EXPERIMENTAL SIMULATION AND TECHNOLOGICAL SOLUTION FOR DEMO DUST DE-TRITIATION

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Abstract

Significant production of radioactive metal dust, mainly due to erosion of plasma facing components, is expected to be present during operations in the vacuum vessel of with remarkable tritium content. Therefore, tritium removal and dust management for safety reasons and for eventual remanufacturing or final disposal are key issues.

Today several techniques are available for producing pure tungsten components, or mixtures of tungsten and other metallic and non-metallic materials. Basically, the tungsten powder metallurgy follows the sequence Mixing, Pressing and Sintering. These techniques could be used to the re-fabrication or the safely disposal of tungsten dust.

The present work describes the study to select and optimize techniques for the DEMO W dust debrisment, capable of producing massive and mechanically stable components to be further processed for disposal or eventual recycling. These selected strategies and techniques aim to reduce the presence of mobilizable tritium on site during operation and to reduce the quantities and / or classification levels of radioactive waste. For this purpose, technological solutions have been studied and the definition of operating conditions to facilitate the handling of these radioactive powders towards their destination, disposal, recycling or remanufacturing, avoiding their dispersion.

During 2021, RINA Consulting CSM carried out experimental activities of hydrogenation of tungsten powders starting from ultra pure commercial powders with an average particle size of 1-20 mm. The sintering tests carried out in 2022 with "polluted" tungsten powders are then described to simulate exogenous species present in the DEMO W powder, with the aim of evaluating the feasibility of sintering and dehydrogenation.

Demo dust characterization

Many data are available according studies [1] and research devices erosion experiments as JET ITER like wall and ASDEX Upgrade [2],[3], mainly referred to W dust production rate as T concentration can not be extrapolated by experiments. Shape, size, base material, and number (mass) are key factors in determining DEMO dust's role in safety and its impact on machine operation.

The activation of Tungsten (W) by neutrons from DD reactions is mainly due to two isotopes, 185W and 186W. DEMO powders are expected to be composed of W with impurities between 1-0.1% of Carbon, W oxydes, alloy metals, Oxygen and Nitrogen. Grain size is in the range 0.1-20 μm, the presence of particles with larger diameter is also expected as W ball-like structures.

Considering W dust production rate of ~ 690 kg/y with 30% uncertainty and referring to 5 years of DEMO operation, 3445 kg of W dust will be produced (1.7 % of the total W armour mass: 196 t) [7]. According to the DEMO-HCPB blanket T inventory [4], T concentration in W dust of ~ 150 ppm is expected, while modeling [5] and experimental data [6] consider a reliable T concentration in W dust of 0.1- 50 ppm.

Adsorption/desorption model used for W dust hydrogenation tests

In real materials the amount of hydrogen (and tritium) retained in lattice imperfections is larger than the solute hydrogen; the difference can be of several orders of magnitude [8]. Diffusion, permeation, and solubility of hydrogen isotopes (H, D, T) in pure tungsten are discussed in [9] confirming that the values of solubility and diffusion coefficient are of the same order of magnitude, and the values of the three isotopes follows the same trend with temperature.

A preliminary estimation of the hydrogen concentration in W by means of temperature and pressure was done with experimental data of hydrogen solubility (figure 1) that can be interpolated by the linear relationships:

$$\mathrm{Log}(S) = -1.4569\cdot(1/T) - 1.5501 \qquad [1]$$

Hydrogen concentration in W as a function of T and P was estimated, resulting ~0.3 ppm at 1000 K and 250 atm (=2.533·107 Pa). The hydrogenation experiment (figure 2) in collaboration with Letomec s.r.l. confirmed the same order of H concentration adsorbed in W powders.

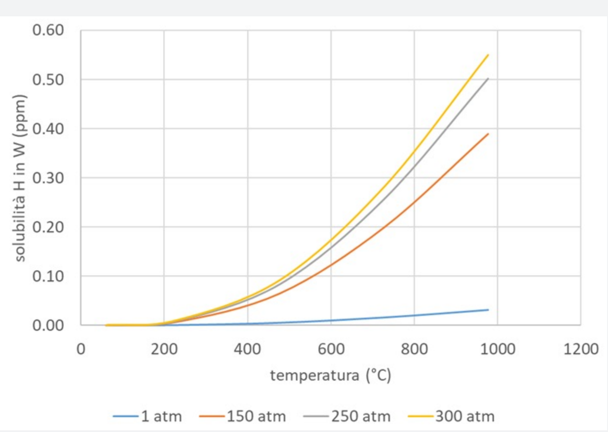
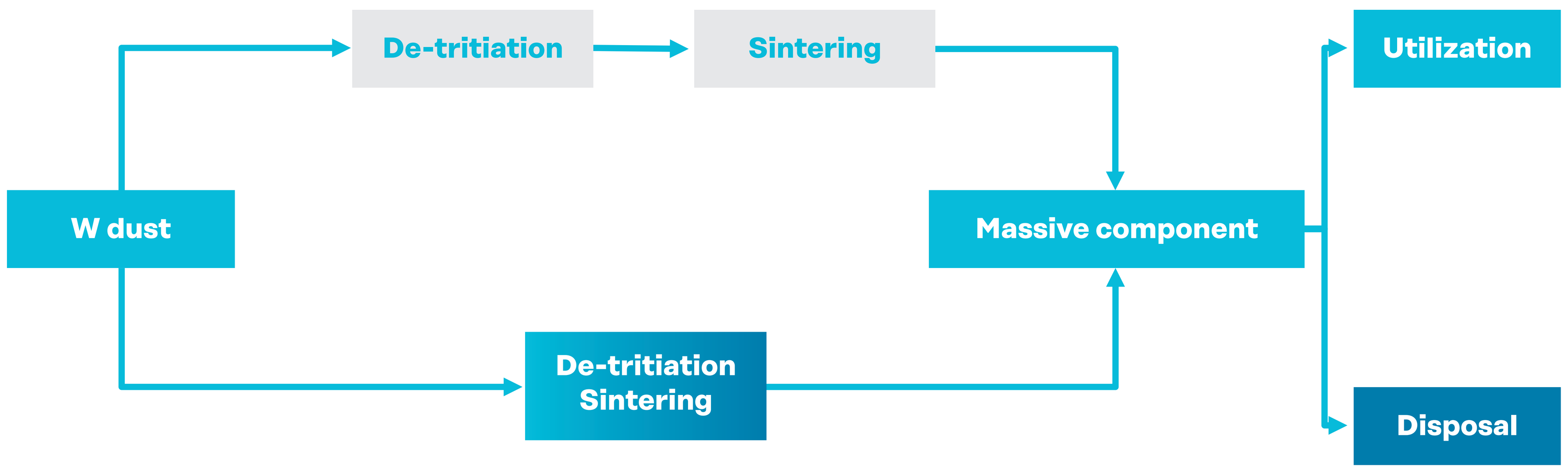


Figure 1:
Solubility in ppm of H in W as a function of temperature at different pressures

Figure 2:
Reservoir where W powders were hydrogenated in autoclave

W dust sintering tests

Sintering technique was used to treat W powders simulating DEMO dust, with the double purpose of studying the behavior of H entrapped in crystal structure during sintering process and of producing massive components to be easily and safely handled for LLW repository disposal.



Blends of W powder with titanium traces (simulating steel contamination) were added to 10% of copper[10] to obtain a low melting phase and then mixed and ground for 3 different times (15, 60, 240 min) under argon atmosphere to elude metal oxidation.

A fully characterized in terms of rheological properties, particle size distributions and morphological and microchemical characterization was done. Powders SEM/EDX show that blends grinding reduces W particles dimension, on which surface Cu particles sticks. This phenomena could help sintering process (figure: 3).

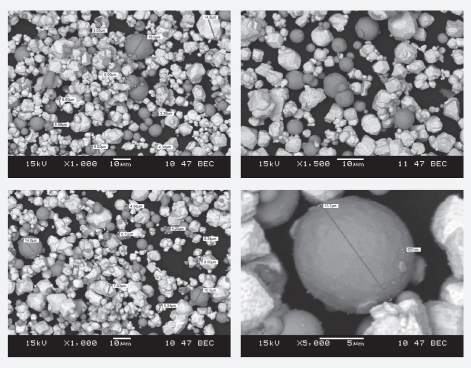


Figure 3 :
blends SEM/EDS analysis 1000 and 3000 magnification

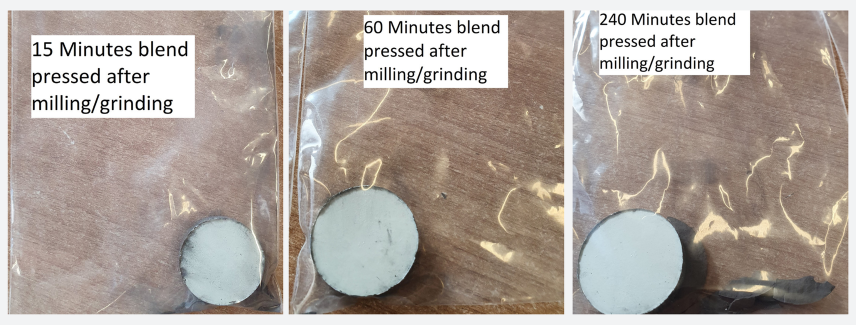


Figure 4: Green components

Afterwards, blends were pressed at 40 bar in an uniaxial press for producing what is called green component (figure:4).

Thermal treatment was done by setting a soaking temperature (i.e., T=950°C, 2 hours long). Density of the samples have been measured before and after thermal treatment (figure 5).

Figure 5: Sintered samples

Conclusion

The results demonstrated that massive component at controlled porosity can be obtained. Next activity will be addressed to individuate the most appropriate operations to extract tritium.

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