

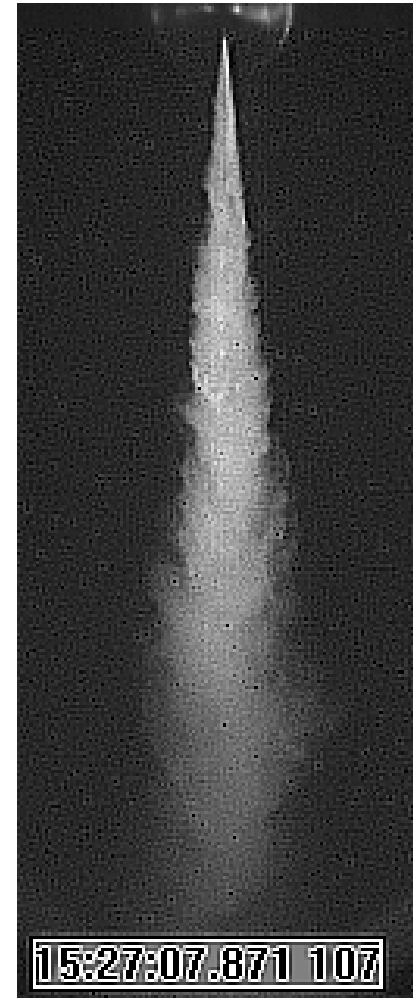
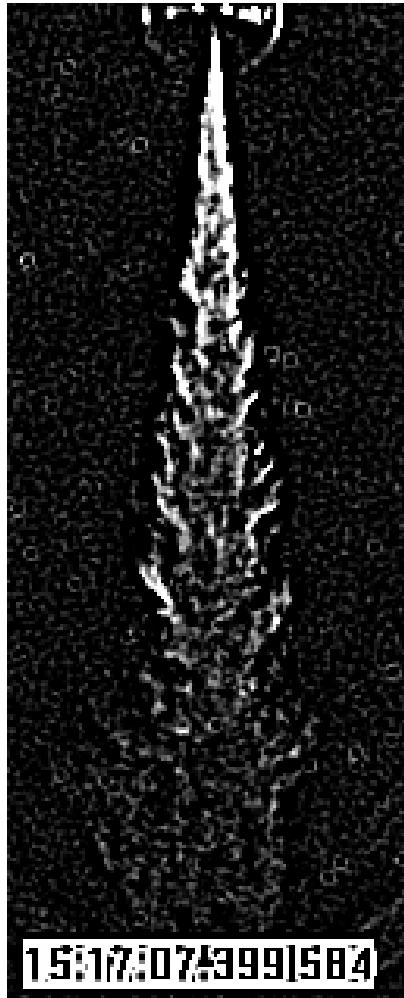
**Coupling between
Grouping and Evaporation
of Fuel Droplets in
Internal Combustion Engines (ICEs)**

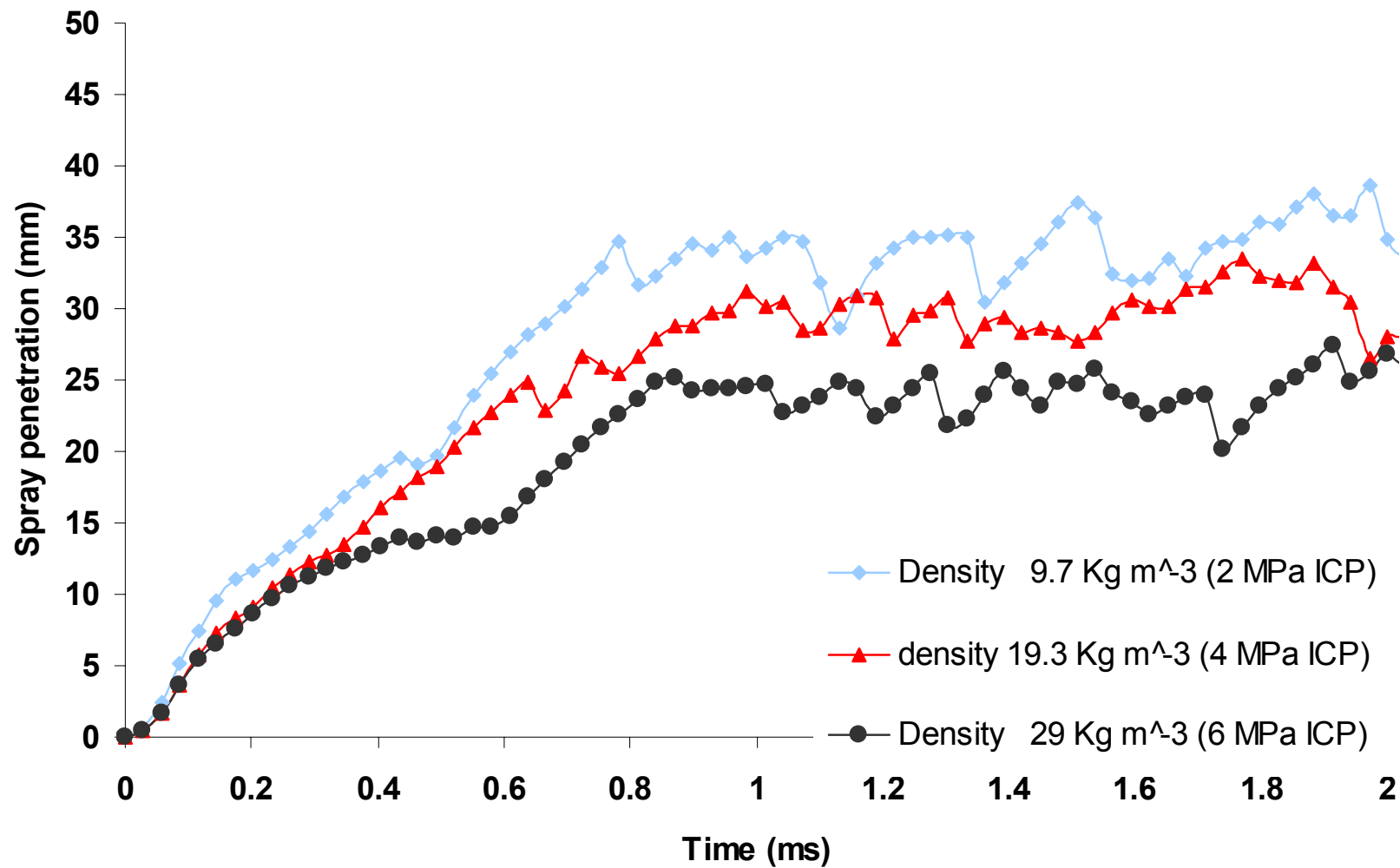
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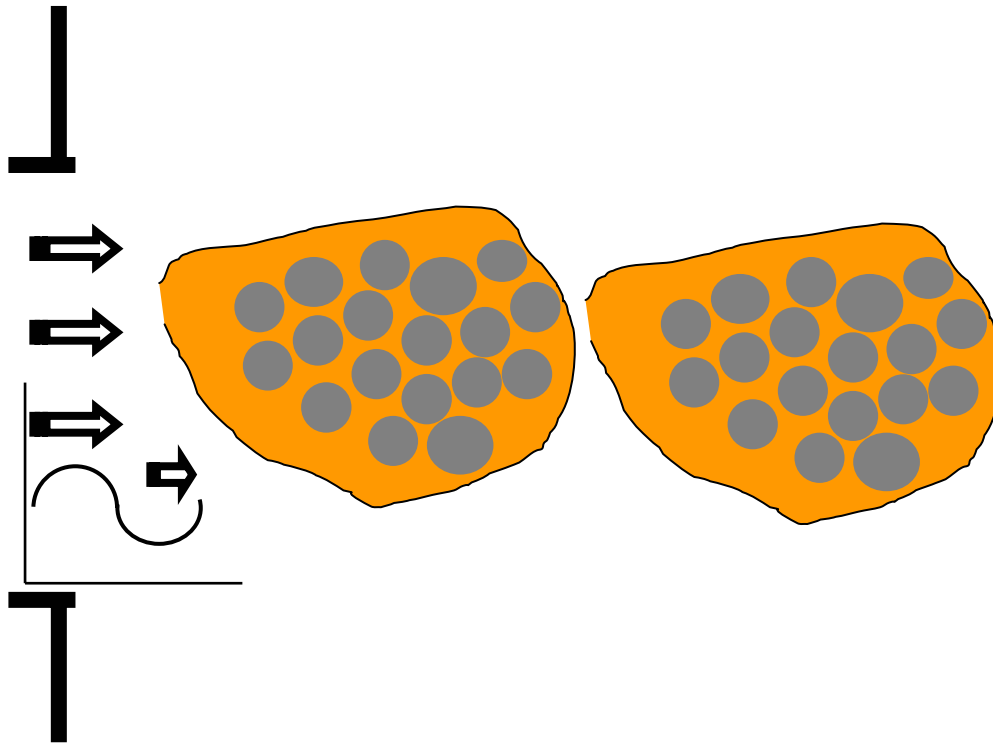


From Experimental Spray Studies





Travel-Grouping of Evaporating Fuel Spray Droplets



Model

Assuming, for the host gas:

$$u(x, t) = U_a - U_b \sin(kx - \omega t)$$

t - time, x - distance

k - wave number, ω - angular velocity

The equation of particle motion leads to

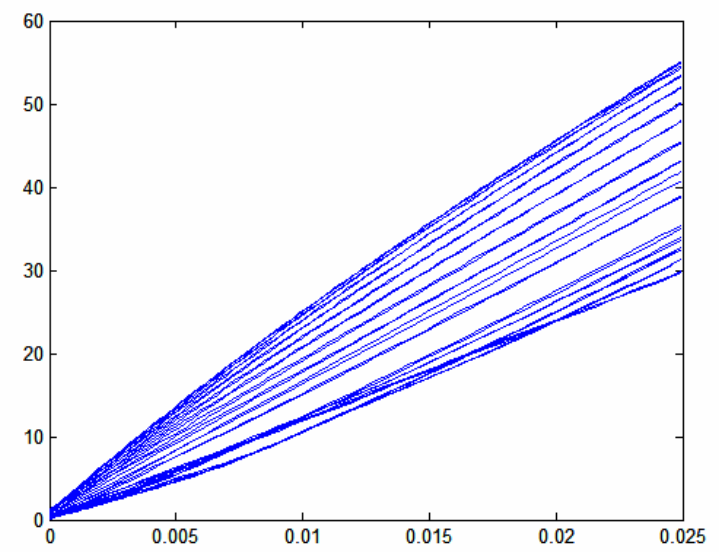
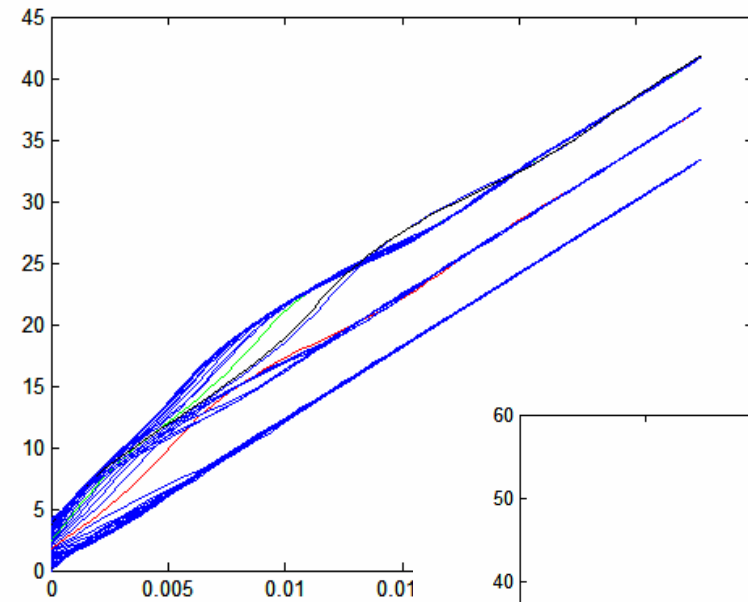
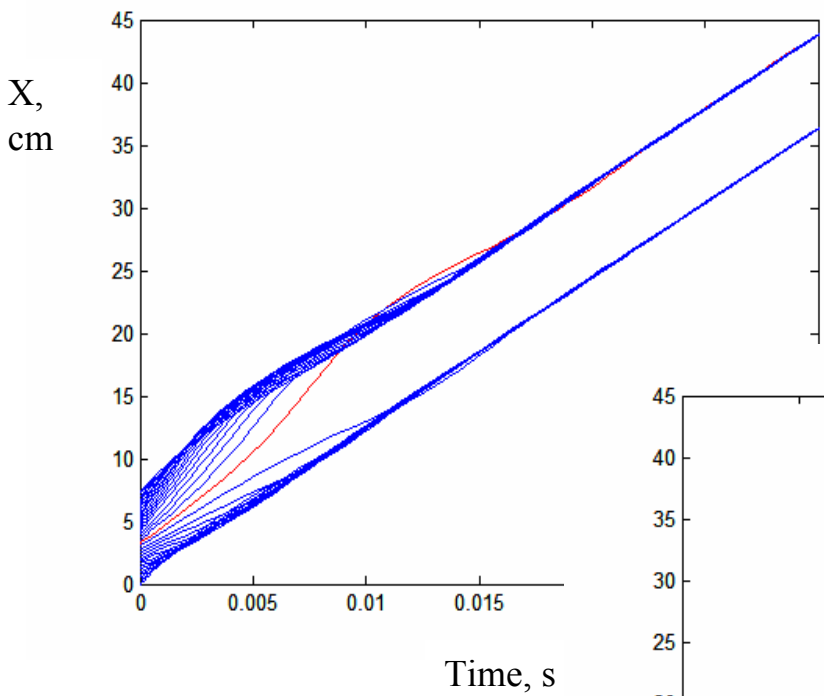
$$\theta'' + \alpha\theta' + \sin\theta = \beta$$

$$\theta = x - t$$

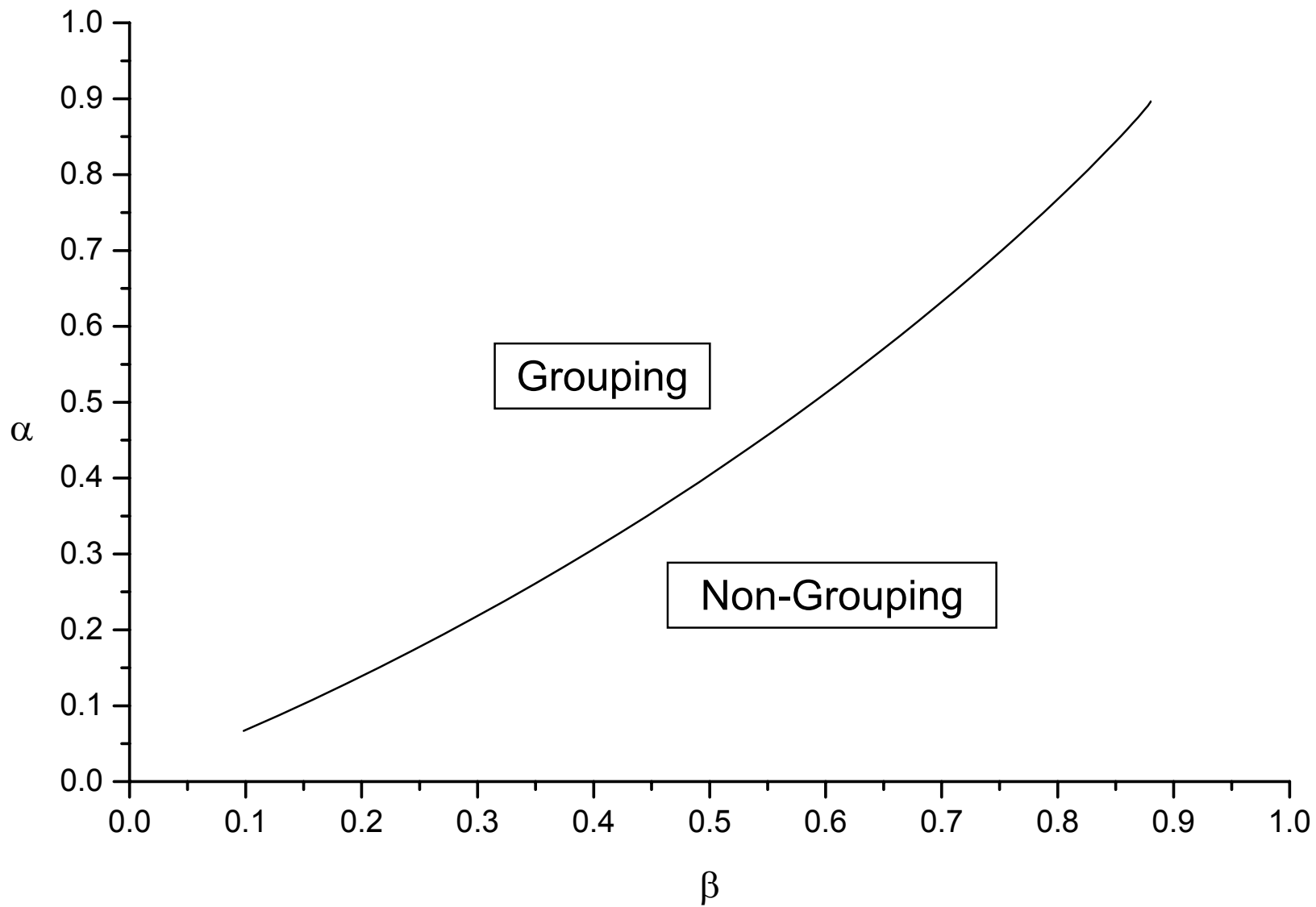
$$\beta = (U_a - 1) / U_b \quad \alpha = 1 / \sqrt{U_b St}$$

where, for normalization we use: $U_w = \omega / k$

Grouping/ Non-Grouping of 30-microns droplets



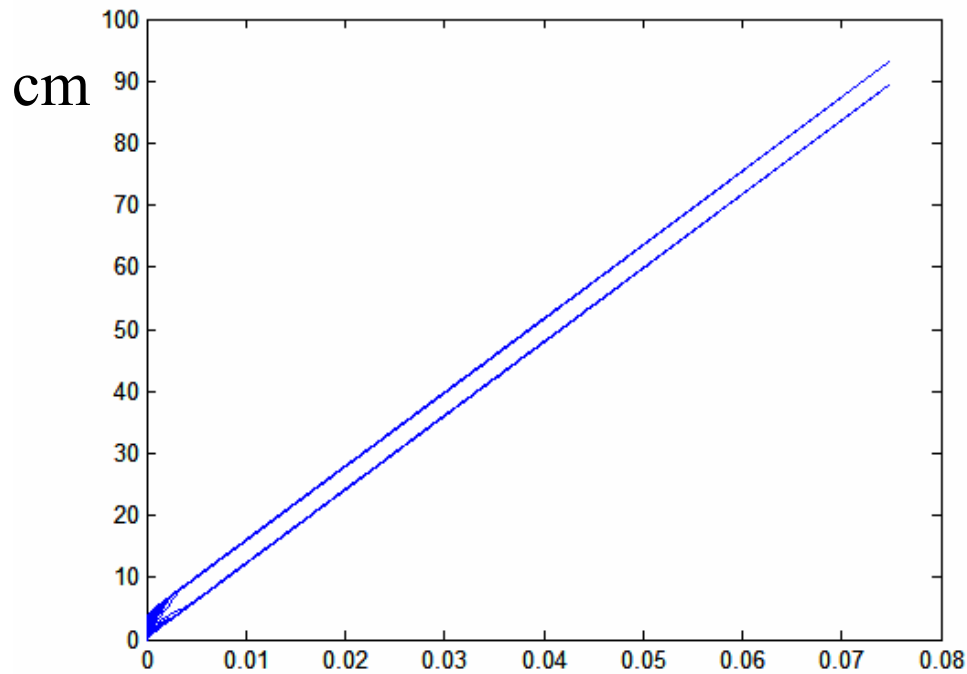
Increase in oscillation frequency



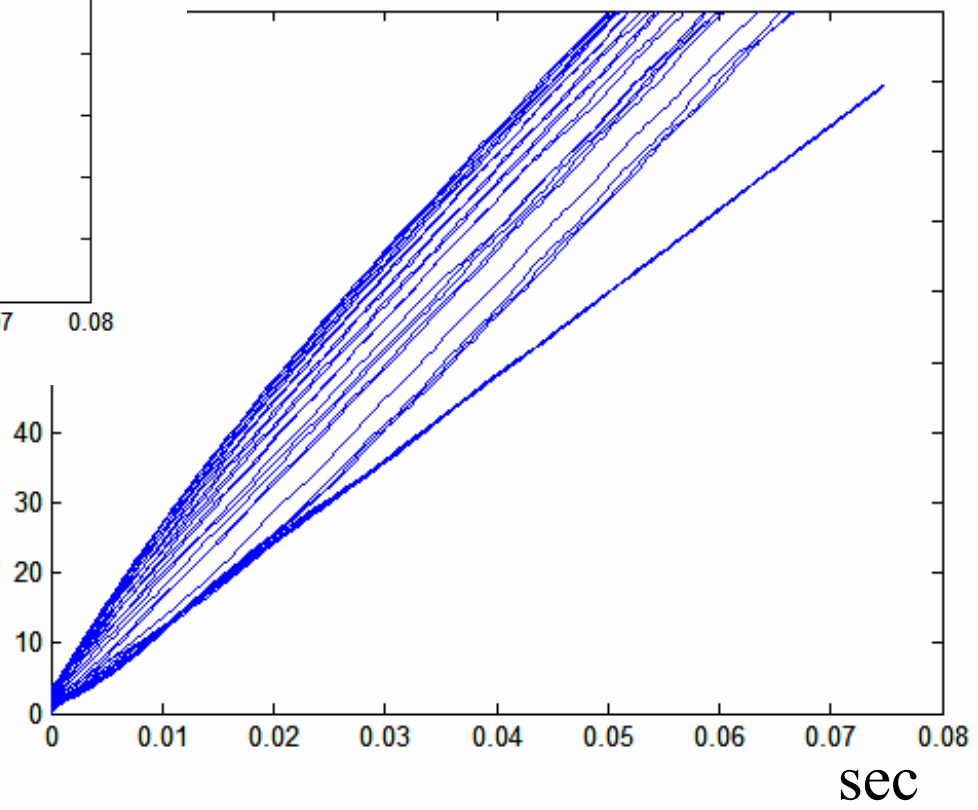
We find that

$$NG = \frac{U_a - 1}{\sqrt{U_b}} \sqrt{St} \gg 1$$

- NG – Non-Grouping conditions



NG<1
(10 microns)



NG~5
(70 microns)

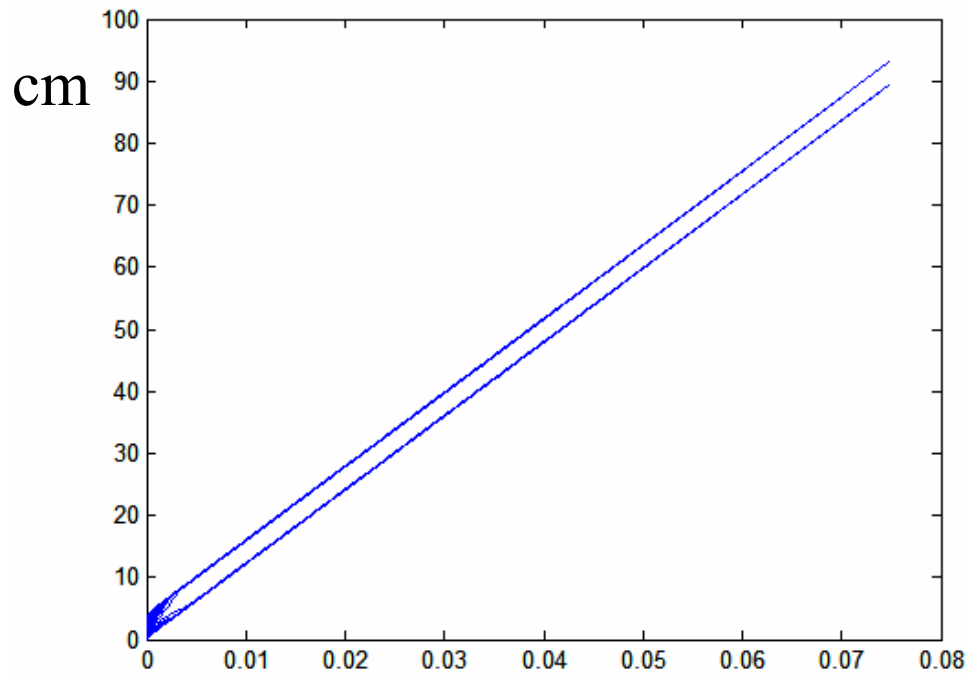
For the evaporation, the “D-Square Law” was employed
in which: $D^2(t) = D^2(t_0) - Kt$

As grouping occurs, evaporation rate decreases (Sirignano, 1999)

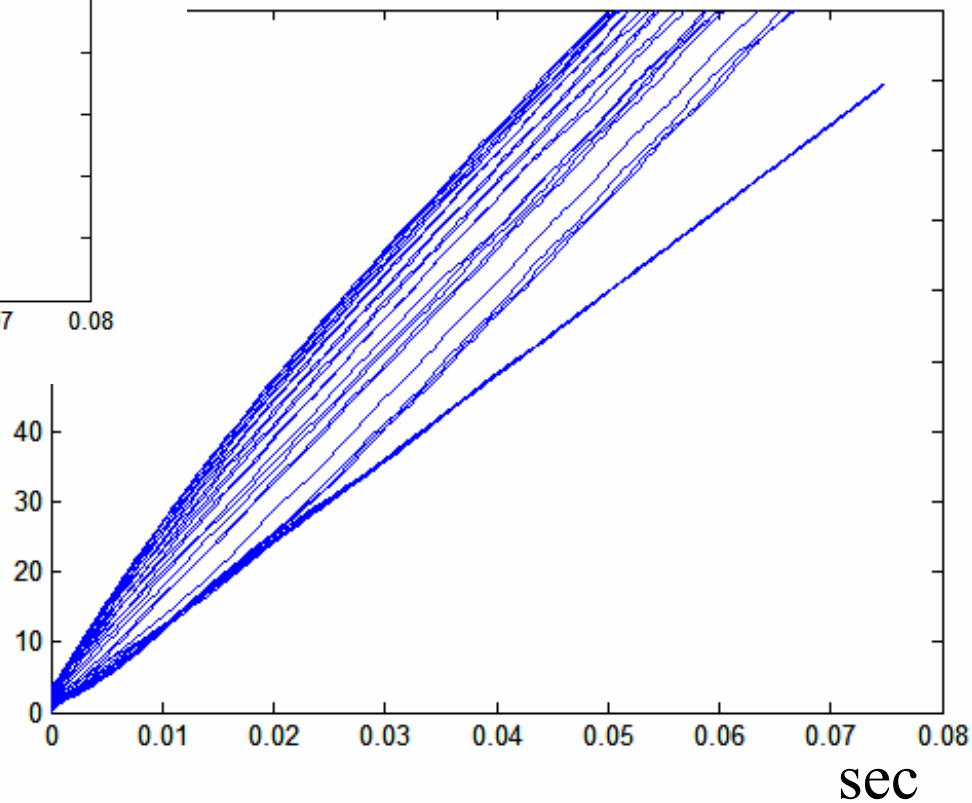
Vaporisation constant, K , for several fuels

Fuel -	K (mm²/s)
Petroleum ether	0.99
Petroleum	0.96
Ethanol	0.81
Benzene	0.97
Ethyl benzene	0.87
O-Xylene	0.79
Iso-propyl benzene	0.79
n-Heptane	0.97

- We find that the effect of evaporation on droplets' trajectories is **negligible**



NG<1
(10 microns)



NG~5
(70 microns)

Due to the coupling between size and the grouping phenomena, the evaporation rate of various droplet - sizes become closer.

Hence, when we have an oscillating flow, the optimized size distribution is not necessarily the one with the smallest droplets (or smallest SMD) !

This may affect the design of the injectors of ICEs and the combustion efficiency, and thus emissions

Once a grouping or a non-grouping mode of behavior has been established,

evaporation does not change this behavior as time passes, or

in other words, “droplet’s history” determines a single mode of time-behavior.

THE INITIAL *NG* IS THE KEY FACTOR

To summarize

Such an analysis is aimed at:

- defining the operating conditions that will minimize fuel spray grouping in ICEs.
- pointing out the optimized droplet size distribution

Thus, maximizing evaporation, leading to a more homogenous mixture and

enhancement of the desired auto-oxidation in ICEs .

A preliminary paper on the mathematical basis (without evaporation) will soon appear in the Journal *Atomization and Sprays*

“Aerosol Clustering in Oscillating Flows – Mathematical Analysis”

By: David Katoshevski, Zusia Dodin and Gennady Ziskind