An Effort to Improve U Foil Fabrication Technology of Roll-casting for Fission Mo Target

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1. Introduction

Mo-99 isotope has been produced mainly by extracting fission products of ^{235}U. The targets for irradiating in reactor have used as stainless tube coated with highly enriched UO_2 at the inside surface and highly enriched UAlx plate cladded with aluminum [1]. In connection with non-proliferation policy the RERTR program developed a new process of Mo-99 using low enriched uranium (LEU) instead of highly enriched uranium (HEU) [2]. LEU should be put about five times more quantity than HEU because the ^{235}U contents of LEU and HEU are 20% and higher than 90%, respectively. Accordingly pure uranium metal foil target was adopted as a promising target material due to high uranium density. ANL and BATAN developed a Cintichem process using uranium metal foil target of 130 μm in thickness jointly and the RERTR program is trying to disseminate the new process world-widely [3]. However, uranium foil is made by lots of times rolling work on uranium plate, which is laborious and tedious [4].

In order to avoid this difficulty KAERI developed a new process of making foil directly from uranium melt by roll casting. This process is very much simple, productive, and cost-effective. But the outside surface of foil is generally very rough. A typical transverse cross section had a minimum thickness of 65 μm and a maximum thickness of 205 μm. This roughness could affect (1) target fabrication, where the U foil, or the Ni foil might be damaged during drawing, and (2) irradiation behavior, where gaps between the target walls and the U metal might affect cooling of the target [5].

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 winkled.

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, the 2nd roll for smoothening the upper foil 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.

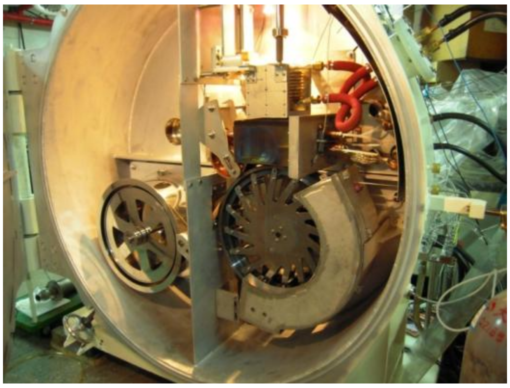

Fig. 1. New equipment of roll-casting

The diameter of main roll was taken as 600 mm, which is bigger than 400 mm of the existing equipment. The bigger diameter generates 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 revealed that a foil could not be formed due to surface tension, the main roll was manufactured finally with copper.

Commonly 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 a certain of 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 Jeong-Min Industrial Company.

4. Experiments of Foil Fabrication for the New Equipment Using a Surrogate Material of Cu

Copper was taken as a surrogate material of uranium metal because the melting point of 1080 °C is similar with 1130°C of uranium melting point. The experiments of melt-flowing through the slot represented that the actual gap available for melt flowing was about 0.5 mm. A flow pattern of Cu melt from the slot was observed to investigate effects of the melt surface tension. As shown in Fig.2, the melt flow coming out from the slot became narrowing with about 45 degree. It is thought that the effect of the surface tension would be very powerful. Therefore the clearance of the slot from the surface of the main roll should be adjusted as minimum as possible.

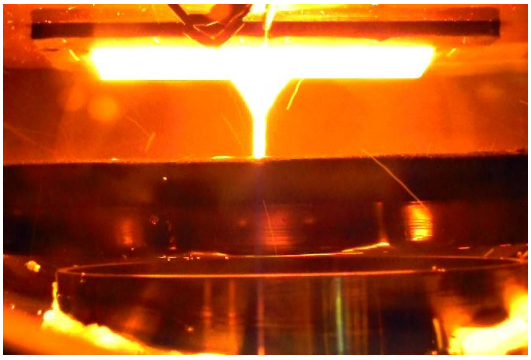

Fig. 2. Melt flow coming down from the tundish slot

Some experiments for fabricating Cu foil were carried out. Cu melt flowing out from the slot was splashed without forming to foil. Even though minimum allowable narrow slot as well as Cu main roll with best thermal conductivity was applied, the splashing phenomenon was not improved. The melt pouring position was changed from the right side of the roll top to the right side of the roll top. In fact, the tundish location was turned in the reverse direction with maintaining the same level. After that the Cu melt formed to foil.

The fraction of forming the foil was observed to be more than 90%. 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 15. However, the upper surface appeared to be rough same as the previous results meters as in Fig 3. The measured thickness variation of the foil was represented in Fig. 4.

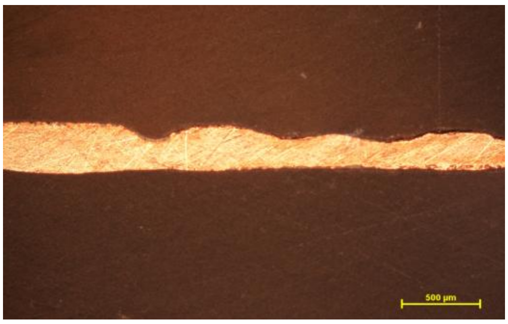

Fig. 3. Cross-section micrograph of Cu Foil

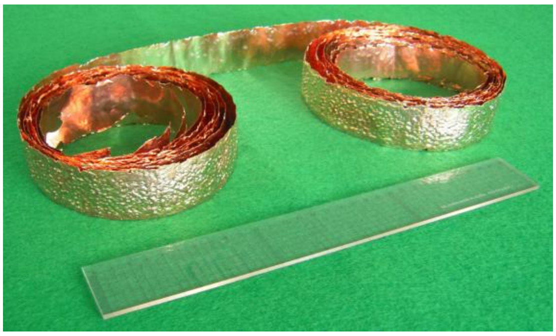

Fig. 4. Cu Foil produced by roll casting

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. Using a surrogate material of Cu for U, some sound foils with various thicknesses were made successfully.

6. Summary

A new equipment for innovating U-foil making technology was designed and successfully manufactured. Through some preliminary experiments using a surrogate material of Cu, 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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