Fragmentation behaviors and mechanical properties of the tritium breeder pebble bed for fusion blanket

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ABSTRACT
• Fabrication and characterization of the tritium breeder Li$_4$SiO$_4$ pebbles were summarized.
• Mechanical properties and fragmentation behaviors of ceramic tritium breeder pebbles were investigated. The effect of pebble size and holding temperature on the crushing load were analyzed in detail.
• Effect of bed dimension and pebble size distribution on contact force distribution and packing behaviors were investigated.
• Flow characteristics (pressure distribution and velocity) of helium in pebble bed and its influence factors were analyzed by the DEM-CFD.

MOTIVATION AND BACKGROUND
• During the operation of the fusion reactor, Under the influence of the severe environment such as irradiation swelling, thermal expansion, alternating stress, and so forth, the tritium breeder pebbles will be broken and pulverized, accompanied by the changes in thermomechanical properties and packing structures of the tritium breeder pebble bed.
• Packing structures, fragmentation behaviors and mechanical properties, flow characteristics of the purge gas in the pebble bed.

FABRICATION AND CHARACTERIZATION

FABRICATION
Li$_4$SiO$_4$ pebbles by MSM.

CHARACTERIZATION
These Li$_4$SiO$_4$ pebbles were fabricated by melt MSM process. The diameters are about ~1mm. The pebble density are about 2.32 g/cm$^3$, it can reach ~96% TD.

Properties
<table>
<thead>
<tr>
<th>Values</th>
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<tbody>
<tr>
<td>Density</td>
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<td>Open porosity</td>
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<td>Closed porosity</td>
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<tr>
<td>Specific surface area</td>
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<td>Average pore radius</td>
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</tbody>
</table>

Chemical composition of Li$_4$SiO$_4$ Pebble: [Ca, Ti, Fe, Mg, Co, Ni, Cu]

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Morphology of the Li$_4$SiO$_4$ Pebbles

CONCLUSION
• The Li$_4$SiO$_4$ pebbles can be scaled fabricated by the new facility based on melt spraying method in SWIP.
• Pebble size, fabrication process, high temperature and holding time have significant effect on the fragmentation behavior and mechanical property of the tritium breeder Li$_4$SiO$_4$ pebbles.
• Contact force distribution and packing structure of pebble bed is influenced by the pebble size distribution, bed width and length, container shape, dimension ratio of container to pebble, vibration, etc.
• Packing structure and gas velocity have significant influence on flow characteristics of helium in beds.

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