

CONCEPT $\alpha\beta\gamma$ -BOX FOR MECHANICAL TESTING OF ACTIVE MATERIALS

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ABSTRACT

Several groups at the Paul Scherrer Institute (PSI) perform mechanical testing of active materials in PSI's hotlab. Thus the Laboratory for Materials Behavior, operator of the hotlab, started to install appropriate shielding and handling equipment for mechanical tests of highly active samples. In a first phase a versatile $\beta\gamma$ -shielding, consisting of 3 parallel but independently usable boxes, has been erected. All these boxes have no inner containment. They can be used only with activated, α -free and clean (without loose contamination) specimens. Therefore we have planned the construction of an α -tight shielded box in a second phase. The concept of this $\alpha\beta\gamma$ -box foresees a universal electro-mechanical testing machine equipped with an 800°C furnace. The furnace chamber is part of the inner α -box and can be flushed with inert gas. The overall design allows easy access to the testing machine drive for service purpose and optimizes the decontamination and decommissioning of the installation. Besides presenting the $\alpha\beta\gamma$ -box concept and the project status, we describe details of the system (e.g. box interfaces) and some aspects of the operational safety.

KEYWORDS $\alpha\beta\gamma$ -box, active mechanical testing

1. INTRODUCTION

The philosophy of Paul Scherrer Institute (PSI) is, with regard to its big installations, that of a user-lab. The specific installations are open to different users coming from inside and outside PSI. One of the big facilities is PSI's hotlab. In the hotlab different scientific teams perform their investigations. With respect to mechanical testing there are 3 groups today:

- A group from the Research Centre for Plasma Physics (CRPP), Swiss Federal Institute of Technology Lausanne (EPFL). It is a group located at PSI who performs mainly simulation irradiation of fusion relevant material and the subsequent mechanical testing. The investigated materials are, e.g., ferritic-martensitic steels, low-activation steels or ODS material. The material to be tested is normally free of possible loose contamination.
- PSI Division Spallation Neutron Source (ASQ). Materials are tested which are in discussion for windows for liquid metal spallation source targets. These targets are irradiated at PSI with an intense proton beam. The main material candidates are different steels that show, for instance, high corrosion resistance against the eutectic target alloy Pb-Bi. High Bi transmutation rates during proton irradiation may lead to α -contaminations on the surface of the steel samples. Those samples need to be tested in a α -tight box.
- PSI Division Nuclear Energy and Safety (NES), Laboratory for Materials Behaviour (LWV), Hotlab. The focus of this group is on testing LWR material, e.g. cladding material that was exposed to high burn-up. Another point is the behaviour of cladding material during – and especially at the beginning of – intermediate dry storage. Principally it can not be excluded that cladding samples show α -contamination and few residual fuel particles. Mechanical testing must therefore be done in a α -tight box.

Until today the mechanical testing has mostly been performed behind light shielding consisting of lead brick walls. Because of increasing doserates of samples and the wish to have the possibility to test also α -contaminated material an integrated concept for mechanical testing at PSI hotlab has been developed.

2. CONCEPT FOR ACTIVE MECHANICAL TESTING

The concept consists of 3 labs, whereas 2 labs are foreseen for mechanical testing and 1 lab for sample preparation. In one of the test labs 3 heavily shielded versatile $\beta\gamma$ -cells are arranged in a row, individually usable. The cells are provided with doors which can be opened so that test machines can be changed. In the second test lab a heavily shielded $\alpha\beta\gamma$ -box with integrated tensile testing machine plus furnace will be installed. The sample preparation lab will be equipped with a combined cell consisting of a heavily shielded $\alpha\beta\gamma$ -box connected with an

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α -glovebox. The room comprises also several hoods for further preparation work and storage cupboards for samples and necessary preparation chemicals.

The today status of the project is:

- The $\beta\gamma$ -cells are erected and are working well.
- The concept for the $\alpha\beta\gamma$ -box for mechanical testing is developed, construction and manufacturing has begun. All parts are ordered. The testing machine is delivered so that we could make first tests.
- The concept for the preparation lab is finished, further planning is ongoing.

In the following the description of the work is concentrated on the $\alpha\beta\gamma$ -box and its testing equipment.

3. GENERAL CONCEPT OF MECHANICAL TESTING IN THE $\alpha\beta\gamma$ -BOX

Before developing the concept for the $\alpha\beta\gamma$ -box, some basic purposes of mechanical testing of relevant samples had to be clarified. The whole equipment should be appropriate for testing possibly α -contaminated and also relatively highly active specimens. Therefore, an α -tight inner stainless steel containment had to be considered. Because of the expected dose-rate it must be surrounded by a heavy shielding. Two types of materials were planned to be tested: ASQ target material and reactor cladding tube pieces.

We liked to have the possibility to perform tests at 300–400°C. This temperature range is typical for the irradiation of ASQ targets. In the case of reactor material 300°C is the relevant core temperature. Temperatures around 400°C are interesting for testing cladding material with respect to intermediate dry storage behaviour. The focus here is on the reorientation of the hydrides.

For the 2 different programs – target and cladding material – we expected different types of samples. In the case of the targets, small flat hourglass like shaped specimens are used. They can easily be put into the sample holders of the testing machine. The gripping sections support the specimen shoulders. The gripping sections of the tube cladding samples are more complicated. Two wedge-like half-cylinders fit into the tube piece and are torn apart, supported by the grips of the testing machine. This kind of test can be used for investigations of hydrides behaviour or crack propagation. It was clear that – using completely different specimen types – the gripping system had to be designed sufficiently flexible.

The operation and maintenance of the mechanical testing machine and the additional equipment should be as trouble free as possible. This meant that the accessibility of the equipment has to be achieved. Some details of the concept idea are described in the following chapters.

At least it was important to think about the waste and decommissioning situation. The assembly of the equipment should be done in a way that easy, modular decommissioning is possible. This concerns especially the testing machine which comprises the biggest and heaviest parts of the device.

4. ASSEMBLY OF SHIELDING

The heavy shielding of equipment raises always the question whether the load of the shielding does not exceed the maximum tolerable floor load. In our case the location is in a basement lab. The basement of the building had no initial thick concrete plate and the maximum allowed load was too small. Therefore the floor had to be reinforced with concrete injections. This had been done already in an earlier campaign. Nevertheless the expected total device load was now just at the limit of the newly allowed load. Moreover, the planning foresaw the possibility to partially open the shielding for better access to the inner parts, e.g. the α -containment and parts of the testing machine. Therefore a heavy, wheeled door was planned for the front side of the shielding. The opening of such a door can only be achieved on a perfect, flat ground. Finally we decided to install large, load supporting and load distributing, well adjusted steel plates. For the adjustment epoxy resin is pumped between the steel plates and the floor. This is the same concept as we already used for the heavy $\beta\gamma$ -shielding in the firstly commissioned active mechanical testing lab.

The heavy shielding consists of 200 mm steel plates (see Fig. 1). The assembly is situated in a room corner so that the back walls do not need to be equipped. At the front side a lead glass window and 2 manipulators (Wälischmiller) are mounted. On the right side is a double-door sealed transfer system.

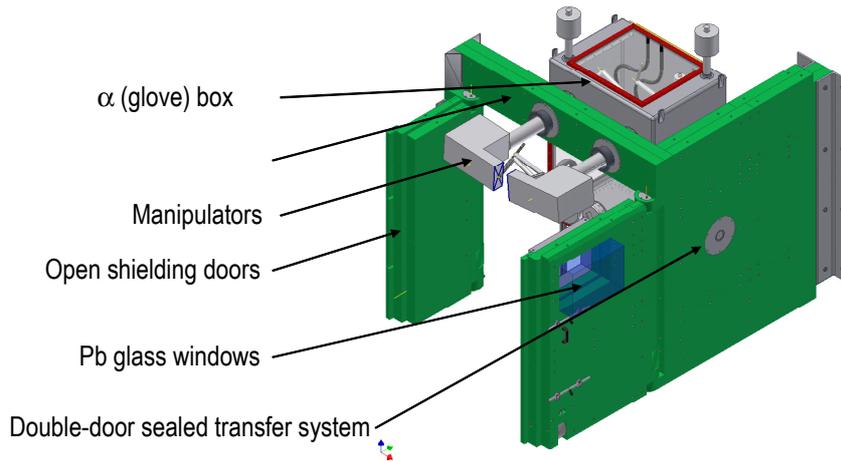


Figure 1. Overview $\alpha\beta\gamma$ -box assembly

5. α -BOX

For the inner α -box we had originally 2 different ideas: The first idea was to install the mechanical testing machine completely in the box. The second idea was to place only the really test relevant parts of the testing machine in the box. The second solution is more complicated. But it has the big advantage of better accessibility of important testing machine parts and better possibilities for decommissioning.

We chose the second solution (see Fig. 2). In this case the furnace is considered as a backpack of the proper α -containment. The testing machine is situated outside the box. Only the pulling rods reach via bellows into the furnace. The bellows are needed to guarantee α -tightness. The pulling rods have interfaces just above and below the furnace, so that a complete decoupling of the testing machine from the α -containment is possible.

In the case of a problem, for instance, with the drive or load cell of the machine, these parts are accessible. Samples with strong dose-rate would be needed to be removed so that then the heavy shielding can be opened and the way is then free around the inner α -containment. The inner containment disposes of glove-holes. This means that some parts of the box can directly be reached "by hand".

The test device includes a digital camera plus long distance microscope on a 3D positioning table. This optics serves for sample observation as, for instance, crack propagation measurements. The camera can be triggered via PC by the mechanical testing machine.

The testing chamber is considered as part of the α -containment. The pulling rods through the metal bellows compose the interface between chamber and testing machine. The chamber can be flooded with inert gas (Ar, N) or a slight vacuum can be created. The pressure in the chamber – as also in the actual α -box – is controlled to maintain the pressure cascade between the furnace chamber, box inside and surrounding lab. The off-gas is directed into the general hotlab off-gas duct. The furnace can typically be operated at up to 450°C. The furnace supplier confirmed us that even a higher temperature between 600 and 800°C is possible, but probably not in continuous operation. The furnace chamber is water cooled. This was a prerequisite; after our opinion the operation of a furnace in a closed box needs active heat removal. The flanges for the cooling water pipes are – in the case of the rear of the temperature chamber – outside the box. The cooling water pipes for the heat chamber door lead through the α -containment. Therefore a special water leak control has to be installed inside the box.

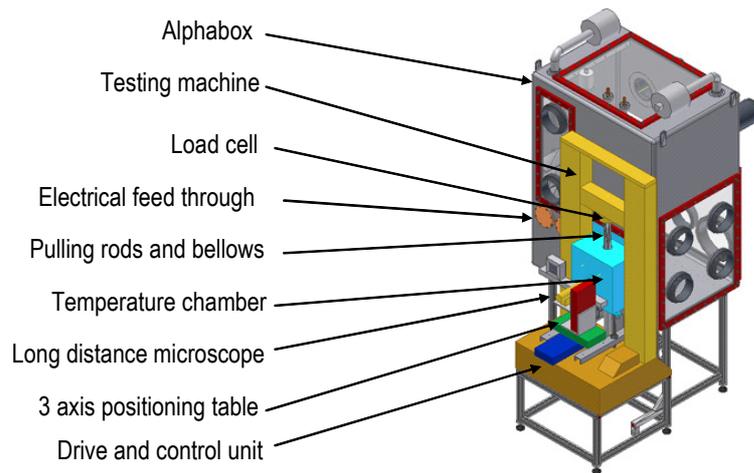


Figure 2. Overview inner part of $\alpha\beta\gamma$ -box assembly

The hot zone in the furnace has a diameter of 100 mm and a length of 140 mm (see Fig. 3). At the front and rear side of the chamber windows with high quality glasses allow the observation of the test region. The temperature chamber door can easily be handled with manipulators (quick lock).

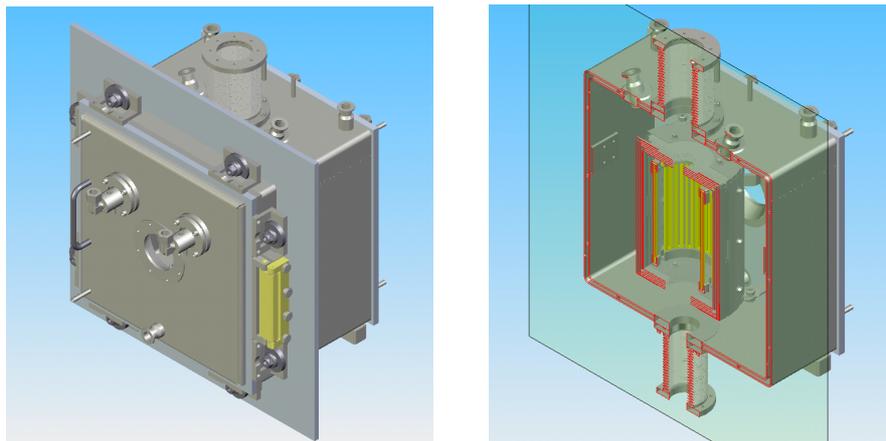


Figure 3. Closed temperature chamber and cross section with furnace

6. TESTING EQUIPMENT

The universal materials testing machine is an electromechanically driven MTS Alliance RT/30 with a maximum load of 30 kN. It is equipped with the testing software TestWorks 4.0 running under Windows XP.

Fig. 4 shows an inactive tube cladding piece with the 2 wedge-like half-cylinders, being mounted in the gripping sections. The sample has 2 edge notches in the mid plane as stress concentrators. These can act as starting points for propagating cracks. For testing active cladding samples the specimen mounting procedure and handling with manipulators is not yet sufficiently defined. Certainly the mounting has to be facilitated and the observation of the sample should be possible both from the front and from the rear side. This implies an amendment of the sample holder.

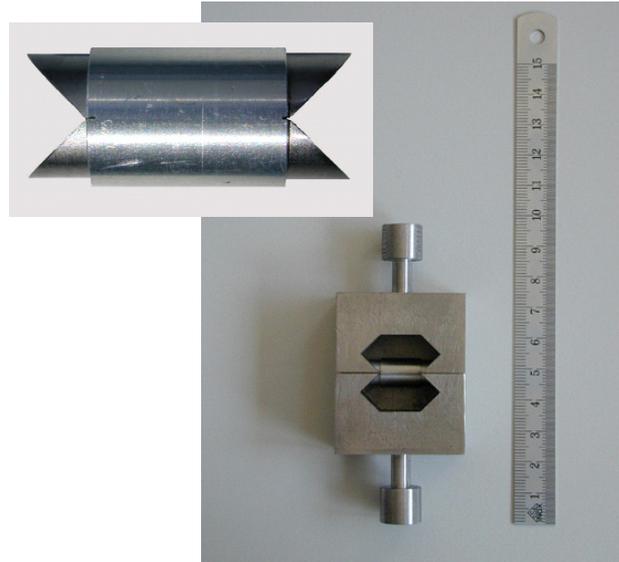


Figure 4. Sample holder with tube cladding sample; sample width = 12.5 mm

7. OPTICAL DATA CAPTURING

The device will be equipped with a digital camera and a long distance microscope. The optics will be mounted on a 3D positioning table.

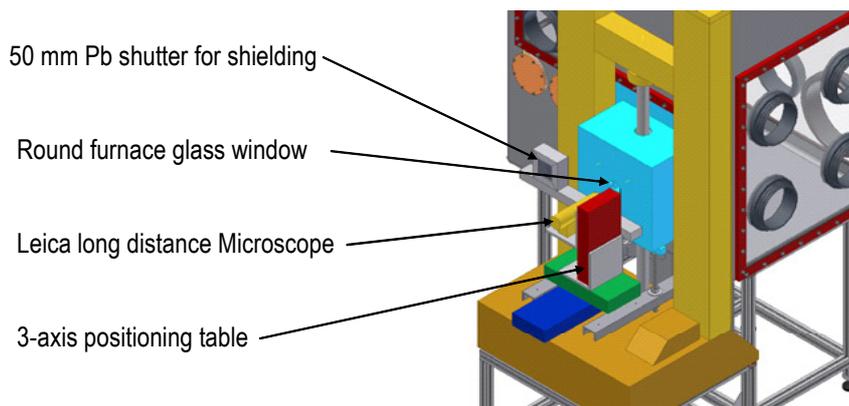


Figure 5. Optics configuration

The positioning system is necessary, because a sample is never mounted at the exactly same place. The optics system must be adjustable. Additionally the camera should be able to zoom and focus on selected sample regions. The linkage of the camera with the controlling PC allows triggering the image capture by testing machine signals. For protection reasons a Pb shutter can be shifted between the sensitive camera and the rear window of the temperature chamber (see Fig. 5).

The following table contains the main features of the camera and long distance microscope. We have chosen these components according to the wished resolution limit and image size. On one hand side we need to observe a whole cladding tube sample with a width of 12.5 mm and its cracks propagating from both edge notches, on the other hand side we like to have a resolution down to around 20 μm .

Table 1. Overview optics

	
<p>Leica Z16 APO A Microscope</p> <ul style="list-style-type: none">▪ Working distance: 297 mm▪ Zoom: 1 : 16▪ Focus: motorised▪ Magnification: max. 100x▪ Field of view: 2.1 – 30 mm	<p>BASLER Area Scan 102f Camera</p> <ul style="list-style-type: none">▪ Model: Colour▪ Sensor: 2/3"▪ Pixel size: 8.5 microns▪ Resolution: 1392 x 1040 pixels (1.4 Mpix)▪ Frame rate: 15 fps▪ Connector: C-Mount▪ Interface: IEEE-1394 (FireWire)

8. SUMMARY AND OUTLOOK

At PSI's hotlab a concept for mechanical testing of active materials is being realized. After having commissioned a row of 3 shielded $\beta\gamma$ -cells, now an $\alpha\beta\gamma$ -box including furnace and sample observation optics is close to its assembly. All relevant equipment is ordered and partially delivered. We expect the delivery of the remaining parts during this spring and summer. First inactive tests are planned for autumn 2005. We hope to start active tests at the end of this year.