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Impact of spheroidization of UO_2 powders on the filling of press molds

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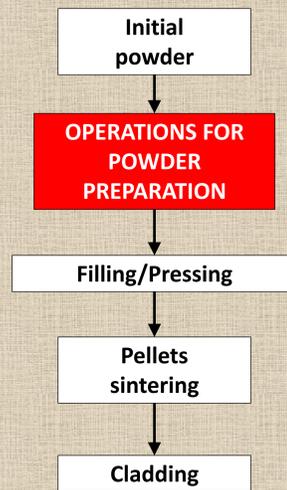
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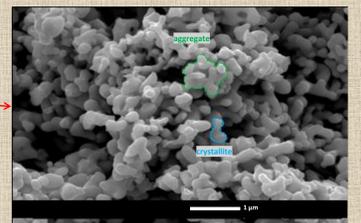
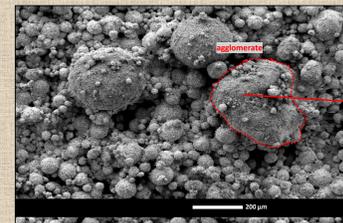
Background

The integrated technology demonstrator called ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration) is a sodium-cooled fast reactor (SFR) currently in design phase [1]. This reactor will use a fuel different to that of pressurized water reactors (PWR). SFR fuel has specific characteristics that require a suitable manufacturing process. Especially, suitable rheological properties are required for the powder feeding the press molds.

There is no standard and universal method to characterize the flow of powders [2], there are direct (shear cells) and indirect methods (dynamic flowability measurements like FT4 Powder Rheometer [3]). We use both methods: the shear cell measurement permits to determine the powder flow in quasi-static system whereas the VFR measurement shows the flow index in dynamic system.



A spheroidization operation could precede the shaping of pellets to improve the filling properties. In this study we observe the influence of particles morphology on the rheological properties of UO_2 powders. Different particle morphologies are investigated in order to obtain a 'good' filling conditions, i.e. homogeneity and reproducible filling. For that, the behavior of the studied powder needs to be well-understood. It cannot be characterized by a single index but by a combination of different tests.



SEM image (SE Mode), uranium dioxide (UO_2) powder

Materials

UO_2 mechanical granules have been manufactured in different ways. The particles are spheroidized by brewing in a mixer at high speed. For a better comparison and understanding, two particle size classes were made for each shape. The fines are particles smaller than 100 μm .

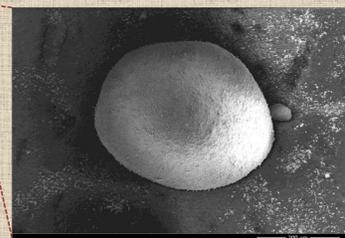
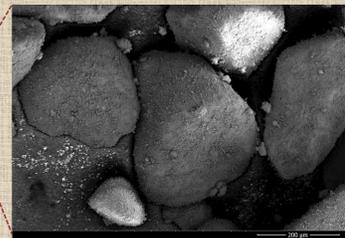
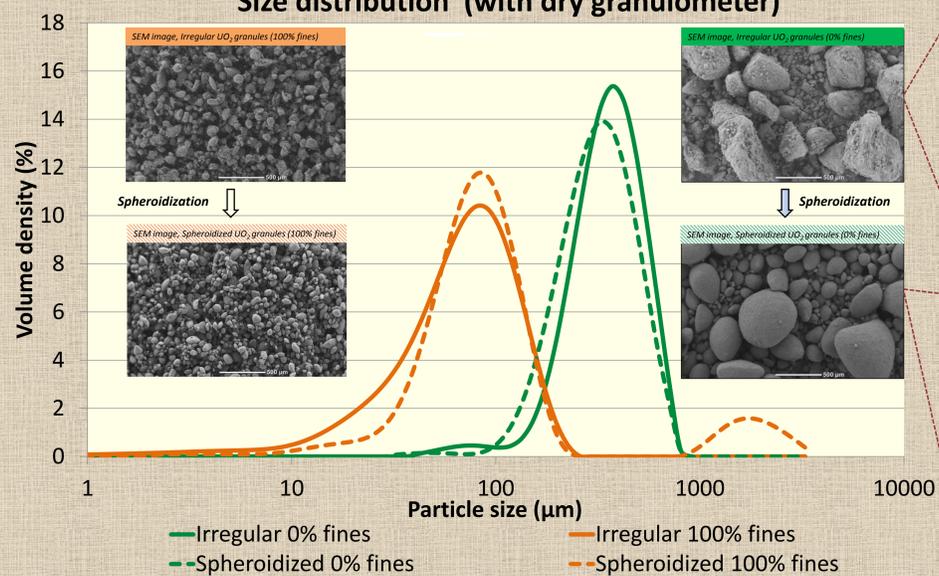
Four samples of UO_2 granules were manufactured:

- Irregular shape with 0% fines
- Irregular shape with 100% fines
- Spheroidized shape with 0% fines
- Spheroidized shape with 100% fines



Mixer

Size distribution (with dry granulometer)

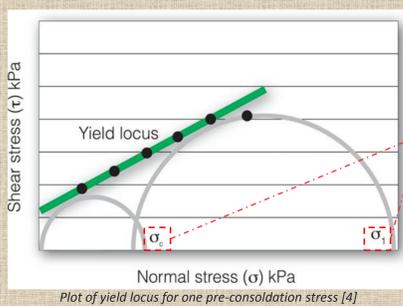


Transition state: static to dynamic

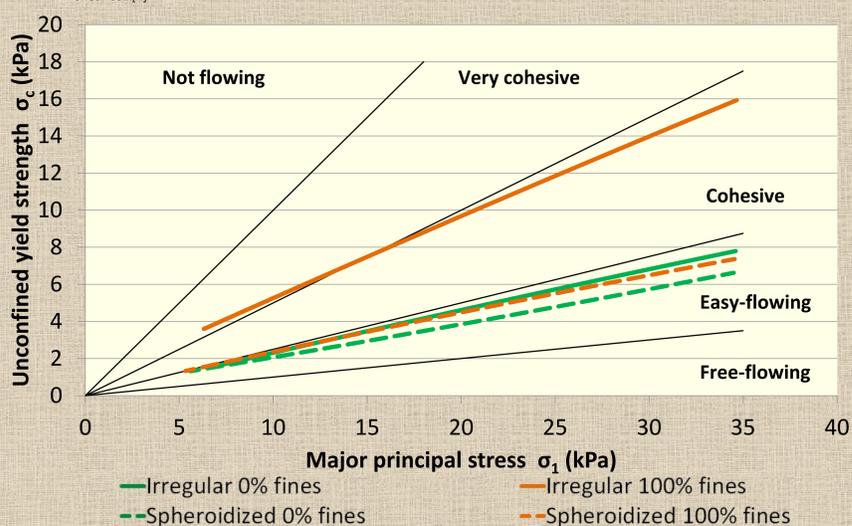
Shear cell



FT4 Powder Rheometer Shear cell [4]

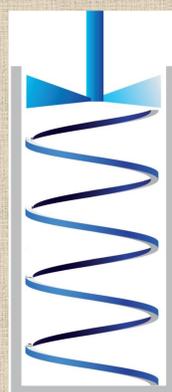


Several couples ($\sigma_1; \sigma_2$) to plot the flow function

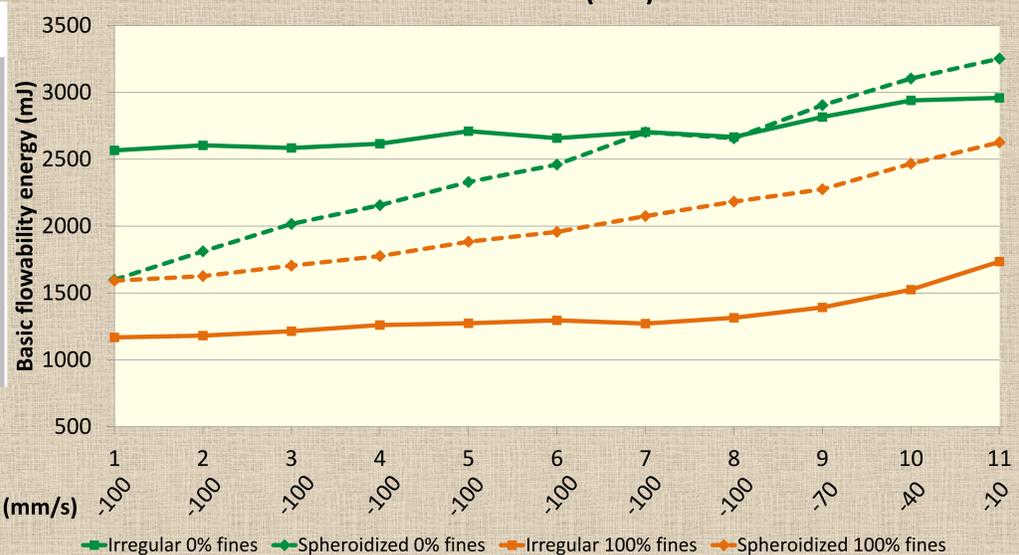


Dynamic state

Variable Flow Rate (VFR)



FT4 Powder Rheometer VFR test [4]



Spheroidization improves the transition from static to dynamic state and also the flowability during the dynamic state. However spheroidized particles are not stable, they evolve during the VFR test. In our study the VFR test modifies the state of the spheroidized powder to another one more stable.

Samples	Stability Index SI [test7/test1]
Irregular 0% fines	1,1
Spheroidized 0% fines	1,7
Irregular 100% fines	1,1
Spheroidized 100% fines	1,3

Conclusion

The degree of spheroidization of the granules has a strong influence on the flow. Spherical particles, whatever their size, seem to have the same behavior. Spheroidization of the particles improves the powder flowability but it does not allow to obtain stable powders. So this operation should be done just before the filling/pressing step.

Additional rheological measurements have also been carried out in order to better understand the behavior of the powder. Validation tests (pellets production) are to be done in order to verify the contribution of the preparation stage on filling's reproducibility (i.e. homogeneity) of the press molds.



Annular pellet

[1] Nuclear Energy Division Monograph (CEA), "Sodium-Cooled Nuclear Reactors", Le Moniteur, 2016

[2] P. Juliano, B. Muhunthan, and G. V. Barbosa-Cánovas, « Flow and shear descriptors of preconsolidated food powders », *J. Food Eng.*, vol. 72, no 2, p. 157-166, Jan. 2006.

[3] J. Schwedes and D. Schulze, « Measurement of flow properties of bulk solids », *Powder Technol.*, vol. 61, no 1, p. 59-68, Apr. 1990.

[4] R. Freeman, "Measuring the flow properties of consolidated, conditioned and aerated powders—a comparative study using a powder rheometer and a rotational shear cell.", *Powder Technol.*, 2007.