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A Remotely Operable Facility for Fabrication of Fuel Pins for test Irradiation

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Abstract

A laboratory scale facility has been set up for fabrication of test fuel pins through sol-gel route for irradiation in FBTR, Kalpakkam. The facility is a train of glove boxes fitted with master slave manipulators for carrying out various operations involved in the fuel fabrication process. The paper describes the design features of the equipment and mechanisms for automation, developed for microsphere production and other processes. The design features include control system and vision systems for man- machine interface.

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*Keywords:*Fuel fabrication; sol-gel; automation; manipulator

1. Introduction

Sphere-pac fuel pins are those which are produced by vibrocompaction of fuel in the form of microspheres. The fuel microspheres are produced through the sol-gel process. Sol-gel process for the production of microspheres and vibrocompaction offer several advantages over the conventional route of fuel pin fabrication using pellets[1] . The major advantages are: elimination of powder handling and associated problems and more amenability for automation and remotisation. However, there is not enough plant experience with these fuels worldwide. Hence it is necessary to generate indigenous irradiation data on these fuels. Towards this, a laboratory scale facility has been set up for fabricating sphere-pac test fuel pins for irradiation in FBTR. The facility comprises a set of glove boxes, specially designed to accommodate articulated master-slave manipulators (AM). It is aimed at demonstrating the remotisation of the fuel pin fabrication through the sol-gel route. Operation of several equipment in this facility has been automated. The facility is described in this paper and the special design features related to automation and remotisation are discussed.

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2. Design approach

Process equipments are automated and supplemented by the use of articulated master-slave manipulators for remote operation and maintenance. Operations such as the nozzle replacement, opening/closing of high temperature furnace, handling of sample crucibles etc., which require high precision and repeatability are automated. Operations such as opening/closing of valves, replacement of fittings, leads etc., which involve maneuverability based on process conditions by monitoring the process through the viewing glass panels are carried out by manipulators. Maintenance of the equipment will be done manually for which gloves are provided in the glove boxes.

3. Production of microspheres

An internal gelation set up inside a glove box in the facility will be used for production of (U,Pu) oxide microspheres of ~ 700 µm size starting from the nitrite solutions of uranium and plutonium The glove box houses process vessels, associated piping, a glass column in which silicone oil at 371 K is pumped upward and in which gelation occurs., a nozzle and a vibrator (Fig.1) The gel produced is washed with carbon tetrachloride and ammonia to remove silicone oil and other reaction products, dried at 373 K and calcined at 773 K and reduced under hydrogen in this glove box.

Fig.1.Gelation setup comprising glass column with silicone oil and other equipments inside glove box

4. Sintering of microspheres

The calcined microspheres are sintered at 1673 K under reducing atmosphere in a tungsten mesh furnace housed in another glove box. The furnace comprises a cylindrical double walled vacuum chamber mounted on a leak tight flange welded on to the floor of the glove box. A gantry 'XYZ' system facilitates positioning of the charge carrier at pre-determined locations inside the glove box. The 'Z' motion is achieved by a telescopically extendable arm with an end effector. (Fig..2) A pneumatically operated, parallel jaw gripper mounted with reed switches acts as end effector which is suitably designed for adaptability for handling charge carrier, flat molybdenum radiation shields on top and the cylindrical radiation shields surrounding the charge carrier . The design incorporates a taper-bush arrangement for attaining concentricity between carriers and shield.

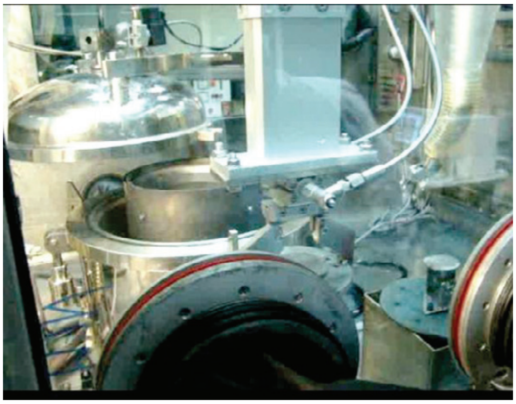

Fig.2. Sintering furnace with remote systems

5. Powder compaction of pellets

A unique remotely operable 5 Ton capacity, automated double end compacting hydraulic press is housed inside one of the glove boxes and operated by manipulators to produce annular pellets by compaction of powder or microspheres. The pellet press comprises a remotely operable and replaceable top punch, a bottom punch , a die block assembly and a core rod block. The control system uses position-based servo control. A pellet handling device holds the pellet by suction and transfers it to various stations. Miniature suctions cups are mounted as end effectors. The end effectors are positioned on a 'Y-θ' indexing mechanism (Fig. 3a).

Fig.3a Press with pick-place device

A gantry 'XYZ' system is used to handle the press components which are heavier. The punches and tools are held by electrical grippers with interlocks. The 'XYZ' system houses a unique hoisting system based on three stages screw -in-screw type (Fig. 3b).

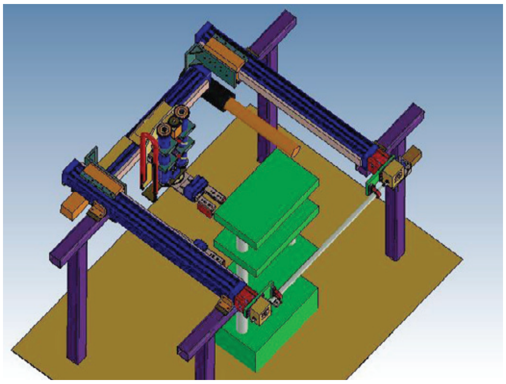

Fig. 3b Solid model of the gantry system for handling die blocks

6. Vibratory compaction of microspheres

Two sizes of microspheres will be used for vibrocompaction so as to get a packing density of 80% theoretical density(TD). Since the ID of the clad for the test fuel pins is 5.7 mm, the coarse fraction of microspheres will be of 710-850 µm and the finer fraction will be of 105-125 µm size. These fuel microspheres are transferred to a container which is placed in a carousel assembly. The carousel is placed in a resistance furnace for vacuum degassing the fuel at 423 K. The degassed microspheres are weighed and made into aliquots for filling into the clad.

7. End plug welding

One of the glove boxes houses, a leak tight sphere feeding device, an electromechanical vibrator with pneumatic gripping gadgets, hardware loading mechanism, vertical welding fixture and 'XYZ' positioning system mounted with parallel jaw grippers operating in tandem to hold the fuel tube. To avoid damage of clad tube during gripping and to ease insertion of the clad tube, a self guiding and floating platform with springs is provided in the hoisting module. The 'XYZ' system with high positioning accuracy facilitates transfer of fuel pin from the vibrator to the welding station and 'peg-in-hole' insertion of fuel tube. The positioning is assisted with Pan-Zoom-Tilt camera interfaced with image processing tools for measurement. The welding of clad tube and end plug is carried out in a high precision welding fixture by operating it remotely, assisted by vision systems (Fig. 4). Using the vibrator in this glove box, vibrocompaction studies have been carried out using both fractions of UO_2 microspheres and packing density of 79% TD have been achieved

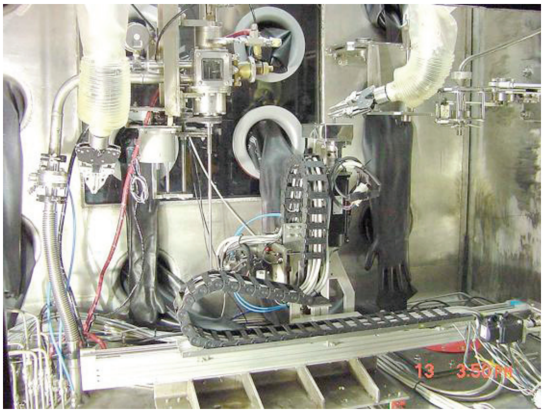

Fig.4.Welding station with pin handling system

8. Summary

The laboratory scale facility for test fuel pin fabrication has been commissioned and the trial fabrication of fuel pins containing both fractions of UO_2 microspheres was carried out. The pins were subjected to quality control steps. The welds have been found to meet the acceptance criteria. The facility is now ready for handling active operations.

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