Development of optical trajectography device for the lagrangian study of the turbulent flow inside a stirred tank used in pharmaceutical industry

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Introduction

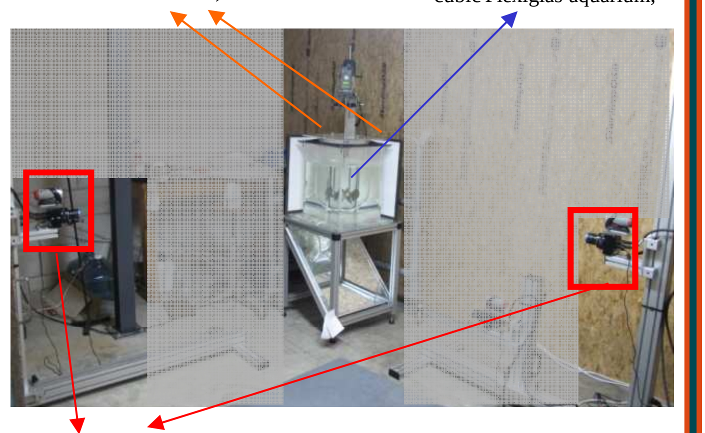
Performance of various processes used in pharmaceutical industry (animal cell culture, crystallization, flocculation) strongly depends on the physico-chemical and hydrodynamic environment present locally in the stirred tank. The classical approach which consists in describing the local environment by an Eulerian approach is not sufficient to predict the impact of agitation conditions on process performances. Indeed, this kind of approach gives access to the spatial distribution of quantities such as fluid velocity, turbulent kinetic energy dissipation rate or concentration which is important information, but it does not give any information on the temporal succession of local physico-chemical and hydrodynamic conditions met by a particle (cell, crystal, floc) and on the time spent by this particle in each condition, whereas this information is also crucial. This kind of information can only be determined by an Eulerian - Lagrangian approach which consists in describing the trajectory followed by the particle and superimposing it on Eulerian fields in order to establish the history of conditions met by the particle**.**

To be able to determine the trajectory followed by a particle, the Chemical Laboratory of Liege University has developed, in collaboration with the Walloon Center of Industrial Biology, its own prototype of optical trajectography device. The objective of this poster is to present the device, developments that were necessary for its use and the results obtained.

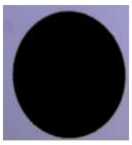
Devices

2 Back-lights (white athermal led, 50x50 cm, Phlox)

20 L glass made cylindrical tank, cubic Plexiglas aquarium,



2 Cameras CMOS Falcon 4M60 (Dalsa, 60 Hz, 2352x1728 pixels)
To measure the position (in pixels) of the particle in the images



A spherical bead made of **calcium alginate gel** in which is encapsulated :
Active carbon to give it a black color
Paraffin oil to ajust it density to 1.028
Mean diameter: 491 µm
➔ **perfect tracer (**Stokes number=0.03)

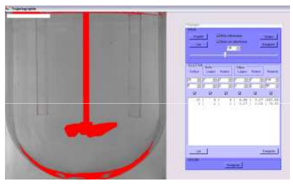
Developments

Models to link positions of the particle in images (pixels coordinates) to its positions in space (meter coordinates)

The relative position of the cameras in space and the images distortions due to cameras lenses are determined by adjusting the parameters of the pinhole model. The pinhole model links to each image pixel a set of points that are aligned along a straight line in the 3D space. The position (X,Y,Z) of the particle is determined by computing the intersection of the two straight lines thus determined. Corrections due to light ray refraction onto materials composing the tank are taking into account in the model.

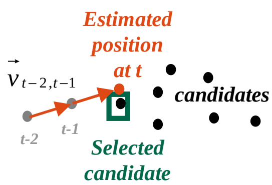
On line treatment of images

To efficiently manage the size of data files, images are analyzed on-line during their acquisition by a software program which selectively records the position of pixel groups the size and the color of which suggest they might be the particle



Sorting algorithm

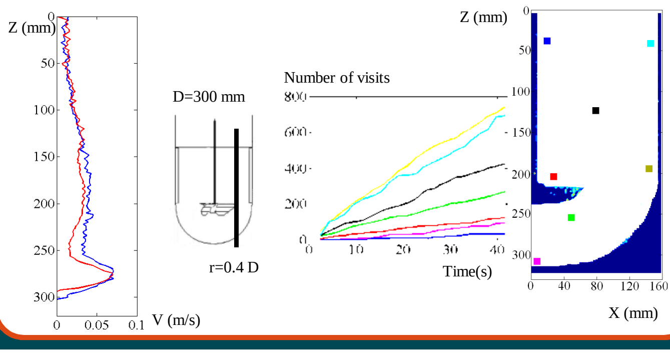
As several objects are detected on each image, an algorithm has been developed to identify the particle among these objects. Objects localized outside the tank are firstly eliminated. Remaining objects are then analyzed on the basis of kinematic considerations knowing previous positions of the particle, thus its instantaneous velocity and acceleration.



Validation

The measured trajectory has been validated by comparing average time velocity fields deduced from it (blue) to those measured, in the same operating conditions, by particle image velocimetry(red).

A very good agreement is observed provided the trajectory acquisition time is large enough. Indeed, some zones of the tank are frequently visited because the number of visits rises rapidly with time. It is not the case of some other zones. Therefore, acquisition time as long as 40 hours is required to allow the particle to perform a large number of visits (more than 30) in all zones of the tank and thus to obtain converged results in the whole tank



Conclusion

The prototype of optical trajectography device elaborated by the Chemical Laboratory of Liege University is nowadays fully operational and the measured trajectories have been validated.

They may then be superimposed on an Eulerian field, the turbulent kinetic dissipation rate measured by P.I.V, for instance, to study the temporal succession of local hydrodynamic conditions met by the particle as a function of agitation conditions. The superposition of the both is a signal that strongly fluctuates with time. It can be analyzed by classical tools of signal processing to determine for instance at which frequency the particle is subjected to a given level of turbulent kinetic dissipation rate and the time the particle spends at this condition at each visit