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Fabrication Method of the Mo-99 Target with Advanced Planar Flow Casting

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1. Introduction

Mo-99 is a parent isotope of Tc-99m for medical diagnosis and very significant owing to its large fraction over 80% of the whole demand of medical radioisotopes in the all countries. Mo-99 isotope has been produced mainly by ^{235}U which is extracting fission products[1]. All the major providers of fission Mo have used HEU as a target material. But RERTR program that is non-proliferation policy encourages using HEU to LEU[2]. KAERI has developed a processing to be able to produce a uranium foil continuously at one go. This processing gave an opportunity for LEU target using uranium foil to be commercialized. It correspond RERTR program. KAERI developed a new process of making foil directly from uranium melt by PFC. This process is simple, productive, and cost-effective. But the foil's air-side surface is generally very rough[3]. A typical transverse cross section had a minimum thickness of 65 μ m and a maximum thickness of 205 μ m. This roughness could affect target fabrication and irradiation behavior. After issuing this problem KAERI launched a further effort since 2008. A new equipment was designed and manufactured in the industry in 2009. While the new equipment being test-operating, some occurrence of appearing problems appeared. Since 2010, Equipment was moved to KAERI, we performed many experiments using depleted uranium, and go get satisfied some results. We have got interesting results and manufactured uranium foil. A typical transverse cross section had a minimum thickness of 87 μ m and a maximum thickness of 194 μ m. The average thickness is 120 μ m as a result of calculation.

2. Concepts for Innovating the Foil Fabrication Technology

After issuing this problem KAERI launched a further effort for improving this foil fabrication technology by direct casting on roll in 2008. The ideas of improving the technology were as following; (1) enhancing a longer holding time of thin layer melt as liquid phase for flattening the surface by surface tension, (2) rolling the solidified thin layer for smoothening the upper surface in-situ before cooling much, (3) replacing the slot crucible of quartz with the common plugging type crucible and slot tundish for eliminating the leaking problem of slot quartz, (4) implementing an automatic winding system to avoid the foil to be wrinkled.

3. Design of Equipment and Manufacture

Based on the above ideas, a new equipment was designed as shown Fig. 1. The main components of the equipment consist of main roll for casting, crucible for melting the raw materials, tundish for control-pouring melt on to the rotating roll surface, and a winding system of collecting the out-coming foil. All components are contained in vacuum-tight chamber, which is evacuated by vacuum system.

Fig. 1. New equipment of roll-casting

The diameter of main roll was taken as 600 mm, which is bigger than 400 mm of the existing equipment. The bigger diameter engenders the lower centrifugal force with respect to a certain of tip speed. The material of main roll was chosen in some variety such as steel coated with Al_2O_3, ZrO_2, and tungsten for investigating an effect of thermal conductivity. After an experiment unearthed that a foil could not be formed due to surface tension, the main roll was produced finally with copper.

Ordinarily used graphite crucible was taken for eliminating the leaks of melt of quartz crucible. The charged materials are melted by induction heating and discharged by pulling a blocking plug. The melt flows into a tundish, in which the melt fills up to the height. It acts a pressure on a slot for feeding the melt on to the surface of the main roll steadily. The tundish is made of assembling two parts of graphite. The winding system was designed to drag upward the incoming foil by rotating wheels at out-skirt and to wind the foil by a rotating drum. A space is put between the out skirt and the winding drum for freely winding the foil in many folds. The conceptual design was carried out by KAERI and the equipment manufacture was done by JEONGMIN Industrial Company.

4. Experiments for Foil Fabrication using the New Equipment

In order to avoid this difficulty KAERI developed a new process of making foil directly from uranium melt by PFC. This process is very simple, productive, and efficient. However, this process has revealed some problems. First, the air-side surface of foil is broadly very rough. A typical transverse cross section had a minimum thickness of 108μm and a maximum thickness of 351μm. This roughness could affect target fabrication, where the U foil, or the Ni foil might be damaged during drawing, and irradiation behavior, where gaps between the target walls and the U metal foil might affect cooling of the target[4]. The length was varied with slot gap width, main roll rpm, and the amount of the charged raw material. The maximum achieved length was about 10meters(Fig. 2). Fig. 3 is shown U-foil of the average thickness about 120μm which is appropriate for using irradiation-target. However, the upper surface appeared to be rough same as the previous results meters as in Fig 4. The measured thickness variation of the foil was displayed in Fig. 4.

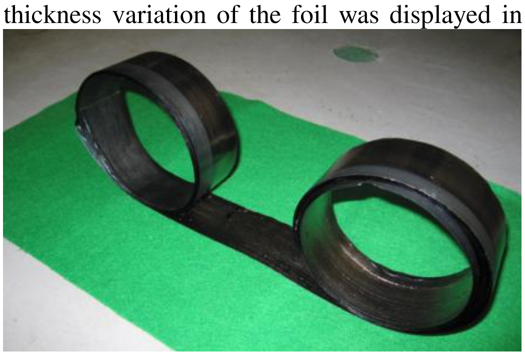

Fig. 2 U Foil produced by roll casting about 10meters

Fig. 3 U foil which Average thickness is 120μm

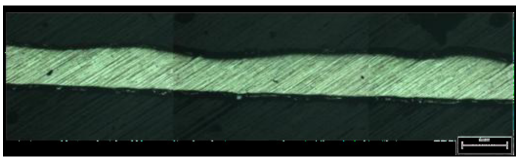

Fig. 4 Cross-section micrograph of U Foil

5. Discussion

When the material with low thermal conductivity was applied for the main roll, the melt tends to agglomerate and splash into many pieces. Cu for roll material is considered to be best. For the melt pouring position the left side of the roll top is very effective for forming the melt to foil. The 2nd roll was too loaded from plastic deformation by pressing on rough upper surface and caused the revolution speed to decrease. When the 2nd roll is removed, a sound thin foil with long length can be made without any disconnection. If this sound foil is roll-worked separately, the newly designed equipment would have some various advantages as followings; (1) thicker foil is available, (2) foil yield is improved much, (3) pouring failure from melt leakage can be reduced much, and (4) slower foil speed at coming out from the slot makes automatic in-situ winding easier.

6. Summary

A new equipment for innovating U-foil making technology was designed and successfully manufactured. Some promising results were obtained such as high yield and easily-controllable thicker foil with reducing melt leakage frequency. If the irregular foil is roll-worked and then applicable to Mo-99 target, this technology is assumed to be very valuable.

7. Reference

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