IRRADIATION OF CANDIDATE MATERIALS FOR PBBI COOLED SYSTEMS: THE TWIN-ASTIR EXPERIMENT

Background

Lead bismuth eutectic is selected to be both coolant and spallation target material for the future experimental accelerator driven system (MYRRHA or XT-ADS). This new concept of reactor type might be one of the possible solutions for the nuclear waste problem as it is conceived to be able to burn up high level radioactive waste and long lived actinides. While both the liquid metal embrittlement phenomenon and liquid metal corrosion in lead bismuth eutectic (LBE) are currently widely under investigation by numerous laboratories around the globe, little is known about the possible synergy between irradiation and liquid metal corrosion and embrittlement. SCK•CEN is one of the candidate sites to actually build the XT-ADS and has therefore also engaged itself within the European FP6 programme EUROTRANS to further investigate the influence of liquid lead bismuth eutectic on the candidate structural steels in a neutron irradiation environment.

Objectives

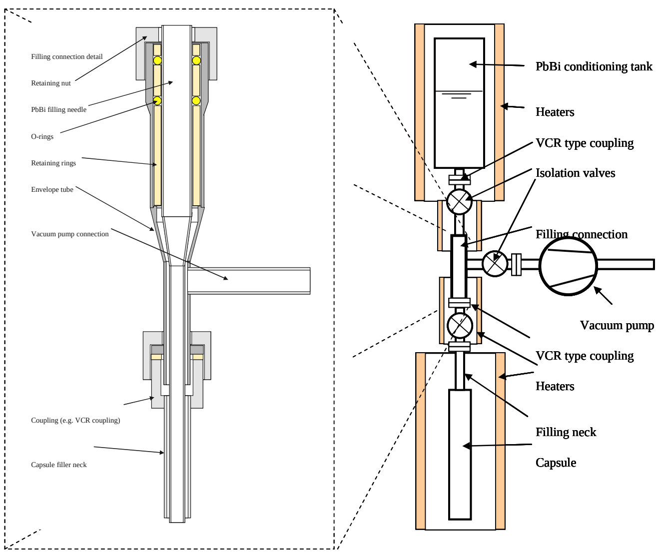
The objective of the Twin Astir experiment - being the first of its kind on a global basis - is a parameterisation study of the most important degradation phenomena of the structural material for the future accelerator driven system at 350°C. The future ADS is expected to have a window of operational temperature (core inlet – outlet) between 300 and 550°C. The lower boundary of the heavy liquid metal coolant core inlet temperature under operation is a very important input for the design. However this leads to discussion among material scientists due to the known irradiation hardening problems at 300°C. For this reason the irradiation temperature of the Twin Astir programme was chosen to be on the lower temperature boundary for operation. The parameters that are thought to be dominating in the material degradation process are irradiation hardening (accumulated dose), liquid metal corrosion, liquid metal wetting and liquid metal embrittlement. These will be assessed by performing corrosion examinations and tensile tests, crack growth tests both in inert environment as in liquid lead bismuth eutectic environment.

Thus it is expected to gain a better idea of the key influencing factors and possible synergies between these factors on the material degradation in a liquid lead bismuth environment under irradiation. This may allow us to focus on replacing or inhibiting the weakest link in the chain of materials degradation and therefore possibly increasing the operation lifetime of the accelerator driven system (ADS) facility.

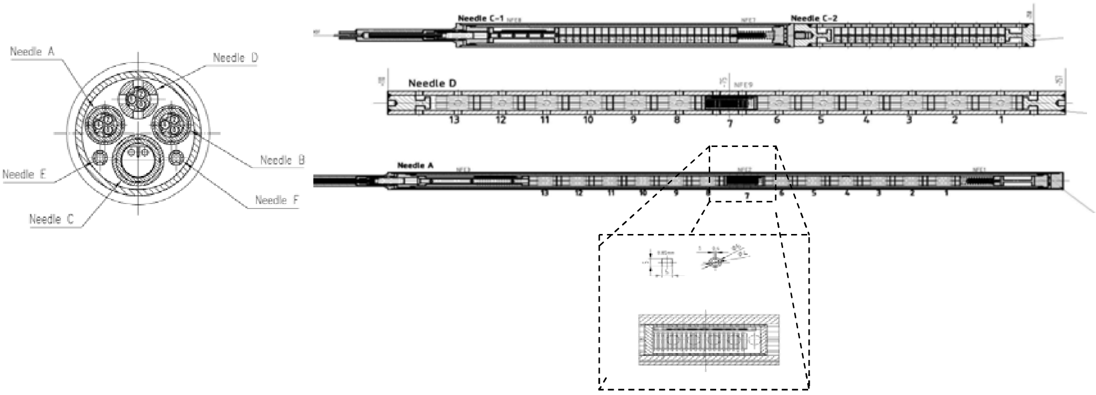
Principal results

Twin Astir has been designed to be irradiated inside the CALLISTO loop of BR2 at an irradiation temperature of 350°C. The irradiation of Twin Astir started in April of 2006 in the second operating cycle 2006 of BR2 for a total duration of 10 BR2 cycles. After 6 cycles part of the experiment will be taken out.

The experiment consists of six capsules containing mainly mini tensile samples and one capsule containing mini DCT's. Three of the tensile containing capsules and half of the DCT containing capsule are double walled and filled each with approximately 20 ml of low oxygen (10^{-6} wt%) LBE. To complete the filling of these capsules with LBE under controlled conditions a dedicated filling installation was constructed.



The other three tensile containing capsules are foreseen with holes to allow the CALLISTO water to enter and flow thru. Thus these capsules are subjected to PWR water conditions, in order to discriminate the effect of PbBi under irradiation from the effect of the irradiation itself. To extract the effect of the PbBi corrosion itself on the material properties, one of the capsules is undergoing the thermal cycles of the BR2 reactor without being subjected to irradiation. This results in a matrix of three irradiation doses in LBE (0, 1,5 and 2,5 dpa) and two environments (PbBi and PWR water conditions).
The tensile filled capsules are designed to contain mostly tensile specimens which are screwed in a retaining plate in an arrangement of three specimens per stage.



The drawing of the capsules is showing both types of tensile capsules (middle and lower right) as well as the CT filled capsule (upper right). The tube containing the corrosion plates is being magnified. Due to the vertical position of the capsule in the reactor, the corrosion plates would be pressed together by the buoyancy forces preventing adequate liquid metal contact. To ensure contact with the LBE, spacers (rings provided with an opening) are placed in between the plates. The CT filled capsule consists of two parts. Half of the capsule containing CT's is in contact with PWR water, the other half, also containing the same amount of CT's is closed, filled with LBE and foreseen of a double wall. Because the PbBi filled capsules are submitted to a strong external pressure of the PWR water, they were pressurized at room temperature by 50 bar of helium. The pressure control of the LBE filled capsules will be discussed more in detail further on.
There are several materials being studied in the Twin Astir experiment, being the most important structural material candidates for ADS, T91 and 316L as well as their welded joints (TIG and EB) and 4 experimental Si-enriched steels. Different samples of these materials are stacked in an identical order for each of the capsules.

Future developments

Even though the experiment is currently under irradiation many questions remain unsolved and a certain amount of open issues will need to be tackled to facilitate the post irradiation examinations (PIE). Due to the very strict legislation concerning Po^{210} and the uncertainty regarding the quality of the LBE after irradiation issues such as the secure retrieval of the samples in the hot-cell and the decontamination of polonium contaminated materials need to be resolved.
A hot-cell was designed and built, dedicated to performing mechanical tests in heavy liquid metal environment under well controlled temperature and chemistry conditions. This facility is currently licensed to perform tensile tests in PbLi environment but still needs to be licensed for tests in PbBi environment. Additionally tensile tests as well as crack growth tests are foreseen to be performed using this facility in both inert gas and LBE environment. Regarding the crack growth measurement in LBE adequate measurement techniques are currently under development.

Main contact person

Joris Van den Bosch, joris.van.den.bosch@sckcen.be

Main reference

[1] Ph. Benoit, *TWIN – ASTIR Descriptive Report*, Internal report I-59.
[2] J. Van den Bosch, Ph. Benoit, A. Almazouzi, R.W. Bosch, W. Claes, B. Smolders, P. Schuurmans, H. Aït Abderrahim, *Rig Design, Fabrication and Assembly: Twin Astir at BR2*, R-4395.
[3] J. Van den Bosch, Ph. Benoit, A. Almazouzi, R.W. Bosch, W. Claes, B. Smolders, P. Schuurmans, H. Aït Abderrahim, *Twin Astir: An Irradiation Experiment in Liquid PbBi Eutectic Environment*, presented at IWSMT-8 in Taos, NM, USA and published in Journal of Nuclear Materials.