Research Approach of MCCI products characterization for debris removal

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1. Background and Objectives of the research

In Fukushima daiichi nuclear power plant (1F) unit 1 and 3, **M**olten **C**ore-**C**oncrete **I**nteraction (MCCI) would occur [1]. MCCI products in PCV will be sampled before sampling of fuel debris in RPV. Although MCCI products are complex materials because of mixture of fuel debris and concrete, MCCI research does not focus on MCCI products handling after accident, but it focuses on severe accident progression. Therefore, urgent and effective collection of information on MCCI products is needed for 1F decommissioning.

This research objective concerning MCCI products is to pick up needs of 1F decommissioning, to plan and to advance higher-priority research.

2. Picking up needs of 1F decommissioning

Needs		Related On-site Task(○) / R&D Approach(●)	
a)	Distribution in PCV	o Radiation protection, Defueling, Criticality management	
		• Severe accident analysis etc...	Result
b)	Inventory	o Radiation protection, Criticality management	
		• Severe accident analysis etc...	
c)	**Characteristics**	o Sampling, Defueling, Analysis, transportation and Conditioning of debris	
		• Labo-scale experiments, thermodynamic calculation etc...	
d)	Analysis technique	o Sampling, analysis, conditioning, measuring control	
		• Labo-scale experiments etc...	Result

- Results of severe accident analysis are used in characterization.
- On the other hands, research of severe accident analysis and characterization is advanced in parallel, because results of characterization will be offered to on-site task such as sampling and defueling by the end of 2015 JPY.
- Plan and advance of characterization research is discussed here.

3. *Planning higher-priority research*

Mechanical, thermal and chemical properties are necessary for sampling, defueling and analysis. These properties depend on their chemical form. Therefore chemical form of 1F MCCI products is evaluated at first. Research is advanced with CEA which has much MCCI test products and knowledge.

3.1. Research method

i. Chemical form estimation

a) Thermodynamic equilibrium calculation :
Chemical form of 1F MCCI products and VULCANO MCCI test products is estimated with the CALPHAD method and thermodynamic data on concrete and fuel debris.

b) SEM-EDS and XRD analysis of MCCI test samples :
Chemical form of VULCANO MCCI products is analysed and compared with calculation results.

ii. Properties evaluation

c) Measurement of mechanical and chemical properties of MCCI test samples :
The properties of VULCANO test samples are measured with chemical form.

d) Estimation of thermal property with thermodynamic data base

3.2. Schedule

Year	Simulation & desk study	Experiment
2013	a) Thermodynamic calculation	*4.* → *5.*
2014 - 2015	b) Comparison of 1F and VULCANO condition d) Thermal property estimation	b, c) Characterization of past VULCANO test samples
2016~		b, c) Characterization of 1F simulating VULCANO test products *(with CEA)*

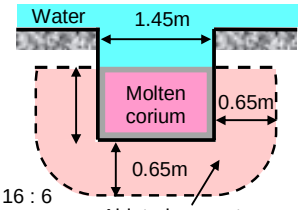
* Typical characteristics are estimated by the end of 2015 JPY.
* Schedule after 2016 is tentative and under discussion.

4. Previous research results: ~Estimation of MCCI products by thermodynamic calculation~

4.1. Calculation condition

Chemical form of 1F MCCI products was estimated with thermodynamic equilibrium calculation [2]. Calculation condition is shown as below:

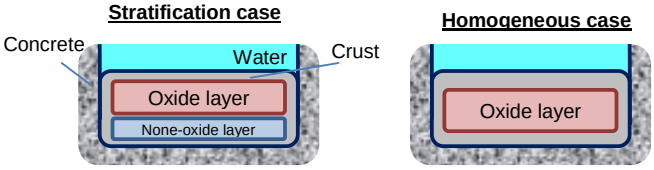
- Software: FactSage 6.2
- Database: NUCLEA ver. 2005-01
- Corium composition [mass%]:
  UO_2 : Zr : Fe = 61 : 25 : 14
  Amount of oxide is changed
- Concrete composition [mass%]:
  SiO_2 : CaO : Al_2O_3 : Fe_2O_3
  = 64 : 13 : 16 : 6



Ablated concrete estimated by TEPCO[1]

4.2. Results

- Chemical form of the bulk of 1F MCCI products was estimated on thermodynamic equilibrium condition. Typical components are (U,Zr)SiO_4, UO_2 and $CaAl_2Si_2O_8$. In the case of stratification, Fe_xSi_y and Fe-Si alloy would be detected in non-oxide layer.
- Chemical form of the crust around molten pool was estimated on Scheil model. Typical components are (U,Zr)O_2 and $CaAl_2Si_2O_8$. The amount of (U,Zr)SiO_4 increases with oxidation.



Typical chemical form

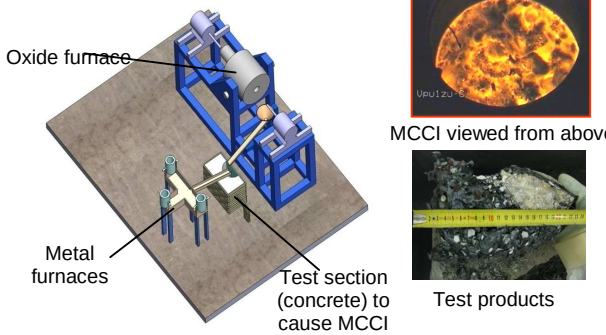
Stratification case	Homogeneous case
Crust: (U,Zr)O_2, $CaAl_2Si_2O_8$ Oxide layer: (U,Zr)SiO_4, UO_2, $CaAl_2Si_2O_8$ Non-oxide layer: Fe_xSi_y, Fe-Si alloy	Crust: (U,Zr)O_2, $CaAl_2Si_2O_8$ Bulk: (U,Zr)SiO_4, UO_2, $CaAl_2Si_2O_8$, $(Fe,Al)_3O_4$

5. Current and future research: ~Cooperation program with CEA~

5.1. Phase I: Characterization of previous VULCANO test samples

a. VULCANO test samples having similar conditions to 1F unit 1 are selected with MCCI simulation, experience and knowledge.

b. Chemical form, mechanical and chemical properties of selected test samples are analysed.



VULCANO facility (offered by CEA)

5.2. Phase II (tentative): VULCANO test simulated 1F unit 1

a. VULCANO test simulated 1F unit 1 is carried out.

b. MCCI behavior such as concrete ablation rate and characteristics of test products is evaluated.

6. Summary

- Although MCCI products will be sampled before sampling of fuel debris, knowledge on MCCI products handling is limited. Higher-priority research on it is selected, planned and advanced.
- Characteristics of MCCI products are evaluated with thermodynamic calculation and previous VULCANO test samples. Typical characteristics are estimated by the end of 2015 JPY.
- Characterization of MCCI products has been advanced with CEA.
  - JAEA estimated chemical form with thermodynamic calculation.
  - CEA has been analysing previous VULCANO test samples.

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Reference: [1] TEPCO press release on 30 Nov.2011 in Japanese, http://www.tepco.co.jp/nu/fukushima-np/images/handouts_111130_09-j.pdf
[2] T.Kitagaki et al., Proc. NuMat 2014: the Nuclear Materials conference, Florida, USA, Oct. 27-30, (2014)