

Aim of the Experiment: To find the d-square law for evaporating droplet

Theory:

Propulsive devices which work on liquid fuels, depends on several processes in order to achieve high efficiency in the combustion cycle and low emissions in the exhaust gas. The evaporation of the liquid fuel in the combustion chamber is one of the processes during combustion. In aircraft and rocket propulsion systems, the fuel enters the combustion chamber in the liquid state. Then the liquid fuel disintegrates into several droplets by atomization process. Simultaneously, the liquid droplets also evaporate before the actual combustion process occurs. The evaporation of a liquid droplet is characterized by the time it takes to evaporate completely and which is governed by a d-square law.

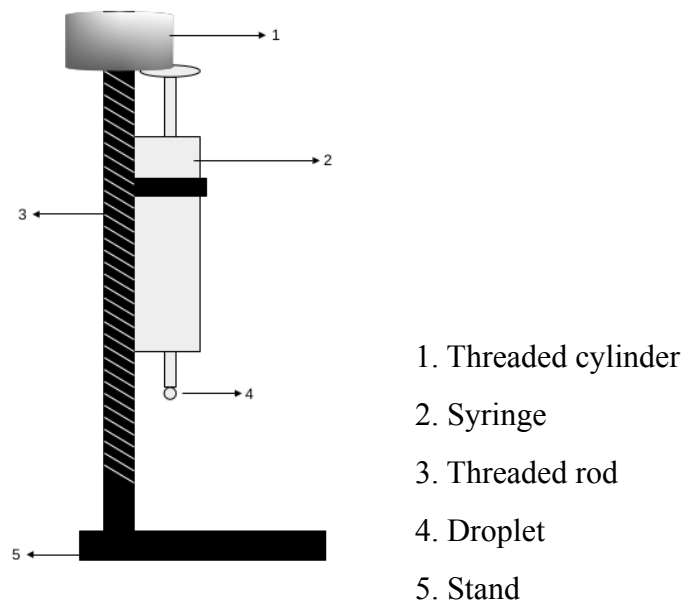


Figure 1: Schematic of the Experiment setup

Procedure:

To find the d-square law, experiments are conducted on two fuels namely ethyl acetate and petrol. The schematic of the experiment setup is shown in Fig. 1.

- The liquid fuel is drawn into a syringe by ensuring that there are no air bubbles in the syringe.
- It is then fixed to a stand, along with a graph sheet next to the droplet.
- The droplet is suspended at the needle end by slowly rotating the threaded cylinder on the top.
- The video/photos of the droplet evaporation process are captured at regular interval of time, till it evaporates completely.
- From video/photos the diameter of the droplet at regular interval of time are calculated and plotted.
- A curve is fitted to get the law of droplet evaporation.
- Using the evaporation law the evaporation time (t_v) is calculated by putting final diameter is equal to zero.

Table: Instantaneous diameters of the evaporating droplet for Ethyl Acetate and Gasoline

<u>Ethyl Acetate</u>		<u>Gasoline</u>	
time(sec)	diameter	time(min)	diameter
0	2.79	0	2
5	2.697	15	1.85
10	2.573	30	1.82
15	2.542	45	1.8
20	2.573	60	1.77
25	2.48	75	1.74
30	2.449	90	1.72
35	2.449	105	1.68
40	2.387	120	1.57
45	2.356	135	1.3
50	2.263	150	1.166
55	2.232	165	1.091
60	2.201	180	0.94
65	2.139	210	0.81
70	1.82	235	0.74
75	1.426	250	0.66
80	1.178	265	0.59
85	1.085		
90	0.992		
95	0.496		
100	0.403		
105	0.372		
110	0.11		

Plot the curves as shown in Fig. 2 for the two fuels and obtain C and n in the relation for vaporization time $t_v = \frac{C}{d^n}$ from it.

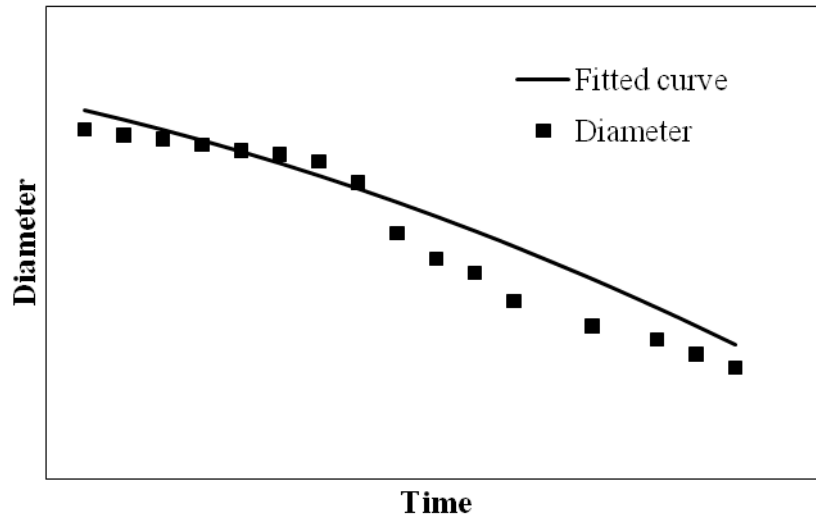


Figure 2: Variation of diameter of evaporating droplet with time

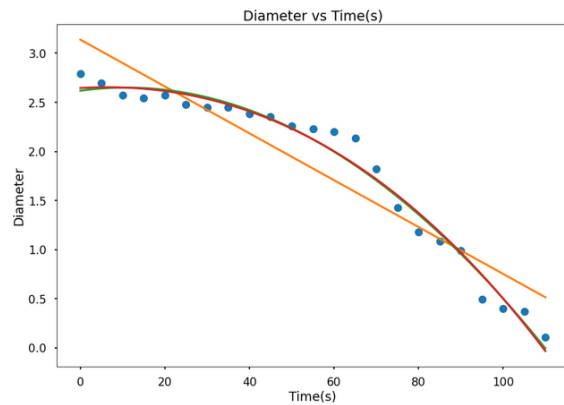
Results:

i. Ethyl Acetate ($d_0 = 2.79$)

For Linear Fit, vaporization time = 131.559 s

For Quadratic Fit, vaporization time = 109.908 s

For Cubic Fit, vaporization time = 109.414 s

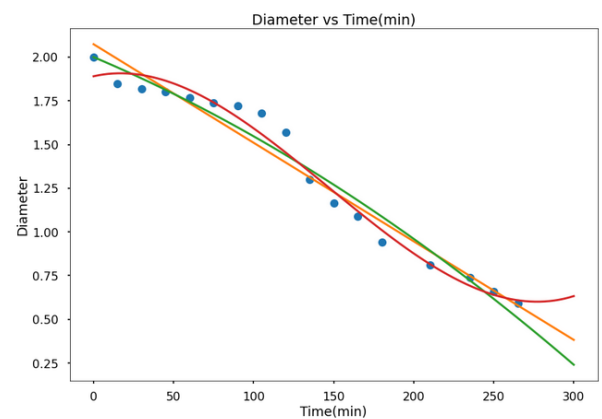


i. Gasoline ($d_0 = 2$)

For Linear Fit, vaporization time = 367.926 min

For Quadratic Fit, vaporization time = 329.781 min

For Cubic Fit, vaporization time = No Positive Root



Thus taking the quadratic fit for further analysis,

i. Ethyl Acetate : initial diameter = 2.79 , vaporization time(Tv_0) = 109.908 s

ii. Gasoline : initial diameter = 2 , vaporization time = 329.781 min

Taking these values, we formulate the table for time taken for vaporization of different droplet sizes.

We do this by using : vaporization time for that diameter = Tv_0 - time_at_that_diameter

Ethyl Acetate

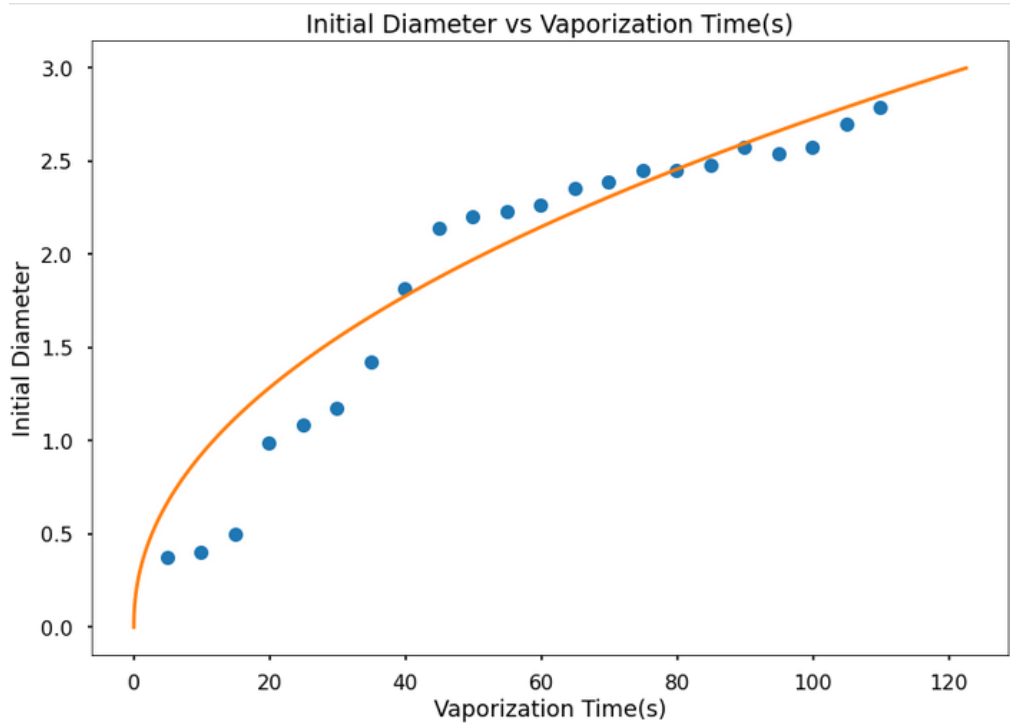
Gasoline

Diameter (in mm)	T _V (in s)		Diameter (in mm)	T _V (in min)
2.79	109.908		2	329.781
2.697	104.908		1.85	314.781
2.573	99.908		1.82	299.781
2.542	94.908		1.8	284.781
2.573	89.908		1.77	269.781
2.48	84.908		1.74	254.781
2.449	79.908		1.72	239.781
2.449	74.908		1.68	224.781
2.387	69.908		1.57	209.781
2.356	64.908		1.3	194.781
2.263	59.908		1.166	179.781
2.232	54.908		1.091	164.781
2.201	49.908		0.94	149.781
2.139	44.908		0.81	119.781
1.82	39.908		0.74	94.781
1.426	34.908		0.66	79.781
1.178	29.908		0.58	64.781
1.085	24.908			
0.992	19.908			
0.496	14.908			
0.403	9.908			
0.372	4.908			
0.11	-0.092			

Calculations and Results:

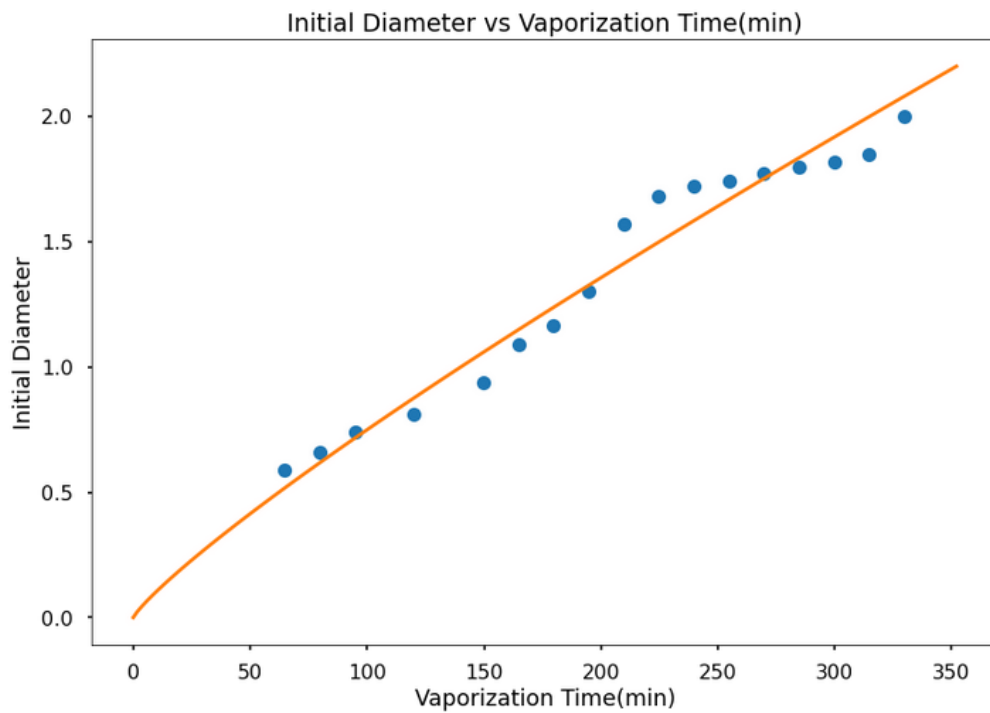
Thus, the evaporation law $t_v = C/x^n$

Ethyl Acetate :



for Ethyl Acetate, we have $C = 11.6827828$ and $n = -2.13925924$

Gasoline :



for Ethyl Acetate, we have $C = 140.10667$ and $n = -1.1686059$

Conclusions

- The d-square law is a constant temperature model
- The d-square law is a good approximation to find time of vaporization for droplets of dilute substances.
- the d-square law is not a good approximation to find the time of vaporization for droplets which consist of non-dilute (concentrated) substances
- Many different models exist for the single convective droplet vaporization case.
Vaporizing droplet models can be seen to belong to six different classes:
 1. Constant droplet temperature model (d^2 -law)
 2. Infinite liquid conductivity model
 3. Spherically symmetric transient droplet heating model
 4. Effective conductivity model
 5. Vortex model of droplet heating
 6. Navier-Stokes solution