Induced Particle Grouping and Coagulation in Diesel Exhaust

Itamar Hite, Michal Ruzal Mendelevich, Tal Shakked,
Prof. Eran Sher and Prof. David Katoshevski

Ben-Gurion University of the Negev
Beer-Sheva, Israel

IAAR 23rd Annual Meeting
February 10, 2010

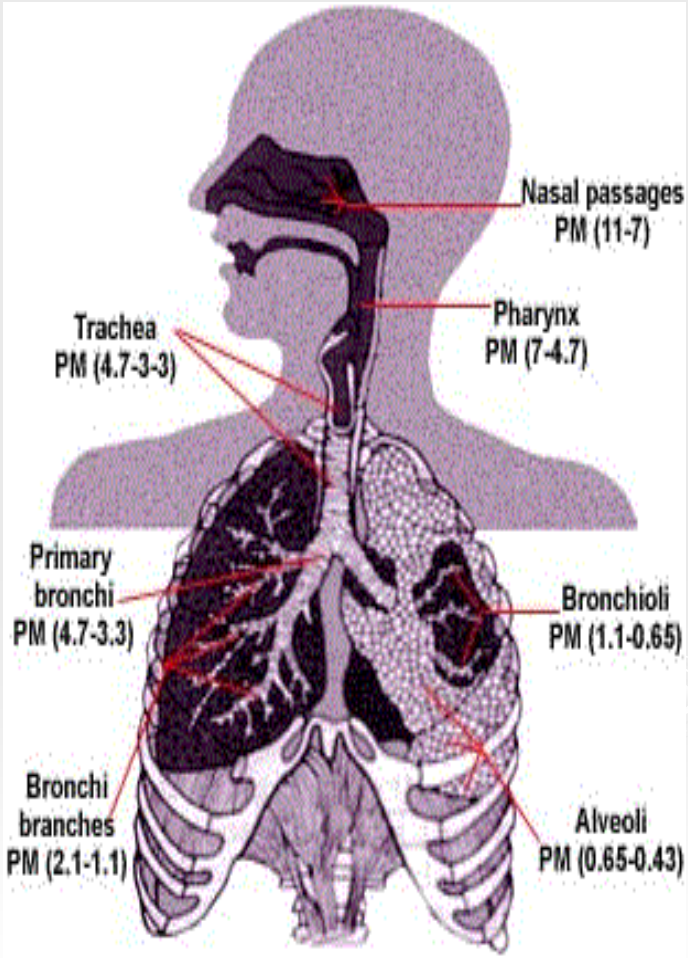
Reduce Air Pollution

Decreasing the sub-micron and microns particles (PM)

- Small particles have two main aspects:
  - Penetrate into the respiratory system
  - Residence time in the air

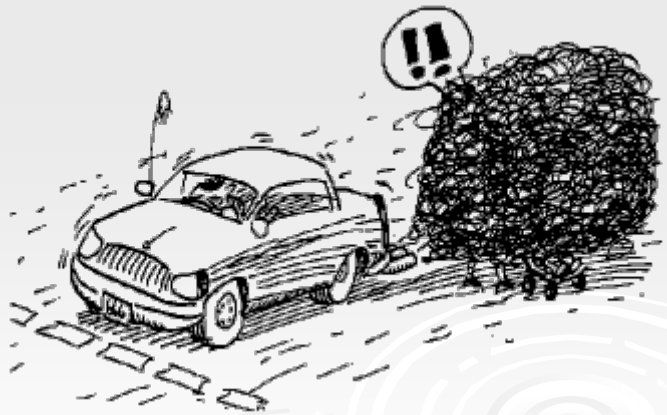
$$U_t \propto D_p^{\,2}$$

1 micron particle will stay **100** times longer that **10** micron

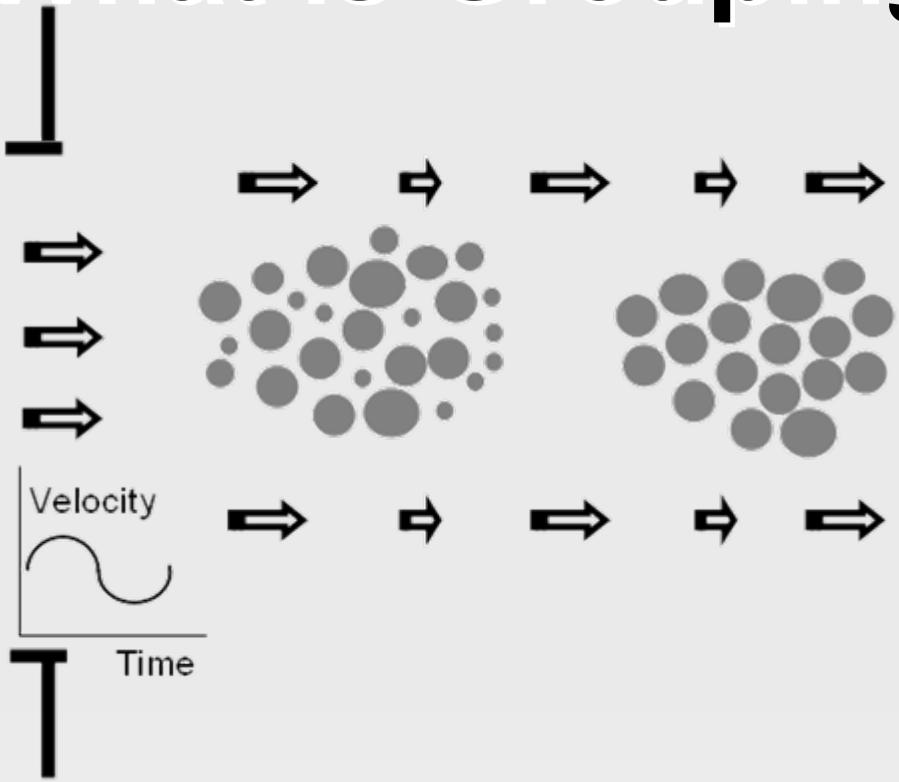


Reduce Air Pollution

- Larger particles are:
  - Able to filtrate
  - Stay shorter time in the air
  - Have a lower penetration potential into the respiratory system



What is Grouping?



The grouping phenomena was examined and proven itself in systems like:

-Suspended sediment in tidal channels.

-Fuel spray in flame.

1D Model for a Standing Wave Velocity Field

$$\ddot{x}^* = \frac{1}{St}\left(U^* - \dot{x}^*\right)$$

$$U^* = U_a^* - U_b^* \cos(x^*)\left(\sin(t^*) + C\right)$$

x^* – Particle position

St – Stokes number

U^* – Flow velocity

U^*_a – Average velocity

U^*_b – Amplitude velocity

$C(>1)$ – Constant

* asterisks denote dimensionless parameters

1D Model for a Standing Wave Velocity Field

$$\ddot{x}^* + \frac{1}{St}\dot{x}^* + \frac{U_b^*}{St}\cos(x^*)\left(\sin(t^*) + C\right) = \frac{U_a^*}{St}$$

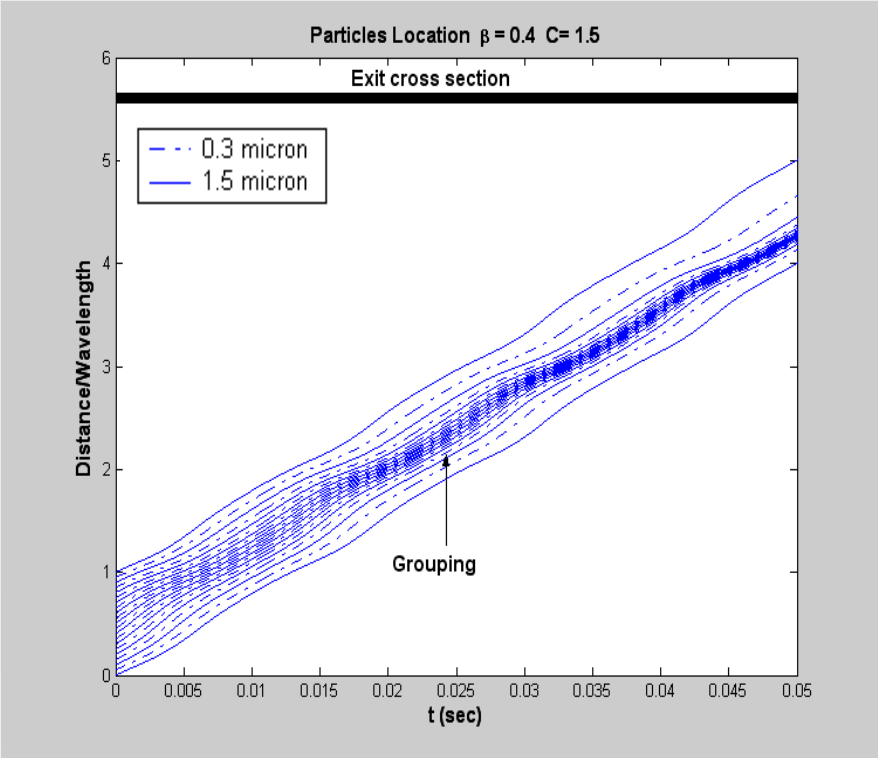
The creation of grouping is depands on $\beta = \frac{\left(U_a^* - 1\right)}{U_b^*}$

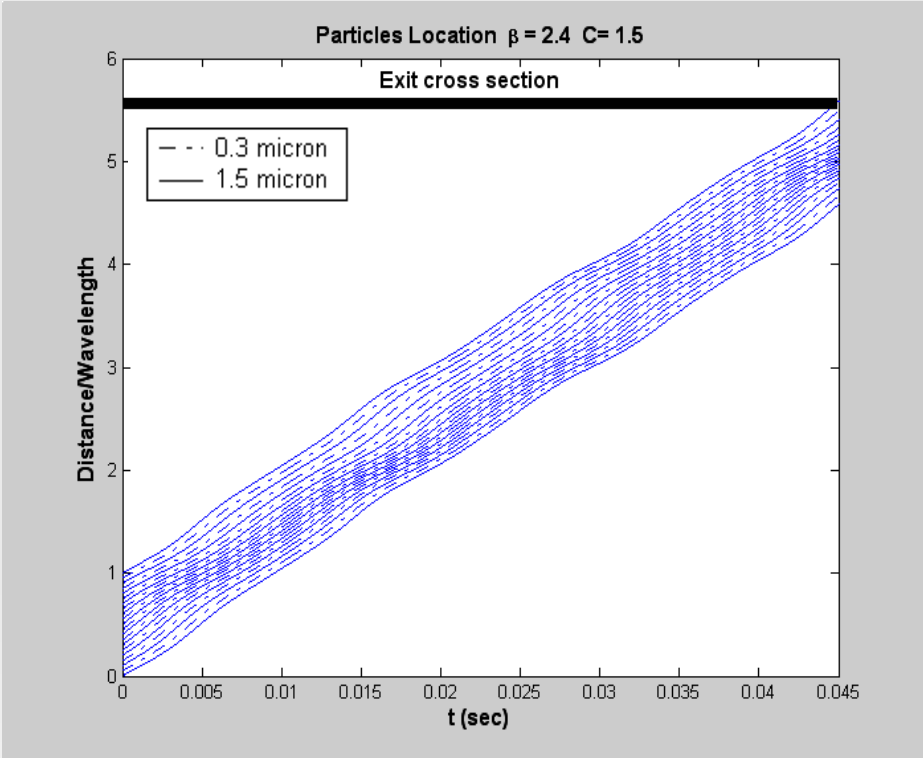
Stable Grouping $\beta<1$

Non-grouping $\beta>1$

Grouping also require $\alpha>>\beta$ when $\alpha = \frac{\sqrt{2}}{\sqrt{StU_b}}$

Stable grouping & Non-grouping





Stable Grouping β<1

$$\beta = \frac{\left(U_a^* - 1\right)}{U_b^*}$$

Non-grouping β>1

Building The Exhaust

The Standing Wave velocity field:

$$U^* = U_a^* - U_b^* \cos(x^*)\left(\sin(t^*) + C\right)$$

- The exhaust shape induce standing wave flow field
- For stable grouping the exhaust dimensions were planned to create β<1
- Every engine needs a different modified exhaust because the particles are emitted in a different velocity.

The Experiments

We control engine speed and engine load

Mitsubishi S3L engine

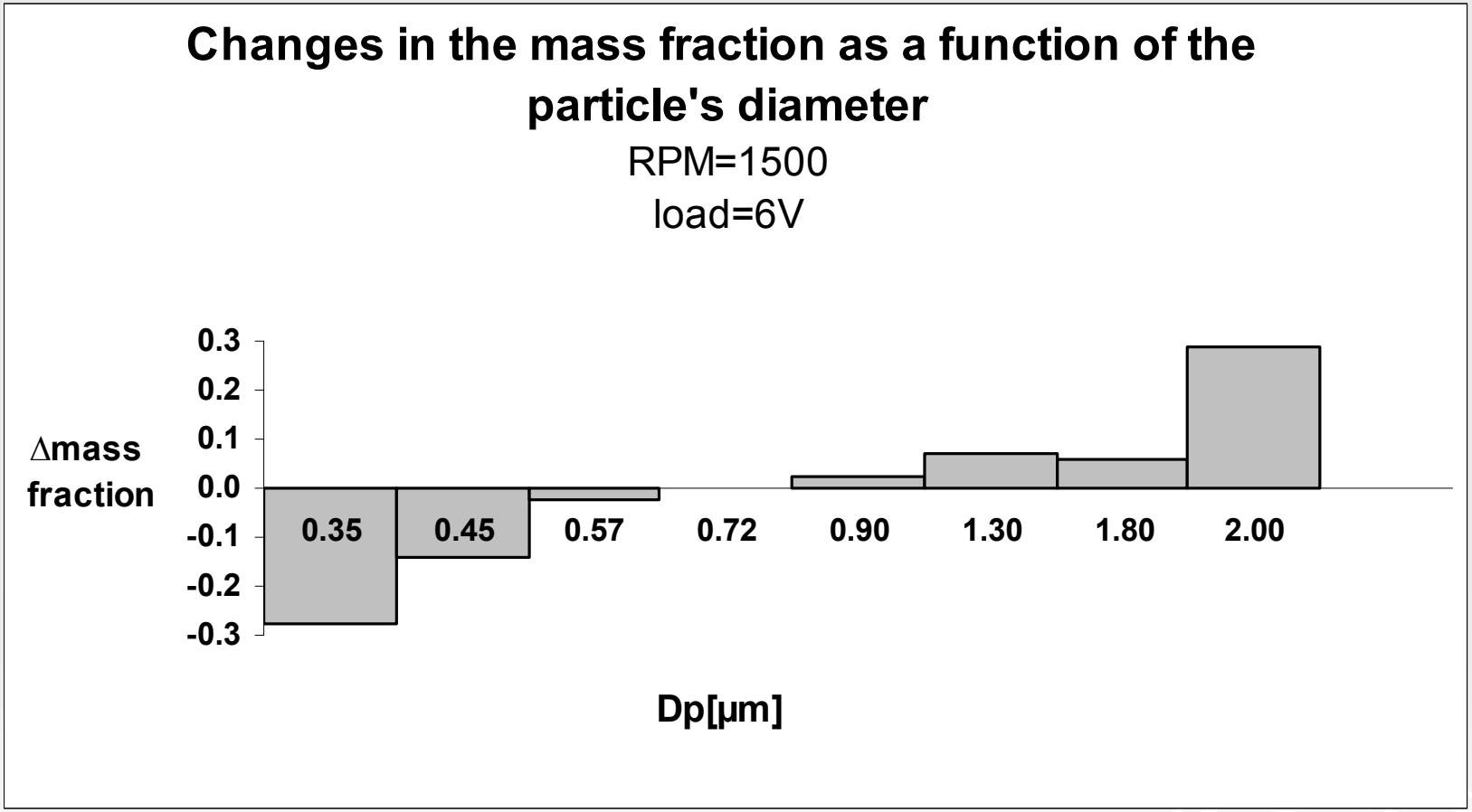
Three-cylinder, 4-stroke

Displacement volume: 1,125 cm3

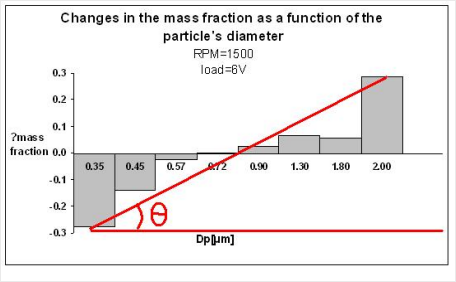
11.8kW at 1,500 rev/min

Size analyzer: SEMTECH PM-300. laser light scattering *300nm-2μm*

Results

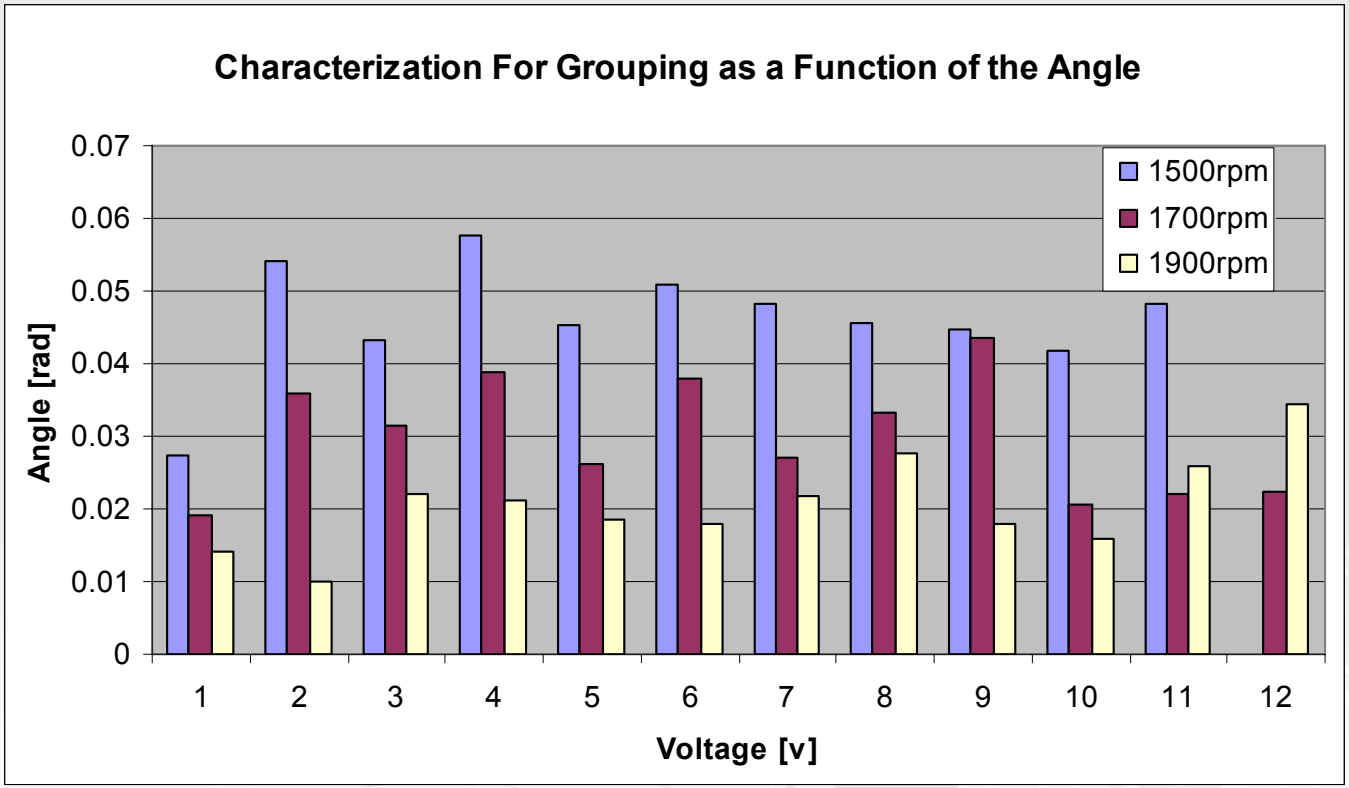


$$\Delta mass\_fraction = M_{\mathrm{mod}ified} - M_{reg}$$



Results

Comparing Operation Conditions

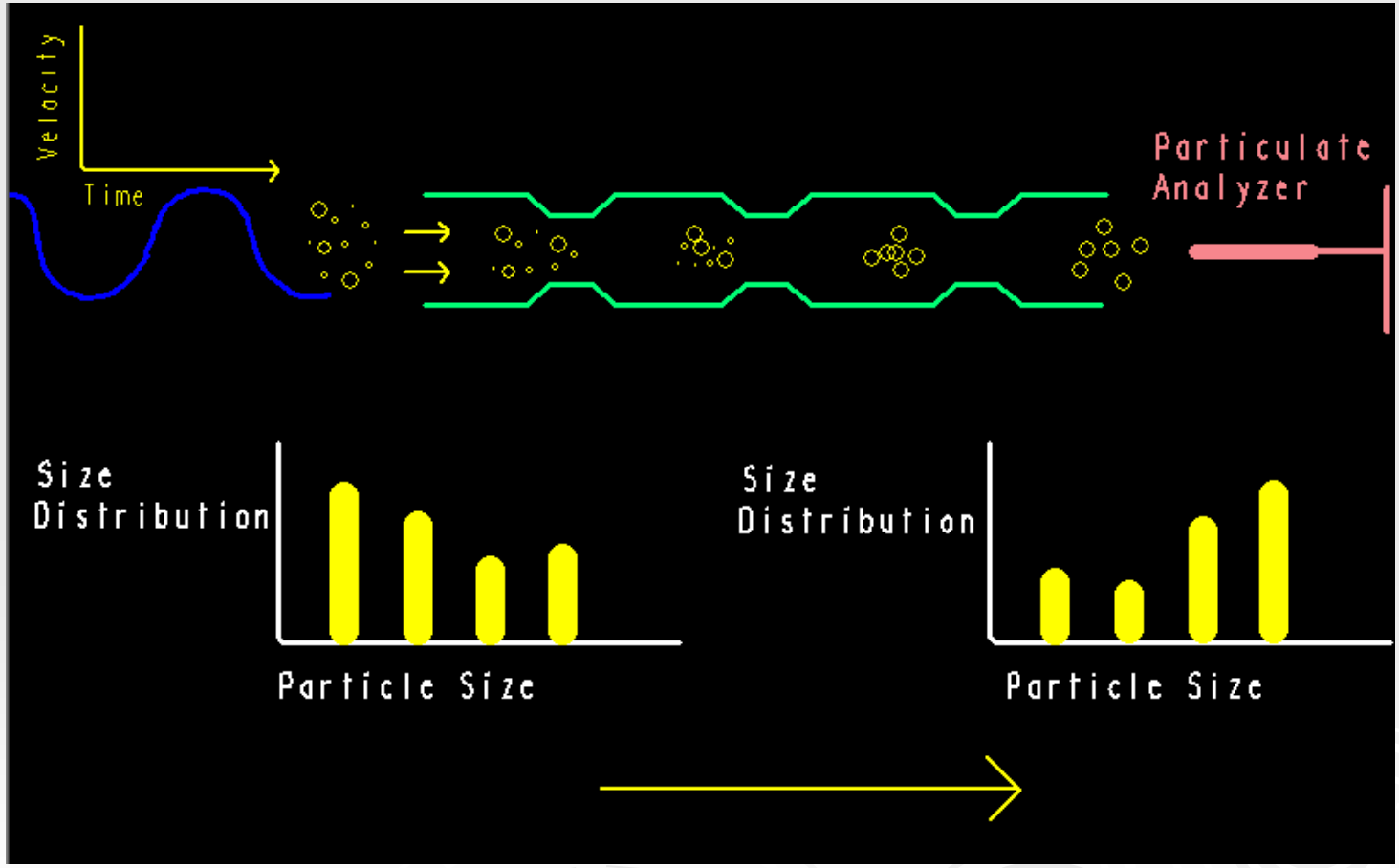


Influences of the Modified Exhaust on the Engine

- No significant change in fuel consumption
- Pressure loss negligible
- No significant decreasing in the engine power

Summery

System Schematics – Enhancing Grouping



Main Conclusions

- Grouping phenomena was observed in modified pipe.
- A new approach for reducing PM from exhaust systems.
- Grouping is more significant in the low values of speed engine.

Future Steps

- Improve the grouping
- Creation of grouping with combination of other wave fields (like acoustic waves)
- Using this concept of modified pipe to reduce pollution from other devices (forklift)

References

- Katoshevski D., Shakked T., Sazhin S., Crua C., Heikal M.R. (2008), Grouping and trapping of evaporating droplets in an oscillating gas flow, International Journal of Heat and Fluid Flow Vol 29, pp. 415–426

- Sergei Sazhin, Tal Shakked, Vladimir Sobolev, David Katoshevski (2008), Particle grouping in oscillating flows, European Journal of Mechanics B/Fluids Vol 27, pp. 131–149

- Winter C., Katoshevski D., Bartholomä A., Flemming B.W. (2007), Grouping dynamics of suspended matter in tidal channels, J. of Geophysical Research, Vol 112, 003423JC10.1029/2005:ido ,08010C

- Katoshevski D., Dolin Z., Ziskind G. (2005), Aerosol clustering in oscillating flows: mathematical analysis, Atomization and sprays, Vol 15, pp. 401-412

Questions?