THERMAL SIMULATIONS OF A NEW TARGET CONFIGURATION FOR PRODUCTION OF RADIOACTIVE NUCLIDE

L.H. Chen#, B.Q. Cui, Q.H. Huang, W.S. Jiang, R.G. Ma, Y.J. Ma, B. Tang,
China Institute of Atomic Energy, Beijing, 102413, China

Abstract

China Advanced Rare Ion-beam Facility (CARIF) based on China Advanced Research Reactor (CARR) has been proposed in order exploring the frontier of nuclear physics. A target with 5 g ^{235}U is proposed in the project. The thermal neutron fission of ^{235}U will produce radioactive nuclei and the great thermal load (~50 kW). The target of CARIF needs endure high temperature and thermal energy deposit. A new multi-targets configuration is proposed. It consists of several discrete targets instead of traditional single-target structure used in accelerator driven facility. Because there is more thermal radiation area in this configuration, thermal radiation capacity is enhanced, so the target can withstand higher thermal power. The temperature distribution of multi-targets was simulated with finite element code. The results show that the configuration of multi targets can effectively reduce the target temperature. From the perspective of target temperature distribution, the configuration could endure 50kW thermal power. It's possible to use 5 g ^{235}U in CARIF for production of radioactive nuclide.

INTRODUCTION

Currently, the research of exploring the area of extreme isospin is limited by the RIB intensity limitation from the narrow isospin range of stable beams [1]. Neutron rich beams are of great importance in understanding shell evolution and astrophysical r-process. China Advanced Rare Ion-beam Facility (CARIF) based on China Advanced Research Reactor (CARR) is proposed. With the high flux neutron (~10^{14} n/cm^2·s) in the horizontal tube of CARR [2] and ^{235}U target, high intensity neutron rich beams is expected. Its concepts is that target/ion source placed in the neutron tube will produce some fission fragment and make them ionized, and then separator will select some wanted ions, further be accelerated. According to the requirement of beam intensity and the technology feasibility, the target of CARIF should contain about 5 g ^{235}U [3]. About190 MeV energy and 160 MeV thermal energy will be released from each heat neutron fission. There are about 2*10^{15} fissions per second in 5 g ^{235}U. The target will produce about 50kW thermal energy. And the diameter of the horizontal tube in CARR reactor is just Φ170mm. So the target not only need endure the great heat disposal, but also need compact design in order to operate simply and reliable.

In accelerator driven ISOL facility, target are generally a single solid cylinder, such as in CERN/ISOLDE, ORNL/HRIBF, TRIMUF/ISAC, BRIF [4] [5] [6] [7] et al. The primary beam enters from one end of target. But in the horizontal tube of CARR, neutron flux is filled the whole tube. Due to the circumstance, a new multi-targets configuration is proposed in this paper. It consists of several discrete targets instead of traditional single-target structure used in accelerator driven ISOL facility. The result of simulations shows that the configuration of multi-targets can effectively reduce the target temperature.

THE THERMAL SIMULATIONS OF A NEW TARGET CONFIGURATION

In the simulations, the porous graphite plated ^{235}U is used as target. The outside of target is covered with high melting point materials, such as Rhenium. Located in ～30 kV potential, the size of target assembly should not exceed Φ100 mm. The cross view of a possible single solid target and multi-targets is shown by Figure 1. The single solid target is a porous graphite target with 1mm Re cladding. The multi-targets which are composed of 10 porous graphite targets with respective cladding are distributed in 100 mm bore. All the target chambers will be connected to an outlet to make radioactive fragments into ion source. The diameter of each target chamber is 20 mm. There are same thermal energy ~2 kW/cm deposited in two configuration. The horizontal tube is surrounded by forced flow heavy water which is used as neutron moderators. The heat of target chambers is released to the surrounding neutron tube mainly by radiation. Finally, the heat released to surrounding neutron tube is taken by forced flow heavy water to cooling system of CARR.

Generally it is available of the porous graphite of above 80% porosity. So the value of its thermal conductivity simply sets to 1/8 of graphite. According to the target surface condition and material nature, surface emissivity coefficient ε is usually between 0.2 ~ 0.8. The neutron tube has oxide coating which will enhance the radiation. In the simulation, the emissivity of the neutron tube sets to 0.5, and Re cladding sets 0.3. The heavy water flow surrounding the neutron tube is forced flow and its temperature is normal, so temperature of outside of tube is set 300 K.

#lihuachen@ciae.ac.cn

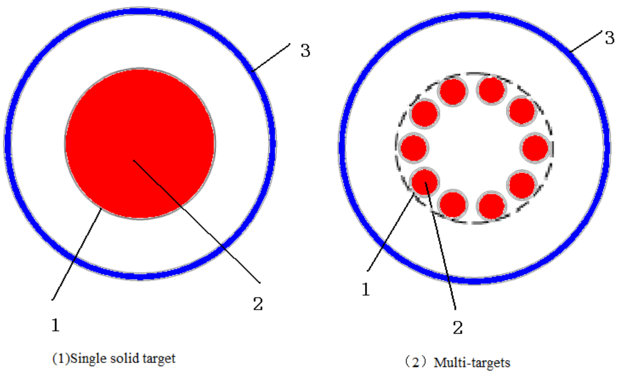

Figure 1: The cross view of two configurations of targets; 1 - Rhenium cladding, 2 - Porous graphite target, 3 - Horizontal tube of CARR.

The temperature distributions of above two configurations of targets are simulated with finite element code. The result is shown by Figure 2. According to the simulation, the maximum temperature of single solid target is 3602 K, near the melting point of graphite (~4000 K). So as it maybe not endure such great thermal energy. But the multi-targets one is just 2623 K, much lower than the melting point of graphite. The reason of this circumstance is possibly that the configuration of multi-targets increases thermal radiation area. Thermal radiation capacity is enhanced. So the target can withstand higher thermal power.

The maximum temperature of neutron horizontal tube is 325 K. The heavy water flow surrounded the tube is able to carry the thermal energy.

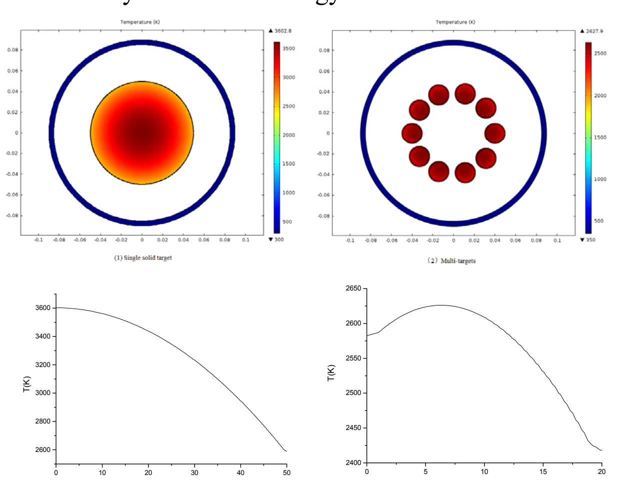

Figure 2: The temperature distribution of two configurations of targets; R- the radial coordinate of target from tube centre, d- the radial coordinate of target.

From the above result, it's concluded that at least 25 cm long target is required for 50 kW deposit of thermal energy. It's a challenging work, but possible. And with higher conductivity, less length is required. The configuration of target is flexible.

In some extreme cases, some target of multi-targets configuration maybe damaged and drop on the neutron tube surface. In this case, the damaged target is adhered to the neutron tube. Its heat will transmit by contact heat transfer. The temperature distribution in this case is shown by Figure 3.

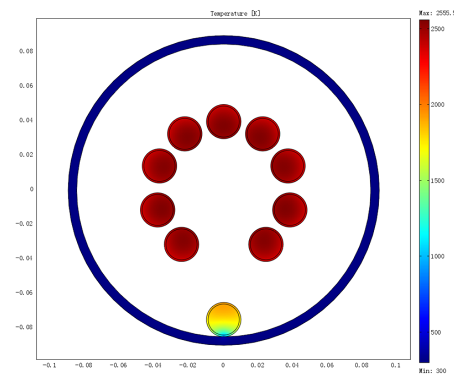

Figure 3: The temperature distribution of the case of one target damaged in multi-targets configuration.

Figure 3 shows that the maximum temperature of the case of one damaged target is lower than the case of all good, 2556 K V.S. 2623 K. And the temperature distribution varies greatly in damaged target. It's shown by Figure 4. It could include that the maximum temperature of damaged target is lower than other targets and the maximum of neutron tube is about 600K, which is much lower than the melting point of aluminium alloy. It can be concluded that the horizontal tube of CARR is safe in case of this accident.

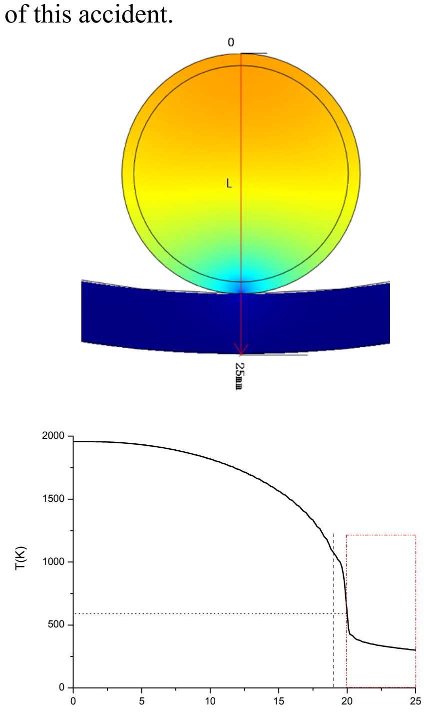

Figure 4: The temperature distribution in damaged target cylinder and neutron tube; Figure origin is surface of the damaged target.

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CONCLUSIONS

The simulation based study of thermal characteristics of the target configuration of CARIF has been presented. The results show that the configuration of multi-targets can effectively reduce the target temperature. From the perspective of target temperature distribution, the configuration could endure 50 kW thermal power. It's possible to use 5 g ^{235}U in CARIF for production of radioactive nuclide.

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