Postdoctoral Position (January 2021-March 2022)

Title: Digital twins and image analysis
for the geometrical characterization of crystallization processes

Host institution: Ecole Nationale Supérieure des Mines de Saint-Étienne (MINES Saint-Etienne), FRANCE
SPIN / LGF, UMR CNRS 5307
Salary (net): ~1800-2000 euros/month (depending on experience)
Candidate profile: PhD in image analysis
Contact: Johan DEBAYLE (debayle@emse.fr)
Duration: 14 months (start date can be changed)

Description

- **General context**

Crystallization, a unitary operation in chemical engineering consisting in isolating a product in the form of crystals, is both highly complex and of vital economic importance. 25 to 30% of the turnover of the chemical industry is made with products obtained in processes involving at least one stage of crystallization or precipitation. This percentage rises to 75 to 80% for manufacturing processes for active ingredients in the pharmaceutical or agrochemical industry.

Nevertheless, crystallization operations are today still managed in a rather rudimentary way and show recurrent problems of malfunctions (fouling, mechanical problems of the equipment, errors in sensor measurements...). In addition, there is a real need for knowledge of the granulometry of the solid. Indeed, this has a significant impact on yields and subsequent separation operations.

The overall project aims to revolutionize the operation and maintenance of batch or continuous industrial crystallizers thanks to the contribution of digital technology and the important advances made in recent years in the development of new industrial measurement technologies.

In terms of industrial measurements, in addition to "conventional" sensors, acoustic and vibration sensors will be provided for mechanical monitoring of the process support equipment and innovative online analysis technologies (camera, acoustic emission, SRS spectroscopy) will be evaluated and developed for access to the characteristics of the solid (granulometry in particular).

Sensor information will be collected, stored and analyzed (intelligent and multivariate analysis) in a computer platform which will also contain a digital twin of the crystallization operation. Comparison of the data with the model will enable the operation to be maintained in operational conditions, process optimization and predictive maintenance.

- **Objectives**

In this general context, the objective of this postdoctoral work will be to characterize size and shape distributions of crystals from images.

Indeed, image acquisition and processing is an alternative to laser measurements for the determination of particle size and shape distributions with clear advantages as the measurement is performed over time and in situ without the need for sampling, which is a major problem as sampling often changes the characteristics of the crystals.

As far as image processing is concerned, advances in the visualization method are needed to go beyond dilute media and use it for studies in media with high crystal content, a general case of industrial crystallizers. In this case, classical image analysis techniques do not easily allow individualizing crystals in agglomerates or when they are superimposed (2-D image acquisition only gives access to the projection/shadow of the crystals). It is therefore necessary to develop more sophisticated and application-specific methods to characterize crystal size.

In order to extract the size and shape distributions of the crystals, advanced image processing methods will have to be developed and studied. Indeed, when the density of crystals is important, clusters or superimposition of crystals appear in the images (see Figure 1). Therefore, conventional image processing techniques do not allow for individualization of the crystals. To overcome this limitation, specific methods of mathematical morphology and/or stochastic geometry will then be developed in this project in order to characterize the geometry (size, shape) of these crystals.

These methods can be validated on simulated model populations.

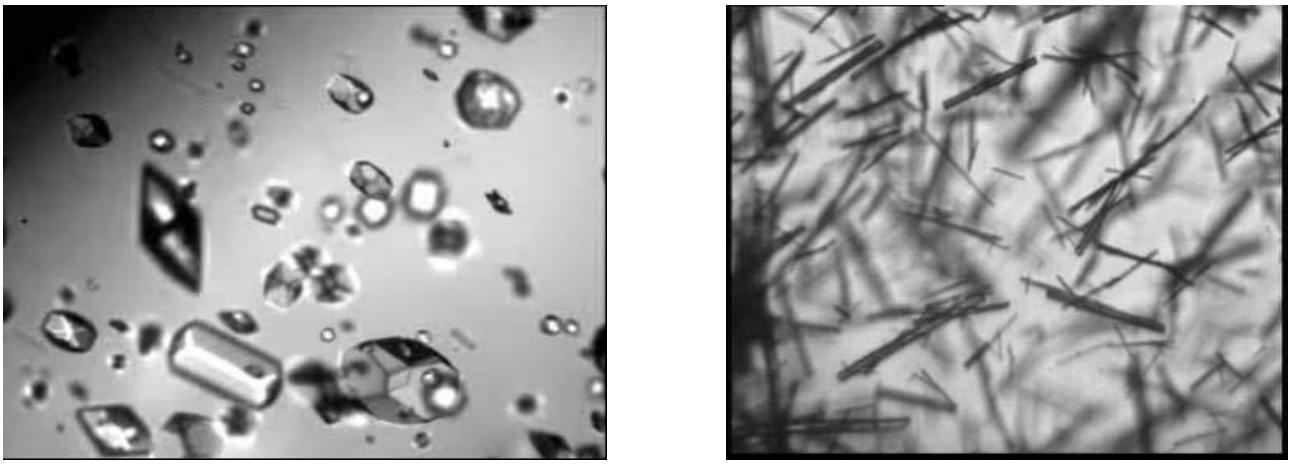

Figure 1: Examples of crystal images from Manuel Henry's PhD: "Development and application of in-situ analysis techniques for monitoring industrial crystallization", University Lyon 1, France, 2006.

References

[1] M. De Langlard, H. Al Saddik, S. Charton, J. Debayle, and F. Lamadie. An efficiency improved recognition algorithm for highly overlapping ellipses: Application to dense bubbly flows. Pattern Recognition Letters, 101:88-95, 2018.

[2] M. De Langlard, F. Lamadie, S. Charton, and J. Debayle. A 3D stochastic model for geometrical characterization of particles in two-phase flow applications. Image Analysis and Stereology, 37(3):233-247, 2018.

[3] O. Ahmad, J. Debayle, N. Gherras, B. Presles, G. Fevotte, and J. C. Pinoli. Quantification of overlapping polygonal-shaped particles based on a new segmentation method of in situ images during crystallization. Journal of Electronic Imaging, 21(2):1-12, 2012.

[4] B. Presles, J. Debayle, and J. C. Pinoli. Size and shape estimation of 3-D convex objects from their 2-D projections. Application to crystallization processes. Journal of Microscopy, 248(2):140-155, 2012.

[5] O. Ahmad, J. Debayle, and J. C. Pinoli. A geometric-based method for recognizing overlapping polygonal-shaped and semi-transparent particles in gray tone images. Pattern Recognition Letters, 32(15):2068-2079, 2011.