Analysis of Irradiation Ability of China Experimental Fast Reactor

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Abstract. China Experimental Fast Reactor (CEFR) completed physics start-up tests in 2010 and connected the grid on full power in 2014. Characteristic of neutron field for irradiation in CEFR has been researched by calculation and experiments. In future, CEFR will be operated as an irradiation test facility for fuel, material and other application. Now some irradiation projects, such as irradiation of cladding material, MOX fuel and (U, Np)O_2 pellet have been planned.

Key Words: CEFR, Irradiation.

1. Introduction

China Experimental Fast Reactor (CEFR) is the first fast reactor in China with thermal power of 65MW and electrical power of 20MW. CEFR is a pool type sodium cooled fast reactor which has a three circuit of sodium-sodium-water thermal transfer system consisting of two independent loops in parallel. The first fuel loading in CEFR is UO_2 with 64.4% enriched ^{235}U **Error! Reference source not found.** .

CEFR achieved its first criticality on 21 July in 2010 and connected the grid on 21 July in 2011. By the end of 2016, CEFR has operated in full power more than 500 hours. Now the first great maintains of CEFR has been carried out and CEFR will startup again in Feb 2017.

2. Overview of CEFR

The CEFR core has been shown in FIG.1. There are 81 subassemblies in CEFR core form first ring to 6th ring for operation loading. 8 control rods (3 Safety rod, 3 Shimming rod and 2 Compensation rod) have been set in CEFR core.

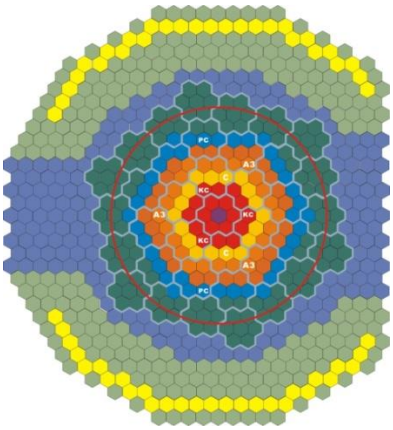

FIG.1. CEFR core

TABLE1: THE MAIN PARAMETERS OF CEFR CORE

Parameter	Value
Normal power	65 MW
Fuel	UO_2(64.4%), MOX later.
Max.neutron flux	E < 0.1MeV, $3.2\times10^{15}cm^{-2}s^{-1}$ E > 0.1MeV, $2.5\times10^{15}cm^{-2}s^{-1}$
Max./Ave. burnup	60.0/44.5 MWd/kg
Core Height/diameter	450/600mm
UO_2 mass	428kg
Max linear power	43 kW/m
Refuel period	80 d
Staying time in the core of fresh fuel S.A.	inner, $3T_r$; outer, $4T_r$.
Staying time in the core of spent fuel S.A.	2,3 T_r

The main parameters of CEFR are given in TABLE 1. The maximum fast neutron flux in CEFR core is $2.5\times10^{15}cm^{-2}s^{-1}$ and the maximum linear power is 43kW/m. One refuel cycle is approximately 80 EFPDs and typical CEFR operational schedule will complete three cycles per year.

3. Introduction of irradiation ability in CEFR

CEFR is a well platform for fuel and material irradiation tests and some irradiation subassemblies have been set in CEFR core for different objectives.

3.1. Irradiation in CEFR core

In principle, each position in CEFR core could be inserted the test assembly for irradiation if the change of neutron physics and thermodynamic character is under the safety limitation. The neutron flux distribution and the neutron spectrum in CEFR core have been shown in FIG.2 and FIG.3. The total neutron flux in fuel zone is more than $2.0\times10^{-15}cm^{-2}s^{-1}$ and the fast neutron flux is more than $1.5\times10^{-15}cm^{-2}s^{-1}$. The neutron spectrum in fuel zone and reflector zone has been shown in Fig.3.

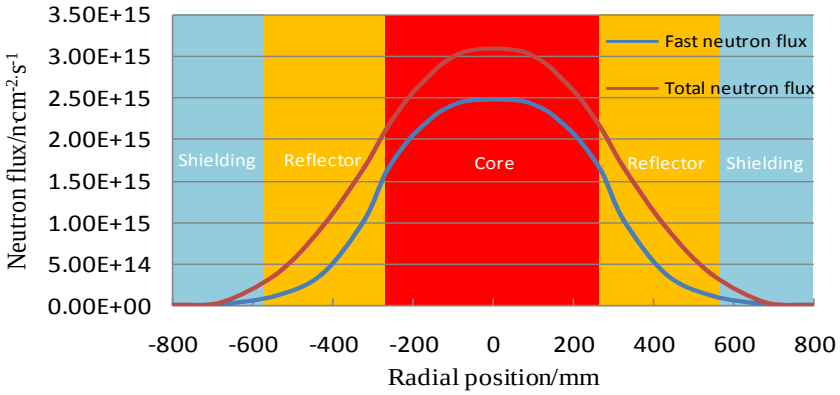

FIG.2. Neutron flux distribution in CEFR core

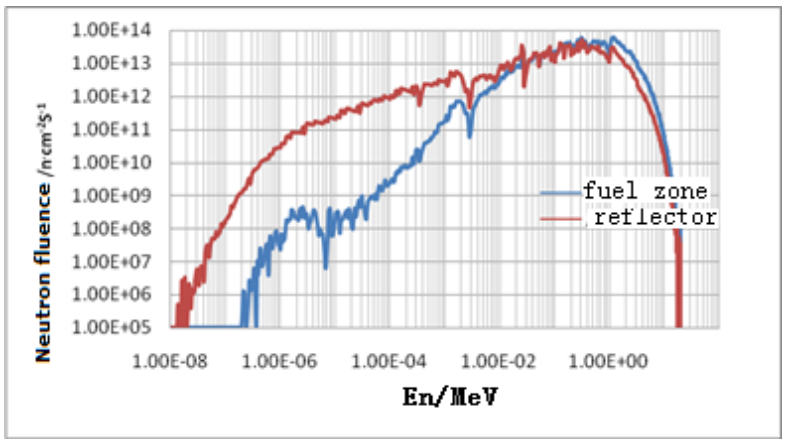

FIG.3 Neutron spectrum in CEFR fuel zone and reflector zone

The neutron flux and the maximum irradiation damage in different round in 80 EFPDs have been shown in TABLE 2.

TABLE 2: THE NEUTRON FLUX AND THE MAX. IRRADIATION DAMAGE IN CEFR CORE

Position	Neutron flux, $n\cdot cm^{-2}\cdot s^{-1}$	Max irradiation damage, Dpa/80 EFPDs
Center position	3.2×10^{15}	8.6
2nd round	3.2×10^{15}	9.3

6th round	2.3×10^{15}	6.4
7th round	1.9×10^{15}	4.5
8th round	1.5×10^{15}	2.6
9th round	7.1×10^{14}	0.8
10th round	4.4×10^{14}	0.5
11th round	3.1×10^{14}	0.3
13th round	1.4×10^{14}	0.2
15th round	2.9×10^{13}	0.04

The fuel zone is from center position to 6th round and the 7th round is the reflector zone. The test assemblies could be inserted into the above-mentioned region.

3.2. Irradiation test channels

There are some irradiation tests channels in CEFR. These channels are prepared for specific objectives, such as nuclear instruments irradiation. Some irradiation channels, such as irradiation channels in the small rotating plus, could be upgraded to install a test loop for fuel and material irradiation. The position of irradiation channels have been shown in FIG.4. The channels are all located in rotating plug of CEFR, and there is no other horizontal channel in CEFR.

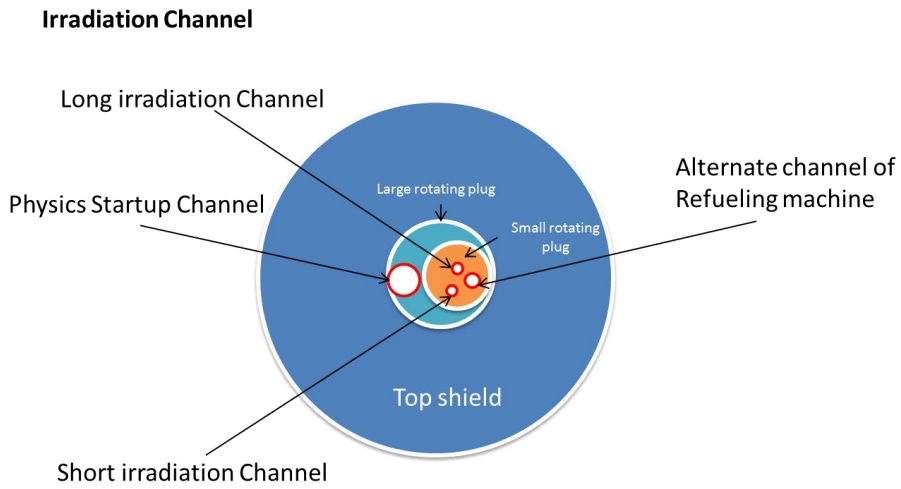

FIG.4 Irradiation test channel to be prepared in CEFR

3.3. PIE

There is a non-destructive examination hot cell close to spent fuel pool in CEFR nuclear island. In the hot cell, the visual inspection, dimensional measurement of SA and pin, X-ray radiography, gamma scanning and eddy current exam could be carried out.

By using non-destructive examination hot cell, the primary performance of the irradiated test assembly and spent subassembly could be obtained.

There is also a destructive examination hot cell in CIAE and the irradiated test fuel pins and the specimens from CEFR could be transported to the hot cell. Some PIE facilities have been installed in the hot cell, and sample cutting, punch test, tensile test, metallographic and

density measurement could be carried out. A new advanced PIE hot cell has been built in CIAE and will operate in 2021.

Considering the material irradiation in CEFR core, the neutron dosimetry detector which includes seven foil detectors has been designed. By using dosimetry detector the neutron spectrum in the irradiation position could be measured. And this utility could be applied to estimate the radiation damage in materials under neutron irradiation in CEFR core. The irradiation test assembly and the neutron dosimery detector have been show in FIG.5.

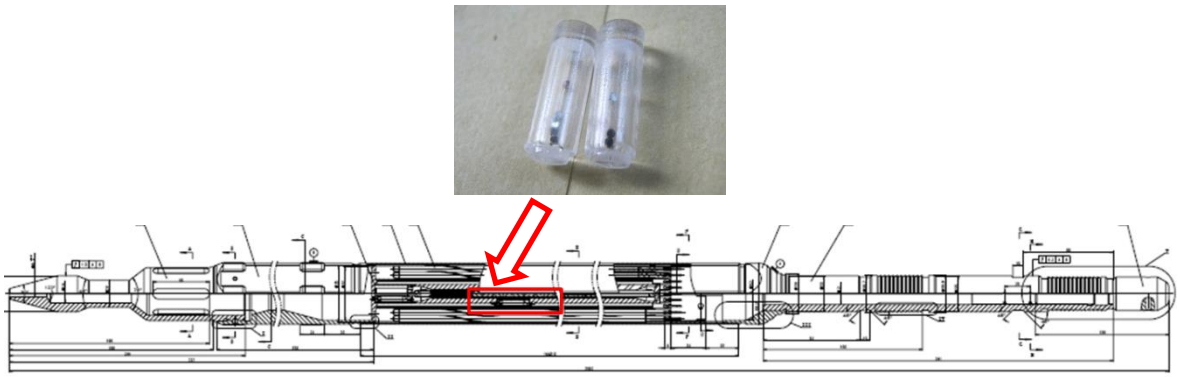

FIG.5 Irradiation test assembly and the neutron dosimetry detector

The neutron dosimetry Lab with high-purity germanium γ spectrometer system has been built to measure the activity of the neutron dosimetry detector and to estimate the neutron fluence and dpa of the irradiated specimens in CEFR core.

4. Irradiation test plan

CEFR is a well test platform for fuel and material irradiation. The irradiation test plan in CEFR within a few years is given in TABLE 3.

TABLE 3: THE IRRADIATION TEST PLAN IN CEFR

Project \ Irra. Time	2014	2015	2016	2017	2018	Purpose
316 (Ti) SS cladding material (ongoing)	1					CEFR fuel development
CN15-15Ti SS cladding material				2		CFR600 material development
B_4C absorb material				2		CFR600 control rod development
Block material					2	CFR600 block material
CEFR MOX test fuel					2	CEFR fuel development
CFR600 MOX test fuel					2	CFR600 fuel development

ODS、FMS material					1	For advanced FR、TWR、ADS
$5\%NpO_2+UO_2$					1	Transmutation technology

The 316(Ti) SS cladding material has been irradiated from 2014. Now the CFR600 which is the first commercial prototype fast reactor in China has been designed and will pour the first concrete in the end of 2017. Many kind of material, such as CN-15-15Ti cladding material, B_4C absorb material, block material using in CFR600 will be irradiated in CEFR in recent years.

CEFR will transform to MOX fuel from UO_2 fuel loading in 2022. Now the CEFR MOX fuel test assembly has been developed for future irradiation. The fuel of CFR600 is also MOX, and CFR600 MOX fuel test assembly has been designed and will start the irradiation test in 2018.

Some advanced material for fast reactor such as ODS, FMS material have been researched and developed in China, and the irradiation tests are planned to start in 2018. Additionally, the transmutation in fast reactor has been researched several years in China. The $(U,Np)O_2$ pellet and test fuel pin are developing and the irradiation subassembly is designed for CEFR transmutation test.

5. Conclusion

CEFR will become a well irradiation test platform for fuel, material and transmutation irradiation of FBRs. The irradiation tests could be carried out in CEFR core by inserting the irradiation test assembly into fuel zone and the reflector. Some irradiation channels in CEFR could be used for specific objectives. The non-destructive and destructive examination hot cells have been built in CIAE using for PIE of irradiated specimens. Some fuel and material for CFR600 and other FBRs will be irradiated in CEFR in future.

REFERENCES

[1] Tian, H., 2002. The design description of China Experimental Fast Reactor (CEFR). Technical Report of China Experimental Fast Reactor, CEFR01Z19LWS01-SM, 2002 (in Chinese).