# UMo atomization – New pilot equipment implemented in CERCA

B. RAVRY[ab], J. ALLENOU[b], B. STEPNIK[b], A. MATHIEU[a], F. BERNARD[a], F. DEMOISSON[a],
[a] Laboratoire ICB – UMR 6303 CNRS / UBFC, 9 Avenue Alain Savary, 21000 Dijon, France
[b] Framatome CERCA[TM], ZI les Bérauds BP 1114, 26104 Romans-sur-Isère, France

## CONTEXT :

- To convert the European High Performance Research Reactors (EUHPPR), the European consortium HERACLES supports R&D efforts on conversion of HEU fuels to LEU fuels.
- A new REP atomizer pilot has been implemented in Framatome-CERCA™'s R&D laboratory, CRIL (CERCA™ Research and Innovation Laboratory). It has been developed in collaboration with ICB Laboratory.

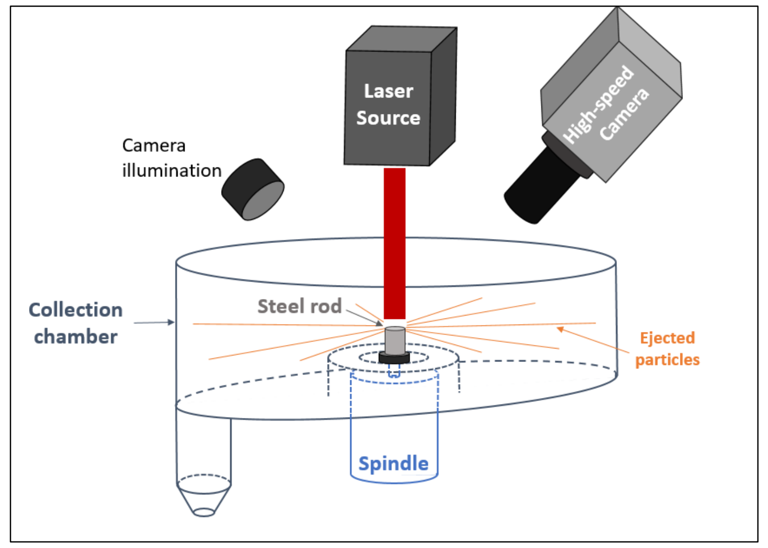
## 1. New REP Atomizer

Rotating Electrode Process (REP) :

- A consumable electrode is melted while rotated at high-speed.
- Fragmentation of the melt in particles under centrifugal forces.
- Particles become spherical due to surface tension before solidification [1,2].

**New CERCA Atomizer** :

- ❑ Custom spindle to atomize 20mm diameter UMo electrodes.
- ❑ Laser source to avoid pollution from standard TIG torch and to allow homogeneous melting of the electrode.
- ❑ High-speed camera to record the process up to 30.000 frames per second.



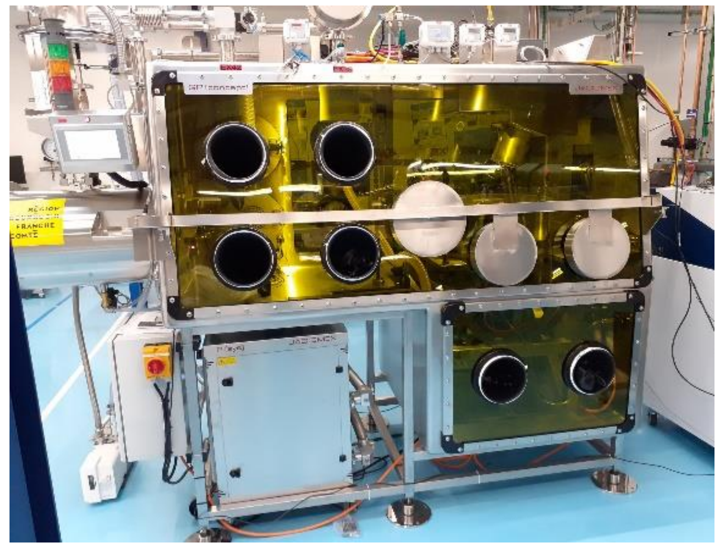



*Illustration of REP Process using a laser source with high-speed imaging and atomizer glovebox in Framatome CERCA laboratory*

**Advantages of REP** :

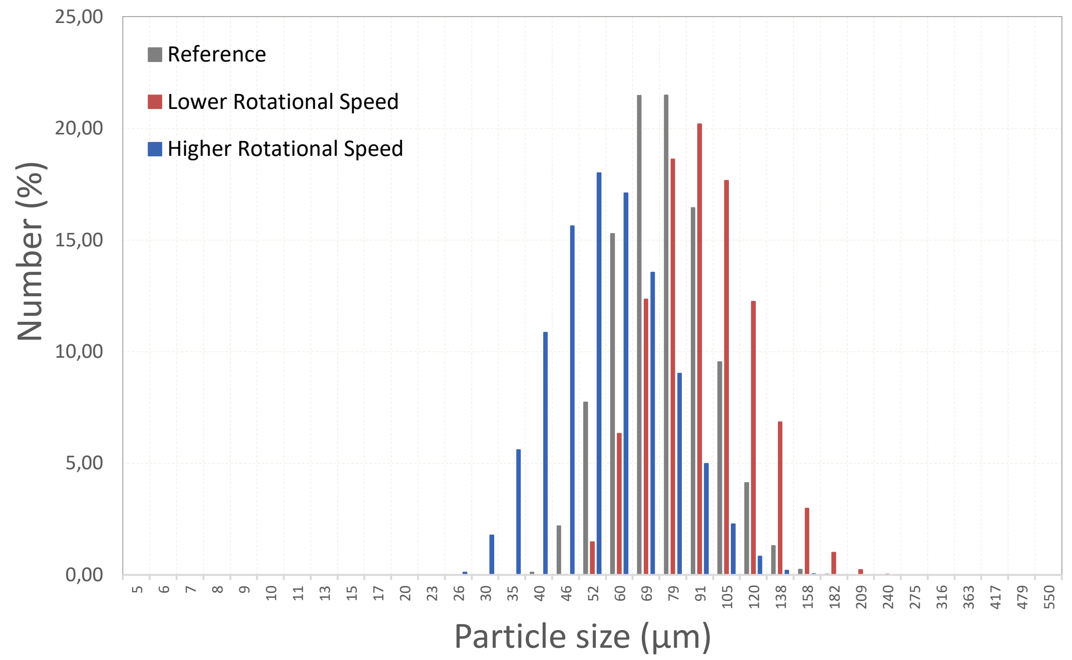
- ❑ High-reactivity powders *e.g.,* UMo powders, can be produced without external pollution due to fast solidification.
- ❑ Production of powders with high sphericity and purity in a narrow Particle Size Distribution [4,5].
- ❑ Particle sizes and shapes are mainly dependent on the rotational speed and material properties as expressed in Equation 1 [2,5] :

$$d_{50} = \frac{k}{\omega}\sqrt{\frac{\sigma}{\rho D}} \quad (1)$$

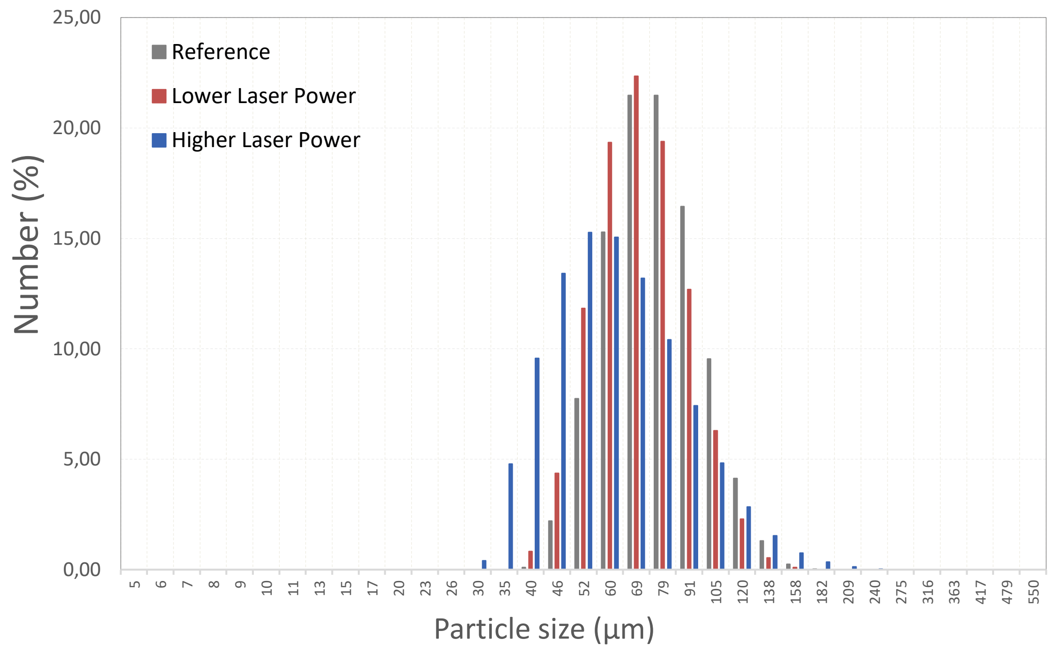
with $d_{50}$ is particle average size (m), k is a constant depending on the material and atomizer configuration, ω is the rotational speed (rad.s$^{-1}$), D is the electrode diameter (m), ρ is the density of the liquid (kg.m$^{-3}$), σ is the liquid surface tension (N.m$^{-1}$).

## 2. Atomization on surrogate materials

Study of the Particle Size Distribution (PSD) of atomized AISI316L powders as a function of the rotational speed and laser power.




- ❑ As expected with Equation (1), higher rotational speed involves a shift to lower values
- ❑ Each peak widths is similar for each batch.

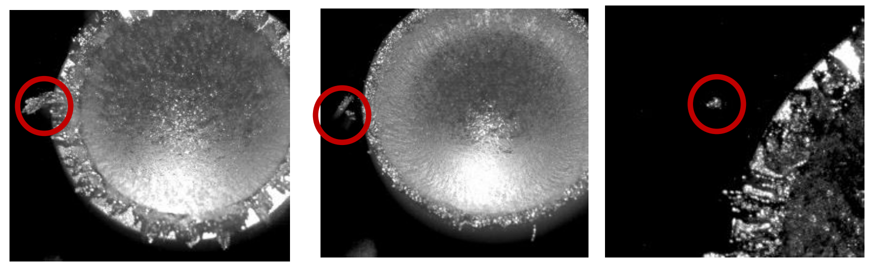



- ❑ Using a higher laser power allows a slight shift to lower values of the PSD.
- ❑ A larger peak width is observed using higher laser power.

→ Observation of Millimeter-sized non-spherical particles ("flakes") have been detected in each batch and have already been reported in REP studies [6,7].

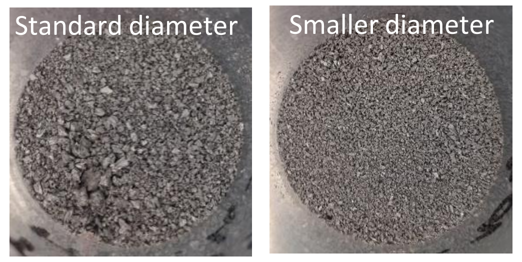
## 3. High-speed imaging to optimize the process

- ❑ Origin of flakes has been identified thanks to high-speed recordings



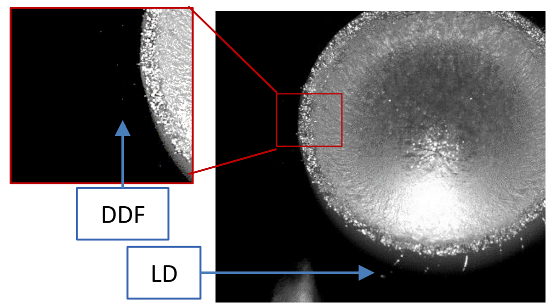
- ❑ Laser power may not be totally homogeneous at the surface. A peripheral zone melting lately where liquid cools down and forms flakes.

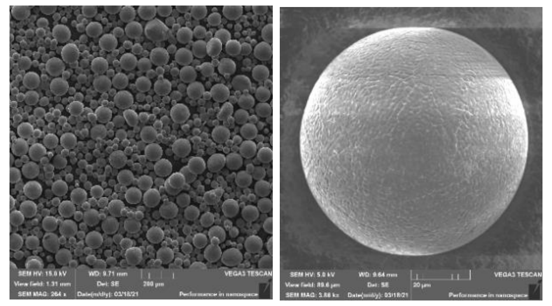
→ New atomizations using electrodes with smaller diameter were carried out




- ❑ Amounts of flakes largely reduces while PSD curve is still centered at same values.
- ❑ Observation of atomized electrodes shows that the width of the unmelted zone and the depth of the crater are reduced by using smaller diameter.

- ❑ Observation of a hybrid DDF / LD regime



- ❑ Regimes known to be the best regimes to produces spherical particles and a narrow PSD. Confirmed by SEM observations on produced particles

## 4. Conclusion

- ❑ A new atomizer pilot has been implemented in CERCA Laboratory, with a higher production capacity than previous version.
- ❑ First tests on AISI316L showed that both rotational speed and laser power are important to master the size and the quality of the powder.
- ❑ High-speed recordings allow to observe the atomization regime and to optimize the process

Next steps :

→ Study of a vibration-assisted spindle to improve ligament break-up and control PSD

→ Atomization of UMo electrodes in 2021.

[1] - O.D. Neikov, Handbook of non-ferrous metal powders: technologies and applications, Elsevier, 2009.
[2] - Y. Millet, Fabrication de poudres métalliques par la méthode PREP®, Techniques de l'ingénieur, 2015.
[3] - M. Zdujić and al., Production of atomized metal and alloy powders by the rotating electrode process, Soviet Powder Metallurgy and Metal Ceramics, 1990.
[4] - F. Průša, and al., Mechanical properties and thermal stability of Al–Fe–Ni alloys prepared by centrifugal atomization and hot extrusion, Materials Science and Engineering: A, 2014.
[5] - J.O. Yin and al., Microstructural characterization and properties of Ti-28Ta at.% powders produced by plasma rotating electrode process, Journal of Alloys and Compounds, 2017.
[6] - R. Angers and al., Formation of irregular particles during centrifugal atomization of AZ91 alloy, Materials Letters, 1997.
[7] - J. Tang and al., Characteristics and atomization behavior of Ti-6Al-4V powder produced by plasma rotating electrode process, Advanced Powder Technology, 2019.
[8] - B. Champagne, R. Angers, REP Atomization Mechanisms., Powder Metallurgy International, 1984.
[9] - J.O. Hinze, H. Milborn, Atomization of liquids by means of a rotating cup, 1950.