Qualification of particle surface probe: Requirements and development of a test bench

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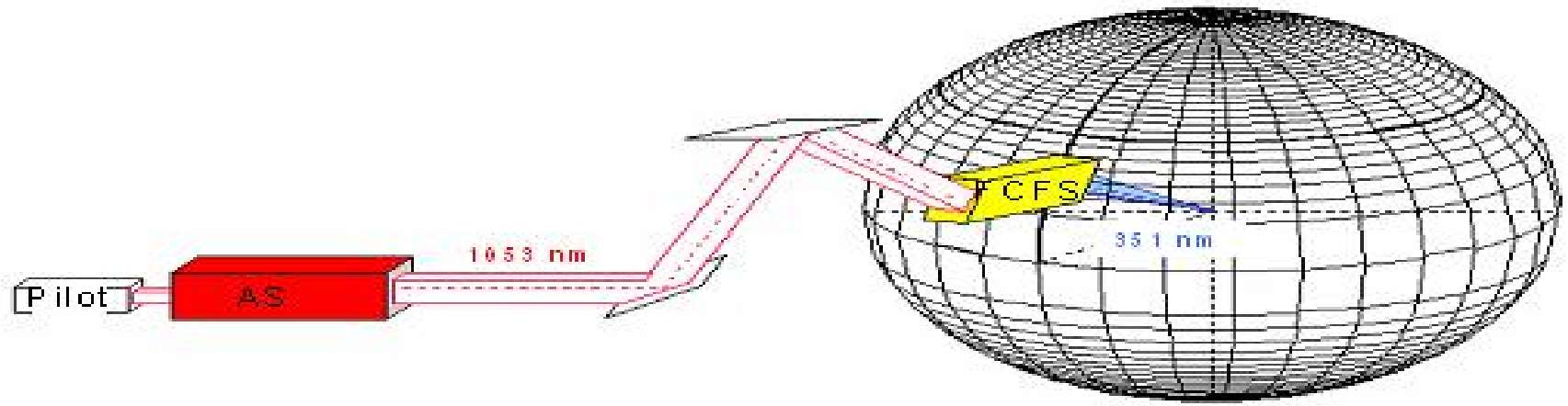
Context and Objectives

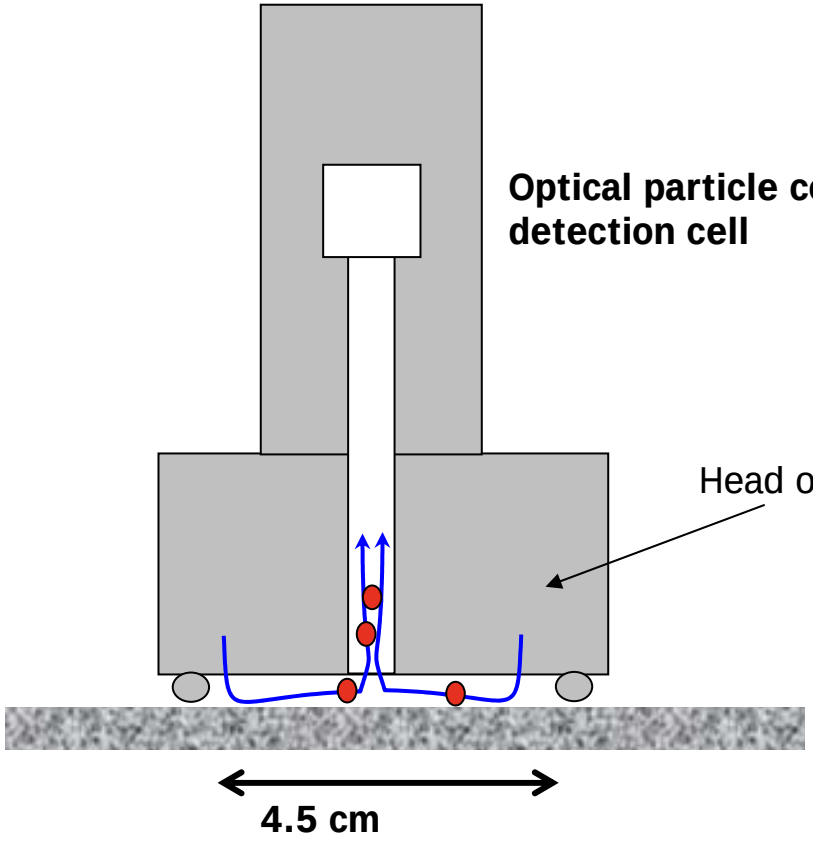
- *Surface cleanliness control of the Mega-Joule Laser components.*



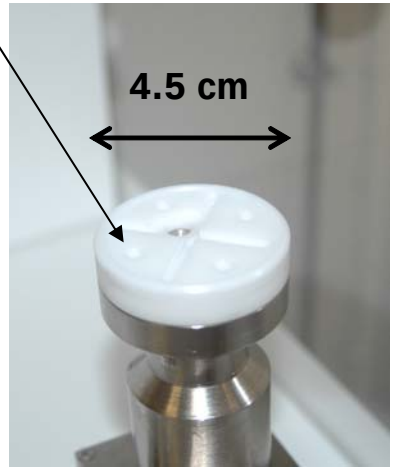
- *Need for industrial device such as surface probes for surface cleanliness control according to STD1246D or the future ISO14644-9.*
- *Development of a test bench and a methodology for the qualification of surface probes.*
- *Qualification of a commercial surface probe based on airflow particle removal coupled with an optical particle counter.*

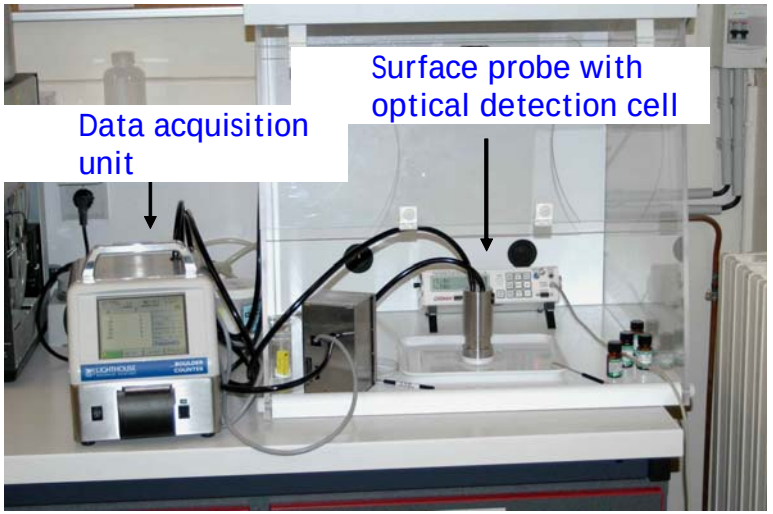
Surface probe tested

The device uses the particle counter's flow-rate which is injected in the probe to allows re-suspension and sampling of particles deposited on surfaces.



: particles on the surface





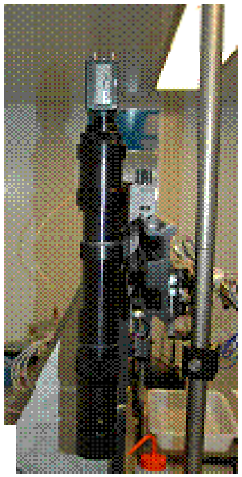
Method

Laser Mega Joule requirements (STD-1246D)

Size range : 5 µm to 100 µm.

Concentration range : 1 to 1780 particles/100 cm².

Computer image acquisition



Microscope coupled with CCD camera

Proposed method :

Particle surface deposition by settling of monodisperse glass beads.

Reference surface concentration is determined by a manual counting of the particles on photographs of the totality of the surface taken with a microscope

(768 photographs for a 4.5 cm diameter disc surface).

Light source

X Y micrometric displacement table

Method, step by step :

Step 1 : Cleaning of the tested surface (alcohol + special tissue + clean air-flow).

Step 2 : Application of the probe on the surface, 3 successive measurements with sampling time equal to 20 s ⇒ verification of background counting equals to 0.

Step 3 : Particle surface deposition by sedimentation of monodisperse glass beads.

Step 4 : 1st measurement of the reference surface concentration by scanning the surface with a camera coupled to a microscope (768 photographs for a 4.5 cm diameter disc surface).

Step 5 : Application of the probe on the surface, 3 successive measurements with sampling time equal to 20 s.

Step 6 : 2nd measurement of the reference surface concentration (always 768 photographs for a 4.5 cm diameter disc surface).

Step 7 : data analysis.

All the experiments are carried out in a clean room (ISO 8) controlled in moisture (32 % to 38 %) and temperature (20°C to 22°C).

Studied parameters

Two types of surfaces are tested :

- *glass surface,*
- *anodic aluminum* **surface** *with low roughness.*

Two particle diameters are studied :

- *glass beads of 30 µm,*
- *glass beads of 80 µm.*

Experiments are carried out with weak surface concentrations in order to be representative of Laser Mega Joule requirements and to avoid a phenomenon of re-suspension by particle saltation.

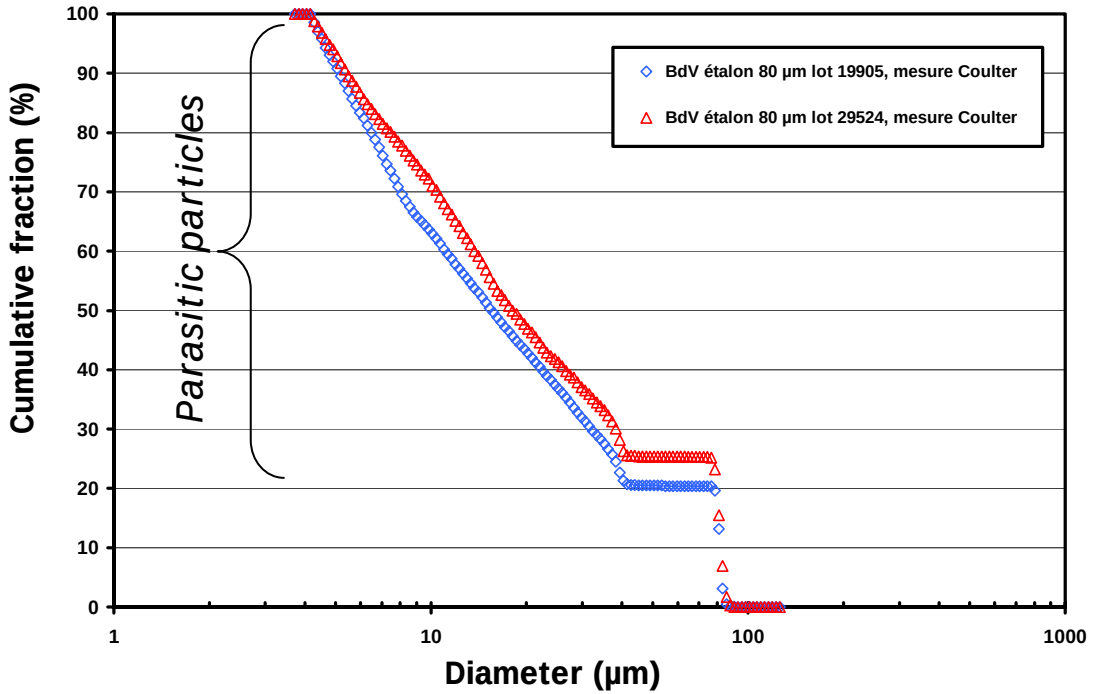
Each experiment is repeated at least 3 times.

Characterization of the particles used

Use of standard spheres (glass beads) certified by NIST

Checking of the size distribution

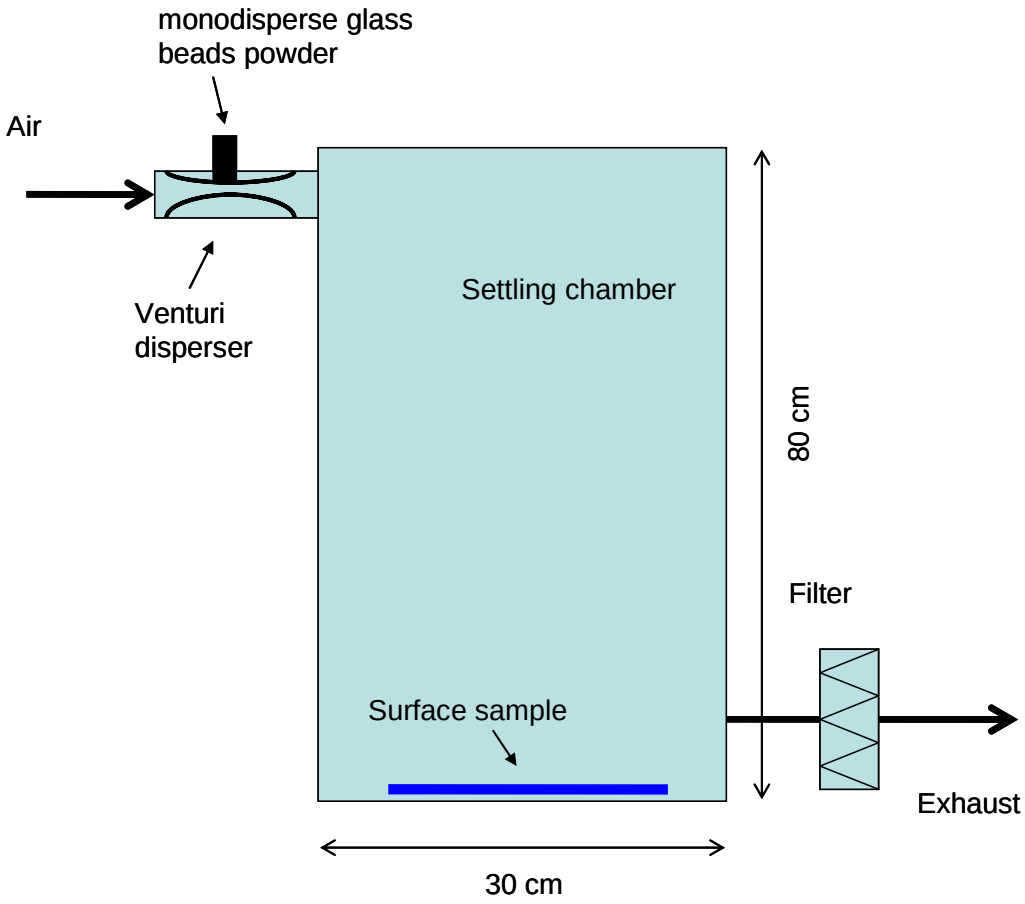
Cumulative size distribution of 80 µm monodisperse standard glass beads (measured with a Coulter Multisizer)



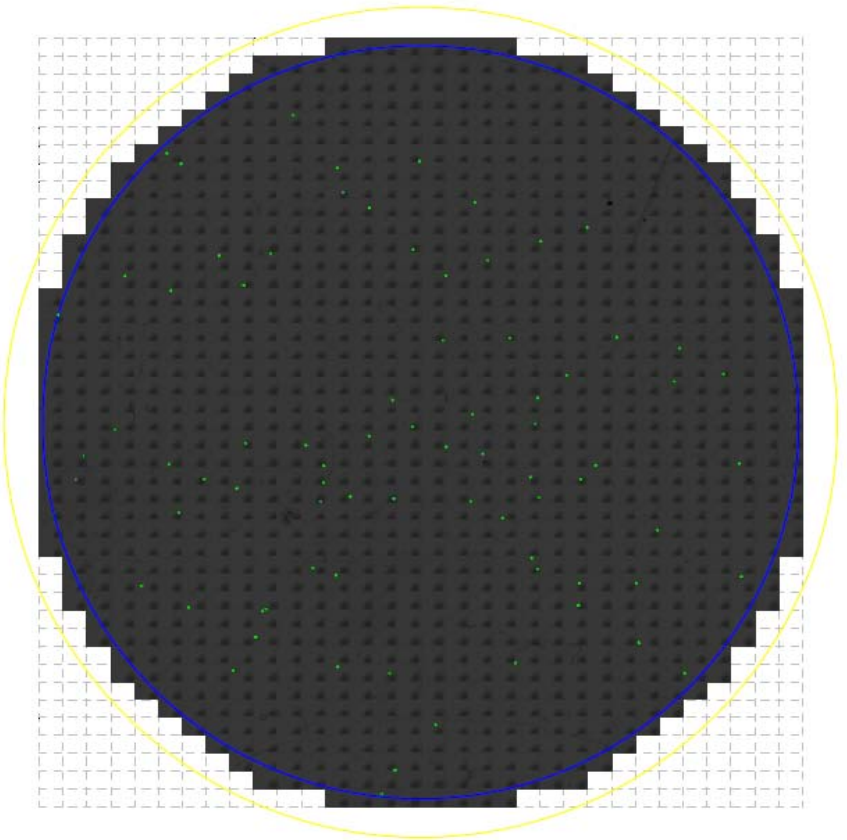
Presence of a considerable number of parasitic particles with diameters lower than 40 µm.

⇒ This fact must be taken into account for the data analysis made with the instrument to test (selection of appropriate channels of the optical particle counter).

Particle deposition : settling chamber



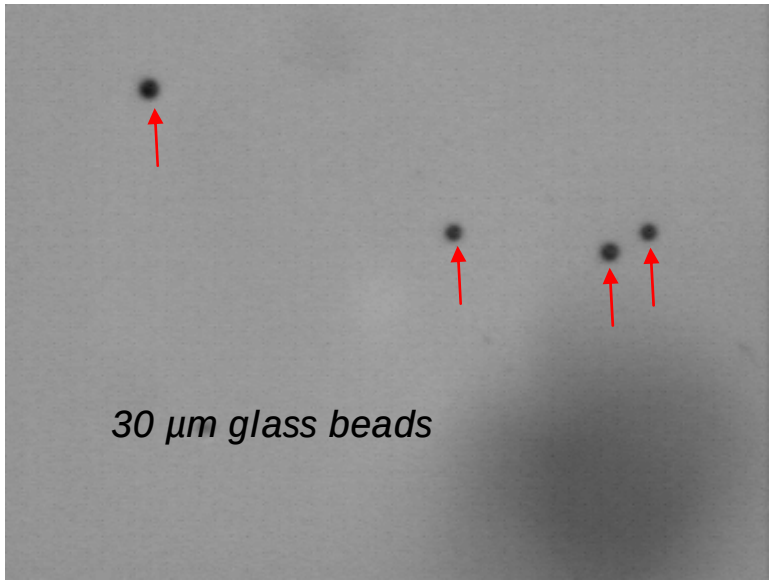
Mapping of particles deposit

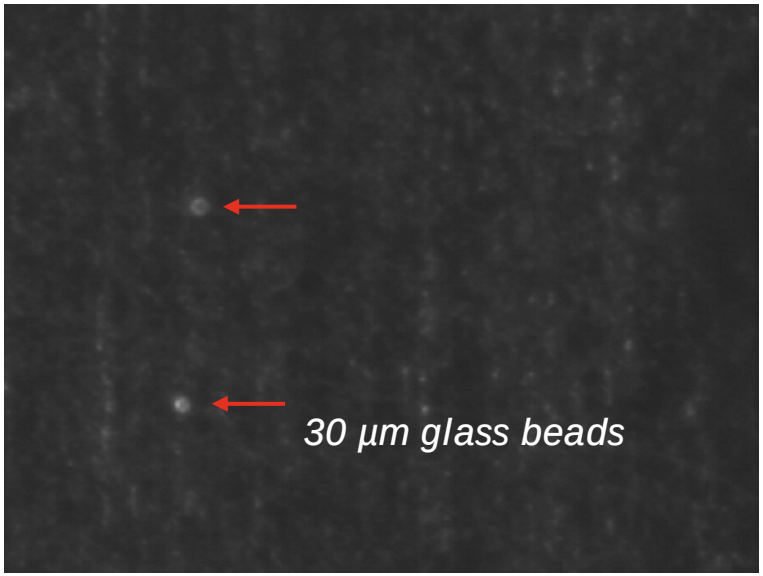


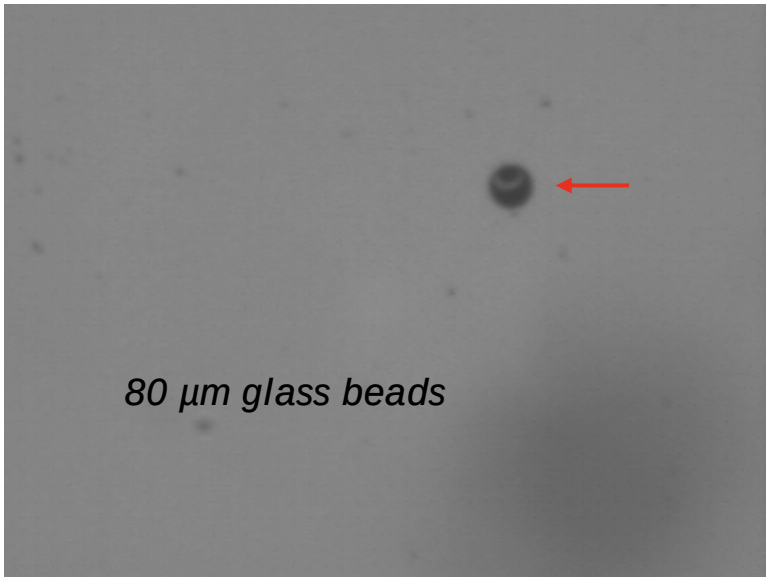
Homogeneous surface concentration on a 4.5 cm diameter disc (768 photographs analysed !)

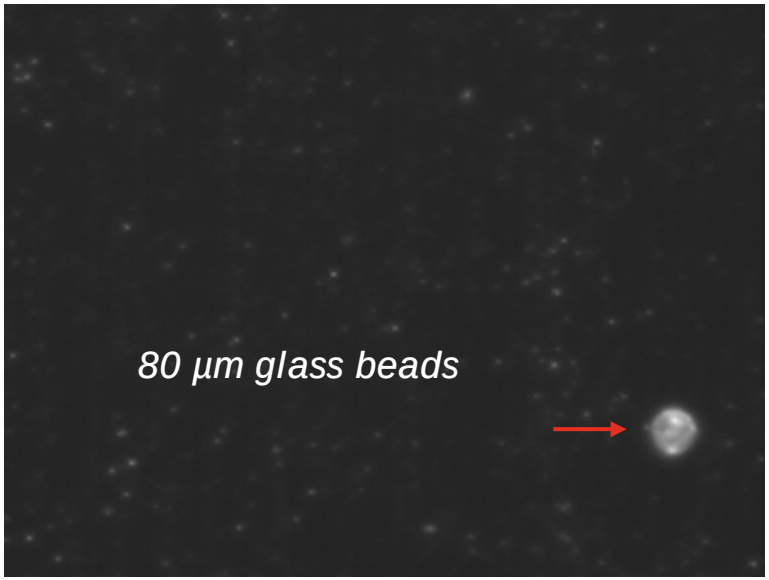
Glass surface

Anodic aluminum surface









Expression of the results

The totality of the surface is photographied with a camera coupled to a microscope; one thus obtains 768 photographs for a surface 4.5 cm in diameter.

On each photograph the particle number is determined manually before and after the application of the surface counting probe.

$Eg = N_{probe} / N1_{ref} \times 100\ (\%)$ — *global efficiency of the instrument.*

$Ed = (N1_{ref} - N2_{ref})/N1_{ref} \times 100\ (\%)$ — *re-suspension efficiency.*

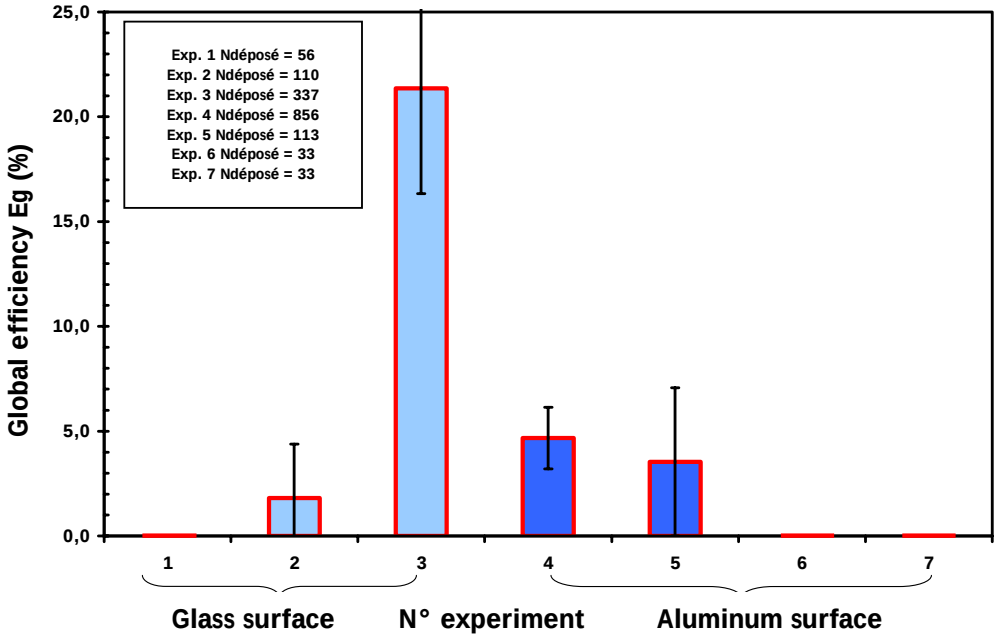
N_{probe} *: particle counting by the instrument on appropriate channels.*

$N1_{ref}$ *: counting of the particles on photographs before the probe measurement.*

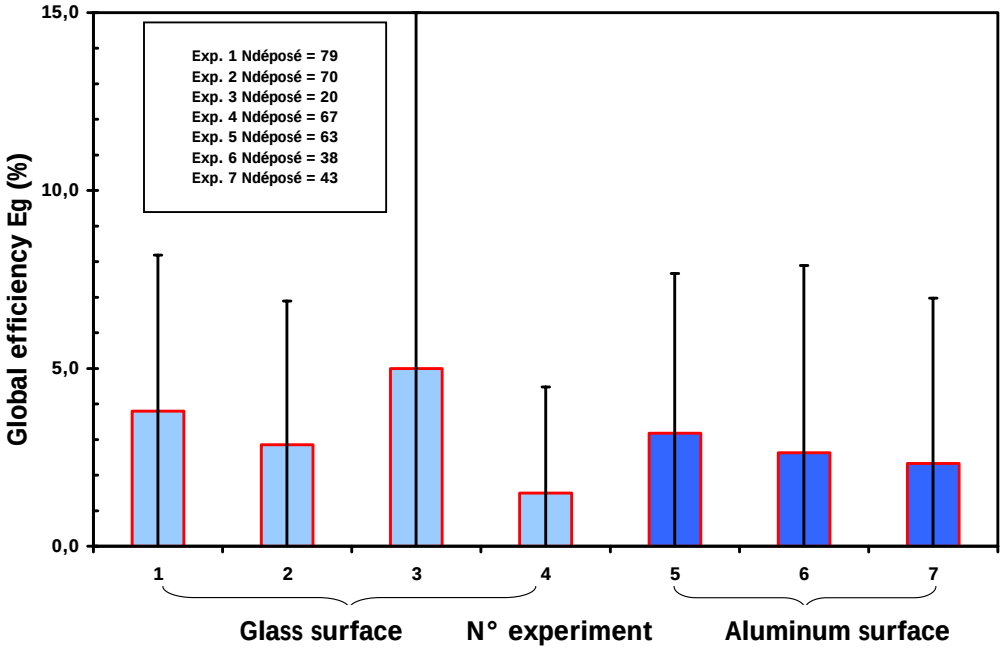
$N2_{ref}$ *: counting of the particles on photographs after the probe measurement.*

Results : global efficiency Eg

30 µm glass beads particles, number deposited ranging from 33 to 856 on 16 cm²

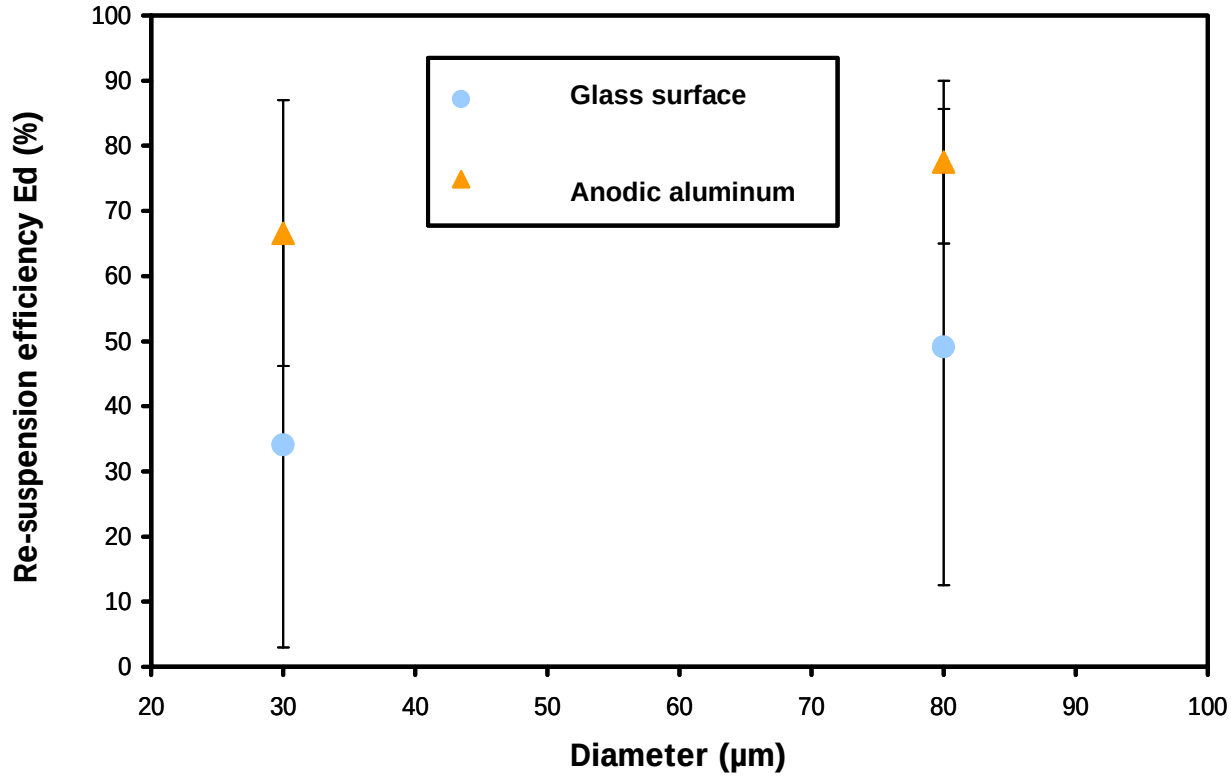


80 µm glass beads particles, number deposited ranging from 38 to 79 on 16 cm²



Global efficiencies are under 5 % for the 2 diameters tested (30 µm, 80 µm) and the 2 surfaces (glass, aluminum) excepted for 1 experiment.

Results : re-suspension efficiency Ed

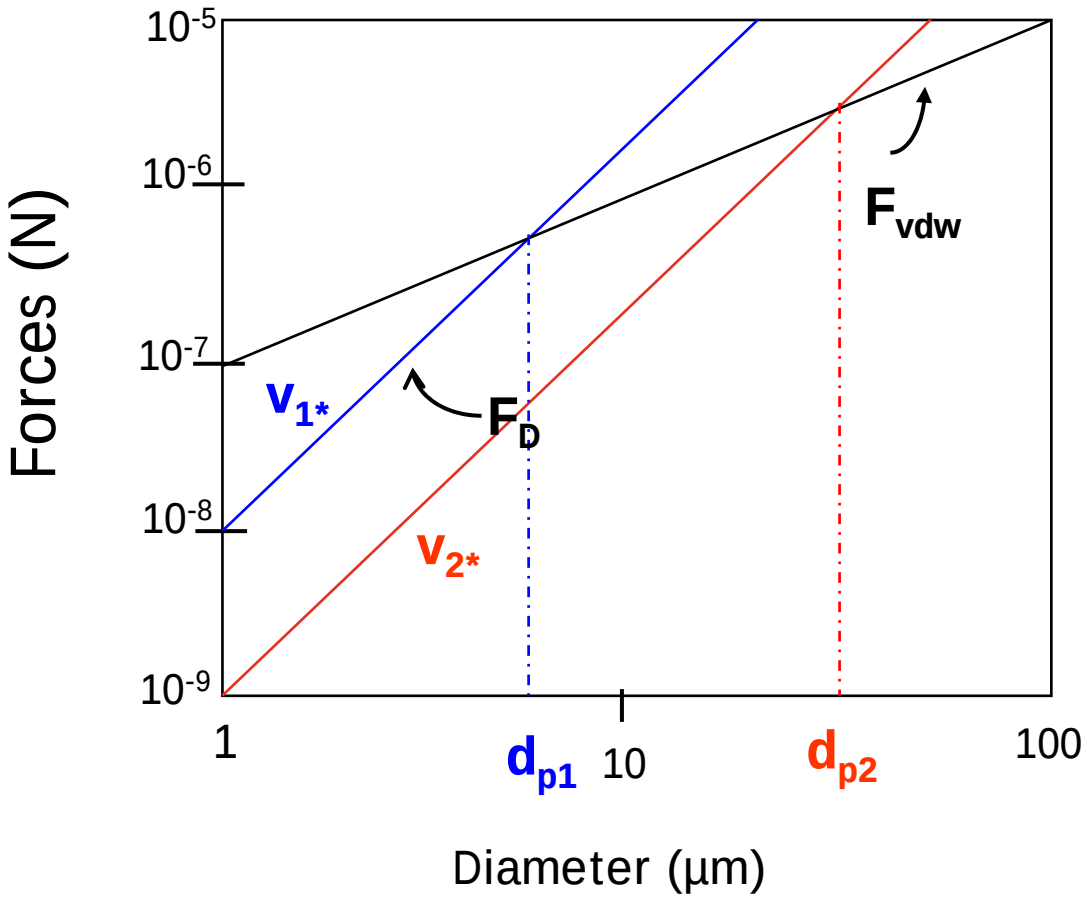


Re-suspension efficiency increases with particle diameter.

Re-suspension efficiency is more important for aluminum surface than for glass surface.

Results are consistent with air-flow particle re-suspension theory.

Comparison : adhesion force vs aeraulic force



Adhesion : Van der Walls force

$$F_{vdw} = \frac{A\, d_p}{12\, z^2}$$

A : Hamaker constant

z : particle surface distance (0.4 nm)

Aeraulic : drag force

$$F_D = 8{,}02\ \rho\, v_*^2\, d_p^2$$

ρ : gaz density

v_* : friction velocity

dp : particle diameter

When the diameter increases, the force of Van der Walls increases ($\propto d_p$), but the aeraulic force increases more quickly ($\propto d_p^2$) what shows that it is easier to take-off the large particles.

Conclusion

- *The method proposed allows reliable measurement to test particle surface counting instruments.*
- *Nevertheless the method is tiresome and expensive in time.*
- *The surface probe tested shows a bad global efficiency for 30 µm and 80 µm glass beads particles.*
- *The re-suspension efficiency depends on the particle diameter and the nature of the surface. Those results are consistent with theoretical approach.*
- *The re-suspension efficiency ranging from 35 % to 75 % can't explain the bad global efficiency (5 %) ⇒ there is probably a bad counting efficiency(optical counter) of re-suspended particles in the instrument tested.*
- *Need to calibrate all the commercial surface probe by this reference method before use.*