RECENT ACTIVITIES OF KAERI RELATED TO FISSION MO-99

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Contents

1. New Research Reactor Project

- HANARO had been designed and constructed from around the middle of 1980s. The operation has been done from the startup operation in 1995.
- HANARO has been utilized for neutron scattering experiments, irradiation tests of material and fuel for power reactor, RI production, silicon doping, neutron activation analysis, and neutron radiography.
- KAERI challenged to the Pallas and the JRTR projects under the base of the accumulated technologies and experiences.
- Fortunately KAERI was awarded in the bidding of the JRTR project. The design and the construction for the JRTR is underway.

1. New Research Reactor Project

- Korea imports radioactive isotope of Mo-99 and experienced the shortage previously.
- Also the need for silicon transmutation doping service is increasing.
- This motivated KAERI to construct a new research reactor.
- Additionally a U-Mo dispersion plate fuel production line using atomized U-Mo power in KAERI will be constructed to supply the fuel for the new reactor according to the non-proliferation policy.

1. New Research Reactor Project

- Objective
  - ❖ A new research reactor which adopts the features that HANARO does not have.
    - ➢ Bottom-driven control rod mechanism for easier movement of irradiation targets
    - ➢ U-Mo plate type fuel
  - ❖ Fulfilling the national RI demands
  - ❖ Enlarging the neutron transmutation doping capacity
- Status and Plan
  - ❖ A feasibility study has been conducted positively by a governmental institute(Korea Development Institute).
  - ❖ The government allocated some budget for the new reactor project.
  - ❖ The associated fund is expected to be supplied through National Assembly Approval from 2012.
  - ❖ Proposed project period : 2012~2016

1. New Research Reactor Project

- The designed major characteristics for the new research reactor are as follows:
  - Reactor power: ~20 MW
  - Reactor type: Pool type
  - Maximum thermal flux: > 3.0×10^{14} n/cm^{2}s
  - Operation: ~300 days/year
  - Fuel: LEU U-Mo Plate type fuel
  - CEDM (Control Element Driving Mechanism) location: bottom of core
  - Reflector: Beryllium and Graphite
  - Reactor life: 50 years
- The reactor site will be located in Gijang-gun, which is a county near Busan city.

1. New Research Reactor Project

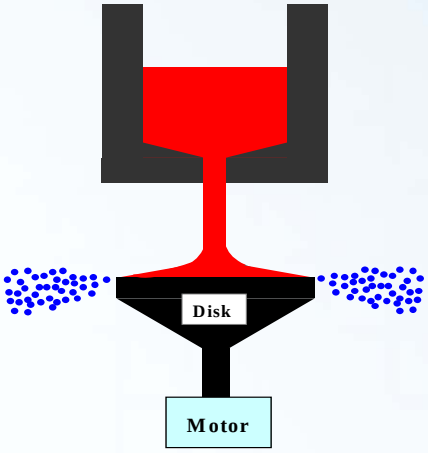
- The major utilization targets are radio-isotope production and neutron transmutation doping.
- The majority of isotope productions will be produced in this reactor including Mo-99, and the capacity will be decided enough to fulfill the national demand and for exportation to regional countries.
- After the completion of the project, the irradiation service functions of HANARO for isotopes will be turned over to the new reactor.
- HANARO will focus on neutron scattering experiments and fuel/material development.

2. Atomized Uranium Particle Dispersion Target

- Many commercial scale Mo-99 producers are using a dispersion plate type target of uranium aluminide.
- The uranium aluminide targets are limited to 3.0 g-U/cc in uranium density of the target meat.
- A high uranium density target using the uranium metal particles dispersion plate target is suggested with taking an advantage of the atomized U powder.
- The target is presumed to be applicable from the low burnup and very short irradiation time.

2. Atomized Uranium Particle Dispersion Target

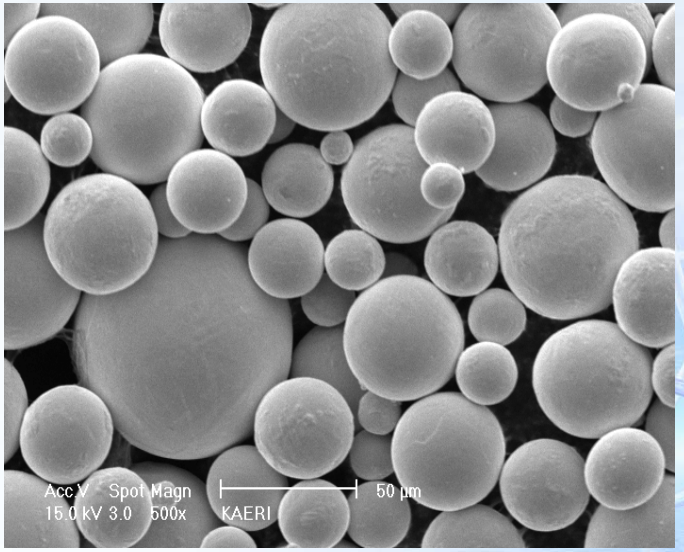
Atomization Technology



Principle

Atomizing

Atomizer

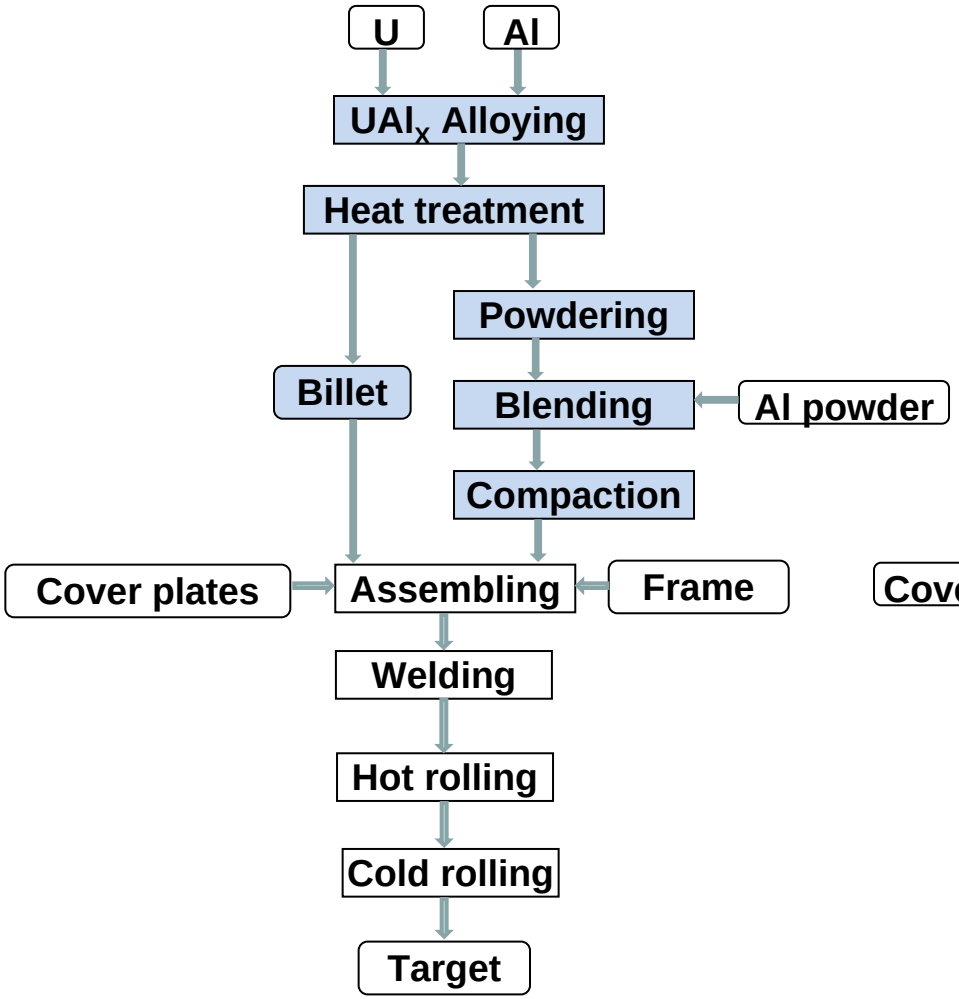


Atomized Particles

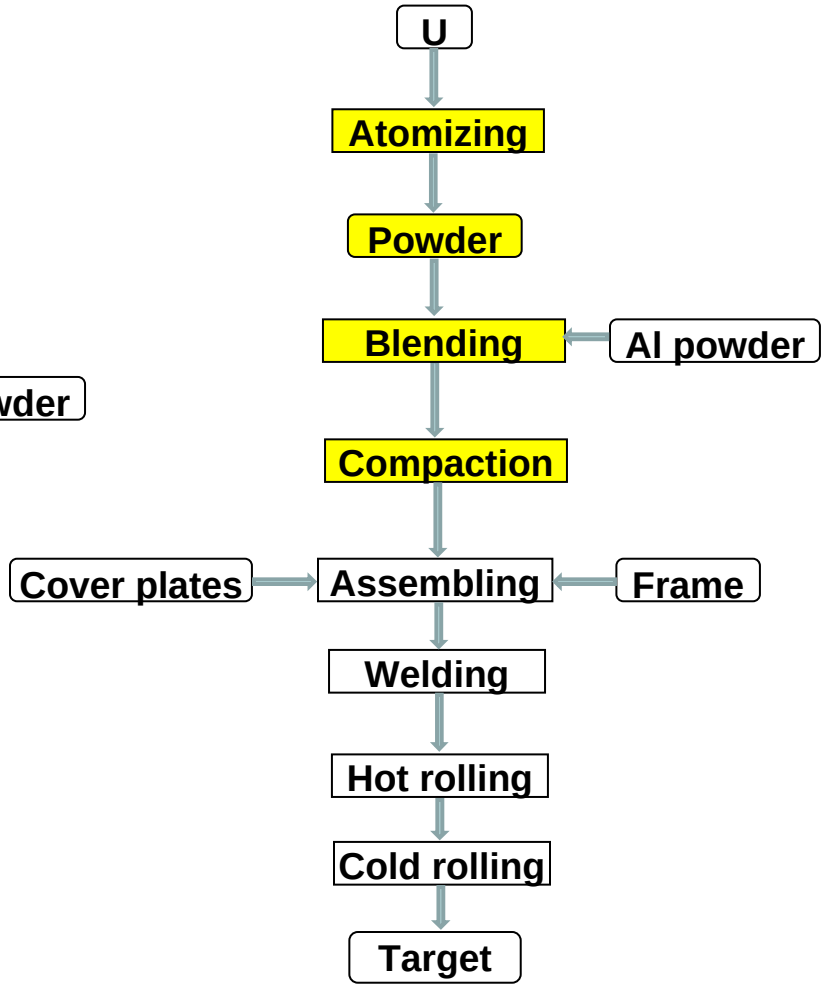
2. Atomized Uranium Particle Dispersion Target

- The atomized particles dispersion fuel could attain some higher density from smooth surface of spherical shape particles.
- Under the base of 45 vol.% in U_3Si_2 dispersion fuel, the corresponded density in uranium metal powder dispersion would be about 8.5 g-U/cm^3.
- The equivalent density for 1.5 g-U/cm^3 in HEU target is about 7.5 g-U/cm^3.
- The atomized U powder dispersion target of more than 8.5 g-U/cm^3 would be applicable.

2. Atomized Uranium Particle Dispersion Target



Existing Process



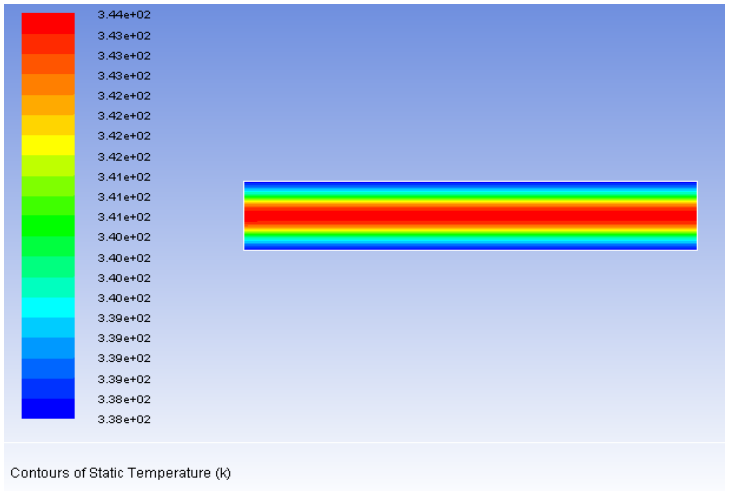
Atomized U particles Process

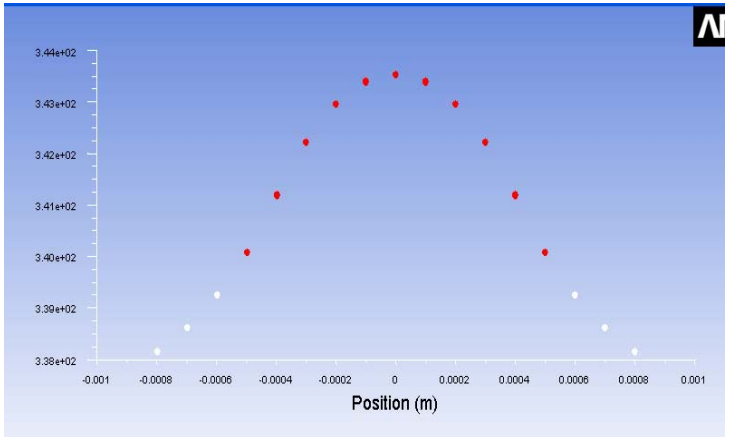
Beneficial Aspects of Atomized Particles

- Available for Mass Production
  - ➢ One batch for two days
  - ➢Batch capacity is about 5 kg, which is depending on the criticality control
- Rapid solidification: about 10^4 ℃/sec
  - ➢ Very fine grain: a few microns
  - ➢ Tendency to form random orientation
  - ➢ Better stability in irradiation performance
- Spherical shape
  - ➢ Better formability in rolling process
  - ➢ Lower porosity in as-fabricated dispersion meat
  - ➢A little higher U density than dispersion meat of irregular particles
  - ➢ A littler better conductivity

2. Atomized Uranium Particle Dispersion Target

- The temperatures was calculated using the PLATE computer code developed by ANL
- Boundary condition
  - Heat flux: 250 W/cm^2
  - Cooling water: 6 m/sec
  - Target meat thickness: 1.0 mm
  - Cladding thickness: 0.3 mm
  - Coolant out temperature: 40 ℃
- Estimated thermal conductivity of dispersion: about 85 W/m-K.
- Estimation
  - ΔT for dispersion target meat: 4.5 ˚C
  - ΔT for cladding: 1.5 ˚C
  - ΔT for interface: 25 ˚C
  - Temp. at center: 71 ˚C
- The temperature of about 71 ˚C would be too low to induce the interface interaction.





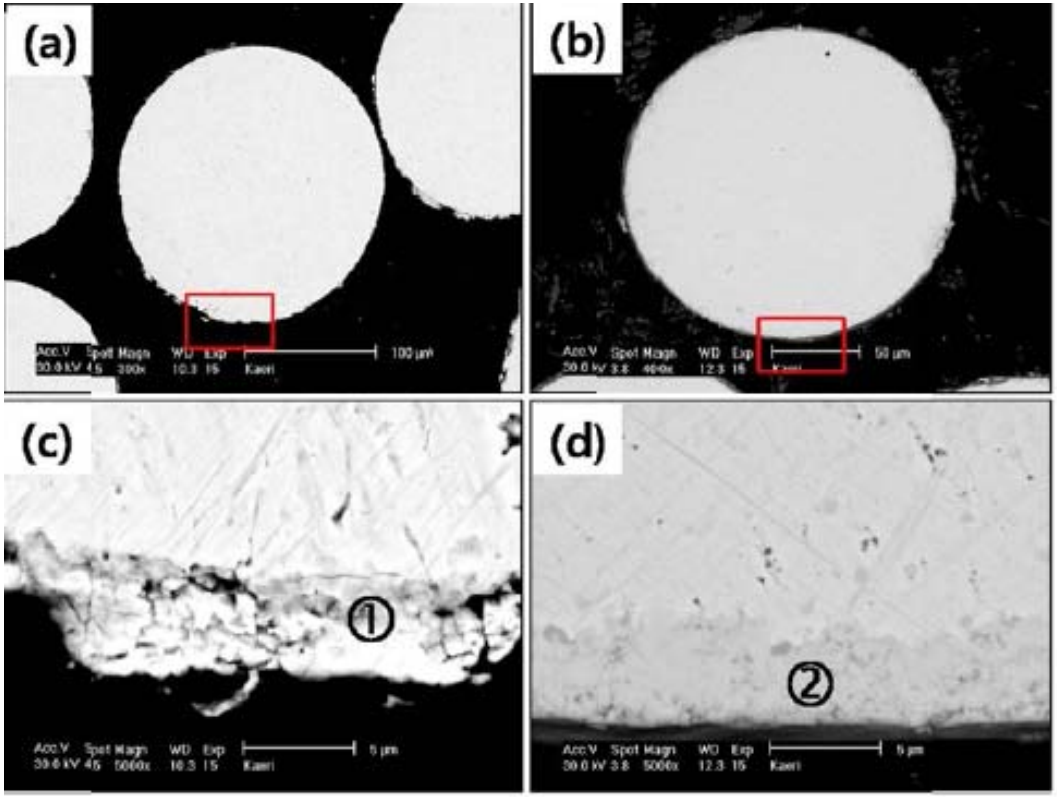
2. Atomized Uranium Particle Dispersion Target

Further improvement for the target performance

- Grain refining
  - Making uranium particles with alloying some elements of Fe, Si, Al, Cr by adding the alloying elements into the crucible during atomizing
- Retarding interaction Rate
  - Silicon addition to aluminium matrix
  - Coating nitride on uranium particles

2. Atomized Uranium Particle Dispersion Target

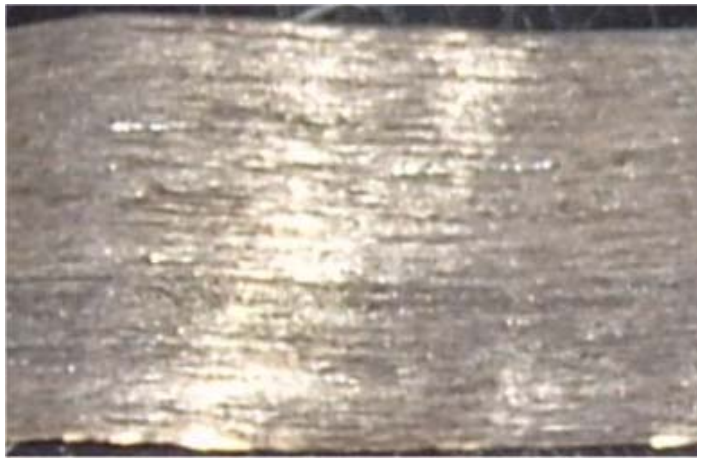
Nitride coating on atomized U particles



. Cross-sectional scanning electron micrographs of U-7wt%Mo powders
(a) as-atomized powder (b) nitride coated powder
(c) enlarged micrograph of (a) (d) enlarged micrograph of (b)

3. Further Development on U Foil Fabrication

- KAERI developed a process of directly forming foil from the melt by roll casting for LEU foil.
- Some foils were distributed to various countries. However, a drawback on KAERI foil was issued.
- The foil thickness is so inhomogeneous that some difficulties would be possibly suffered in applying to fission Mo target.
- KAERI made efforts on improving the foil quality as well as the fabrication efficiency in 2008.



3. Further Development on U Foil Fabrication

Previous system

Quartz crucible with open nozzle

-Approaching
-Feeding melt with pressure

Roll casting

-Diameter of 400 mm
-Higher speed at about 500 rpm
-Flying from strong centrifugal force

Collection of foil in space

-Crumpling in foil

New system

Graphite crucible with plugging

Tundish
•With nozzle

-Without approaching movement
-Feeding melt with self-gravity

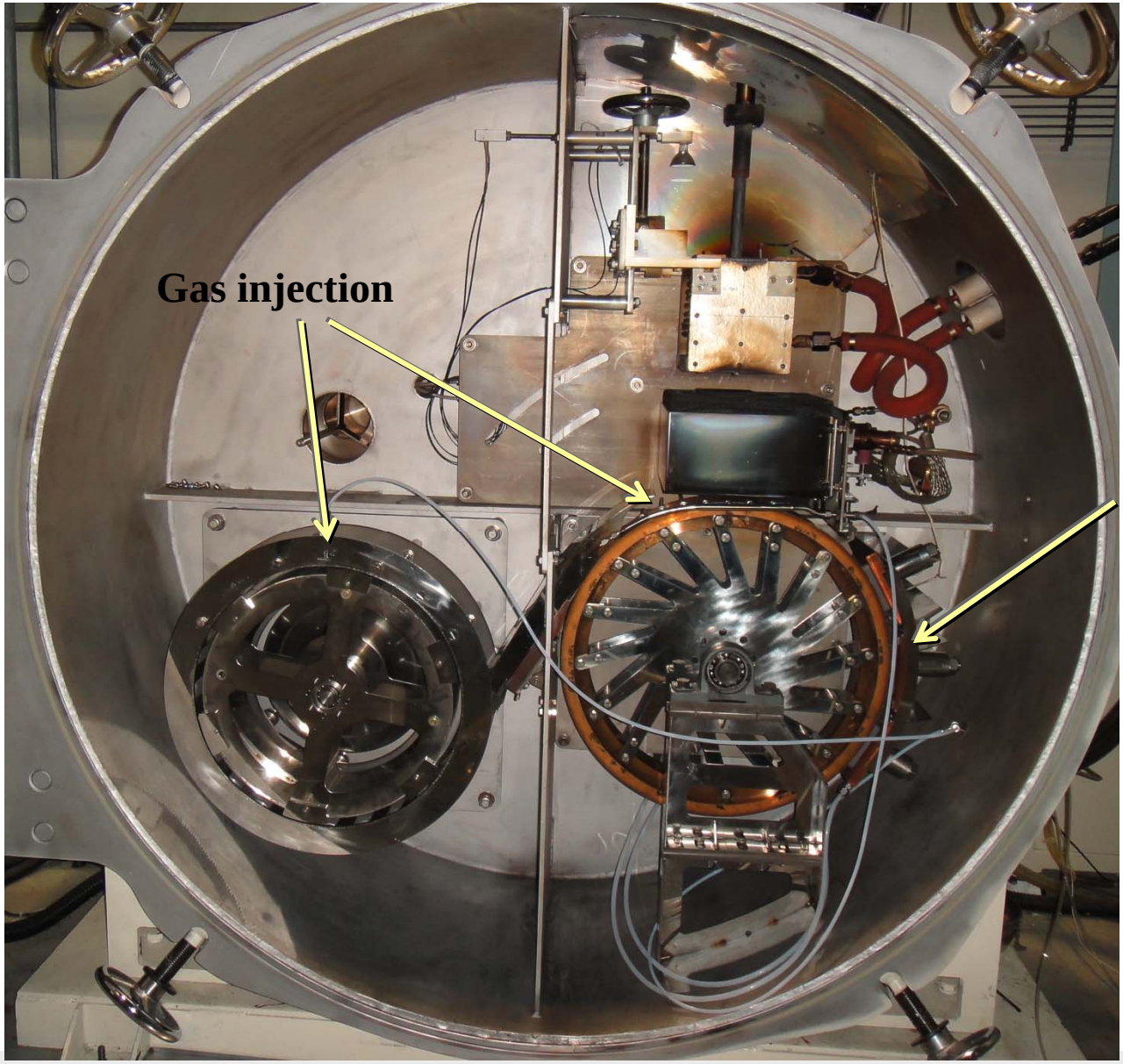
Roll casting

-Diameter of 600 mm
-Higher speed at about 60 rpm
-Suppressing with gas injection on to solidifying

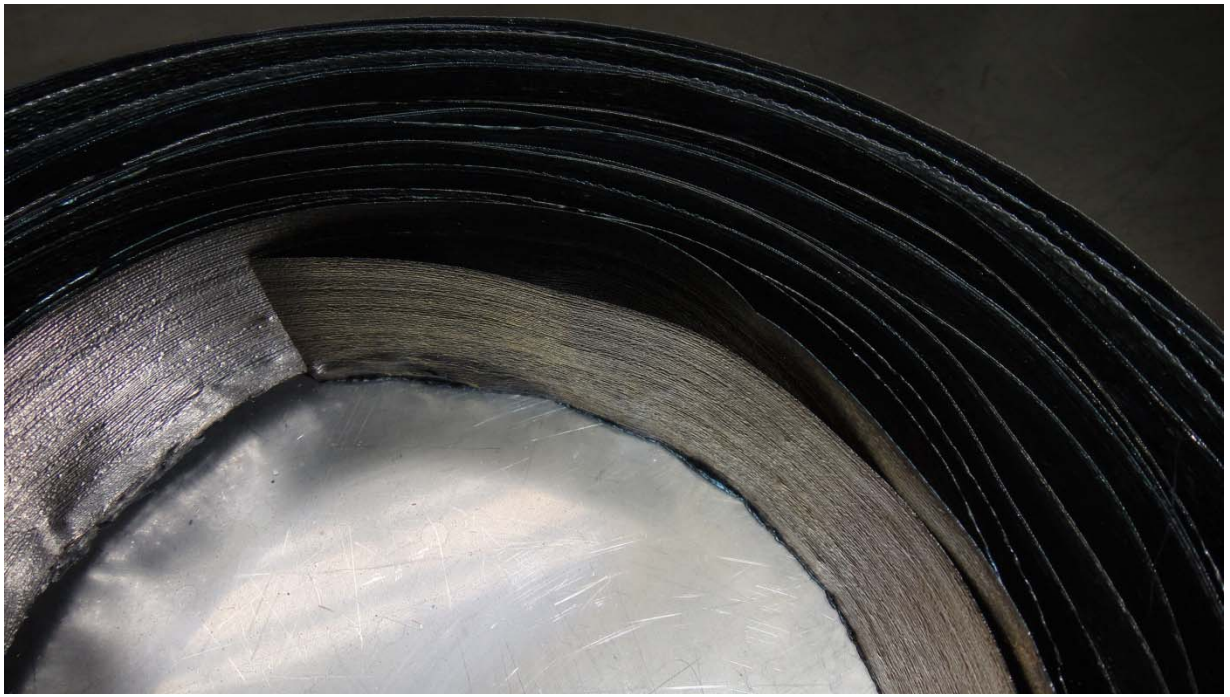
Collection of foil in space

-Straitened foil without any crumbling

3. Further Development on U Foil Fabrication

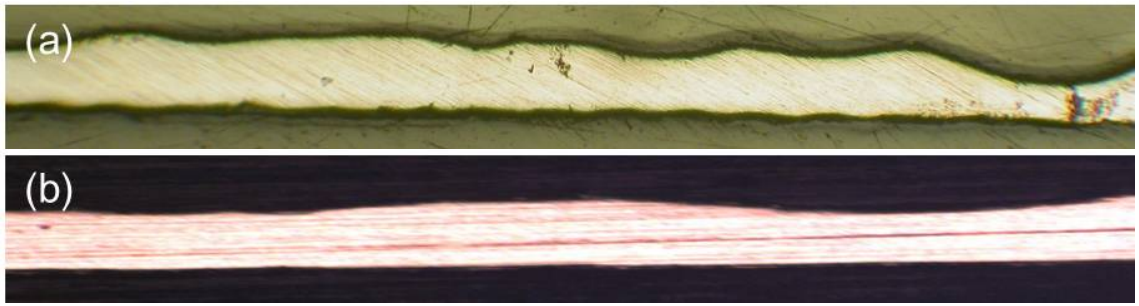


3. Further Development on U Foil Fabrication



Previous

Present



3. Further Development on U Foil Fabrication

	Front end part	Middle part (5m from front tip)	Tail part (10 m from front tip)
width(mm)	6.5	5.2	4.2
thickness	199	182	167
	198	160	136
	221	242	198
	172	176	203
	119	169	124
	150	120	107
	158	133	120
	136	146	136
	131	131	127
	139	142	146
average(μm)	135	139	145
standard deviation	34	35	33

3. Further Development on U Foil Fabrication

- The foil thickness was effectively controlled by revolution speed of casting roll and the clearance between melt feeding nozzle tip and casting roll surface.
- By additional installation of diffusion vacuum pump and the precise maintenance for connection parts, the foil appeared more ductile with having luster surface.
- The upper free surface of solidifying foil was changed from short range regularity to longer range regularity. The roughness of the upper surface got a little improved through this development effort.
- The cooling jacket pad affected positively to form sound foil without any holes.

4. Summary

- New Korean Research Reactor
  - The project was fixed through a feasibility study of KDI. The associated fund will be provided through approving the nation assembly from next year.
  - The construction project is expected to be for 5 years from 2012.
  - The reactor will be utilized for radio-isotope production and neutron transmutation doping.
  - The production capacity of Mo-99 will be decided enough to fulfill the national demand and for exportation to regional countries.
- Atomized Uranium Particle Dispersion Target
  - The uranium density would be up to 8.5 g-U/cm^3.
  - The target performance could be improved by alloying and coating.

4. Summary

- Further development on U Foil Fabrication
  - A sound uranium foil could be produced by adapting cooling jacket pad, forcing down the forming foil by Ar gas injection, accurately controlling the clearance between melt feeding nozzle tip and casting roll surface.
  - The thin sound foil approaching to 135μm without any holes was obtained.
  - The foil yield was advanced with producing long foil of more than 10 meter.
  - The foil roughness was not much improved.