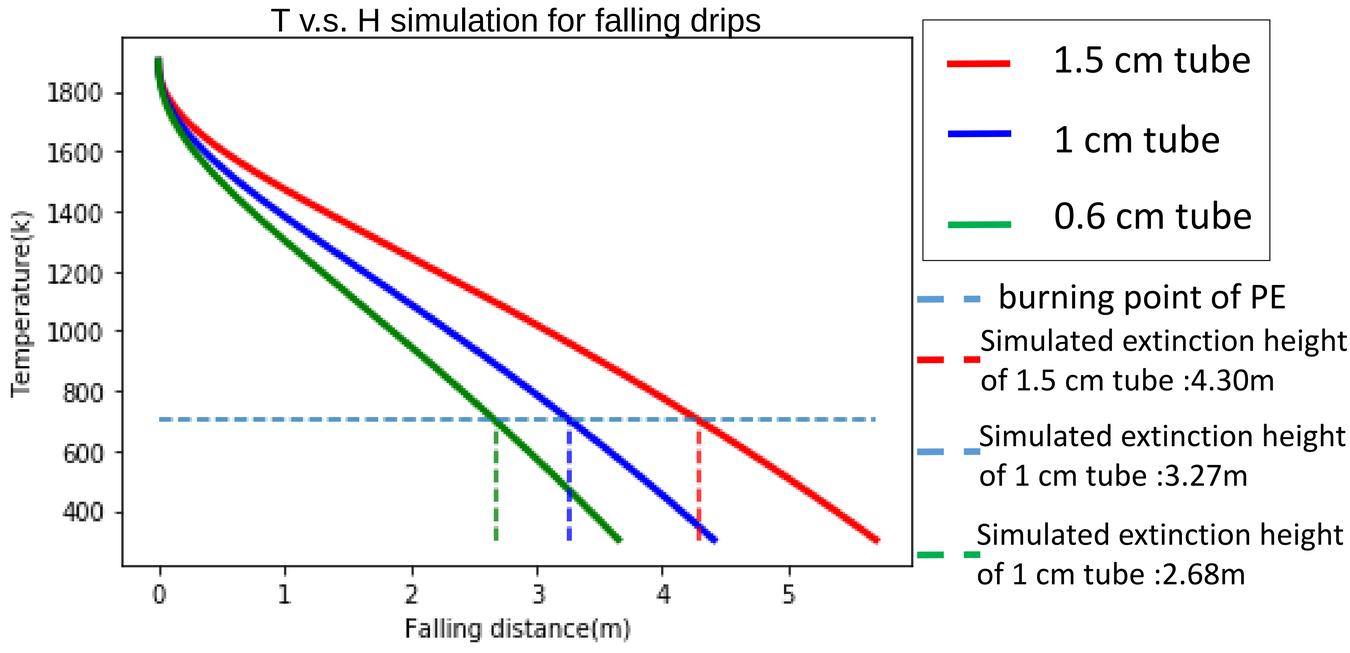

Fig.6 The simulation curve of temperature versus falling distance for drips

The result shows that , when drips fall to the extinction height , their temperature declines below the burning point of PE , which is not able to maintain flame on drips. This explains why all drips falling to the extinction height don’t ignite tissue paper.

IV. Conclusion

1. Drips from larger diameter of tubes have higher probability to ignite tissue paper.
2. Drips falling through longer distance have less chance to ignite tissue paper. Certain heights where the probability of ignition is zero are found to be 2.6m for drips from 0.6cm PE tube , and 3.2m for drips from 1 cm PE tube .
3. Extinction of flame on drips is caused by environmental cooling effect making drip temperature lower than PE burning point.

Reference:

[1] Xinyan Huang Critical Drip Size and Blue Flame Shedding of Dripping Ignition in Fire, Scientific Reports 8, Article number: 16528 (2018)
[2] Turns, S. An Introduction to Combustion: Concepts and Applications. (McGraw-Hill Education, 2011)
[3]Incropera, F. P. Fundamentals of heat and mass transfer. (John Wiley, 2007).