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Sleeveless fuel compact support: spacer design and flow-induced vibration analysis in HTGR

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INTRODUCTION

Sleeveless fuel compact

→ an innovative fuel design for

High-Temperature Gas-cooled Reactor (HTGR)

higher heat removal efficiency by direct cooling method

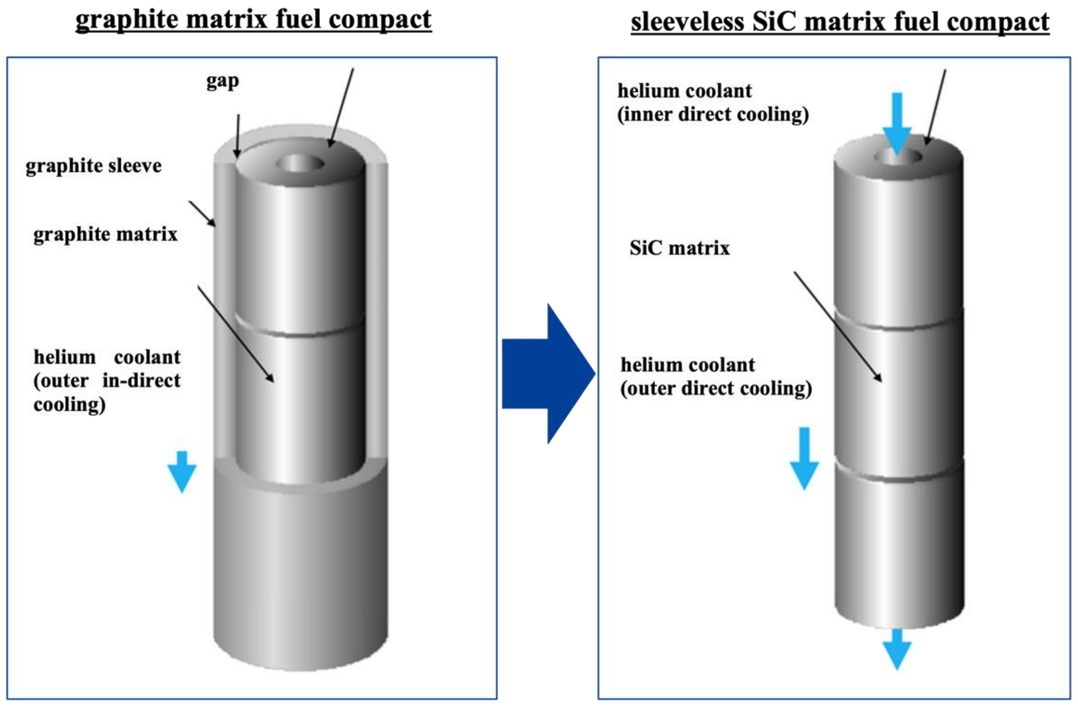


Fig. 1. Illustration of sleeveless SiC-matrix fuel compact design
Left: conventional design with graphite-matrix
right: newly proposed design with SiC-matrix

Target model: *HTR60S*, updated core by Japan Atomic Energy Agency (JAEA)

1.2 times higher power density **operation than previous model HTR50S [ref. 1]**

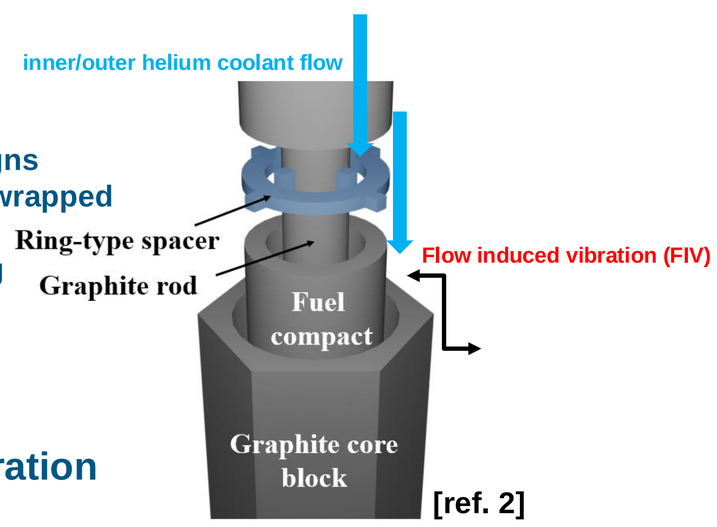
Concerning issue

- **How to support each fuel compact without sleeve**
- **Designing fuel spacers is a major challenge**

The fuel spacer 1) supports fuel compacts, 2) maintains open flow channels, 3) stabilizes all fuel components while minimizing vibration, mechanical wear, and mechanical/thermal stress

Objective of this study

- Introduces four types of spacer designs including ring-type and helical wire-wrapped
- Produces real-scale prototypes using 3D printer
- Experiment on **pressure loss *ΔP***
- Experiment on **flow-induced vibration**

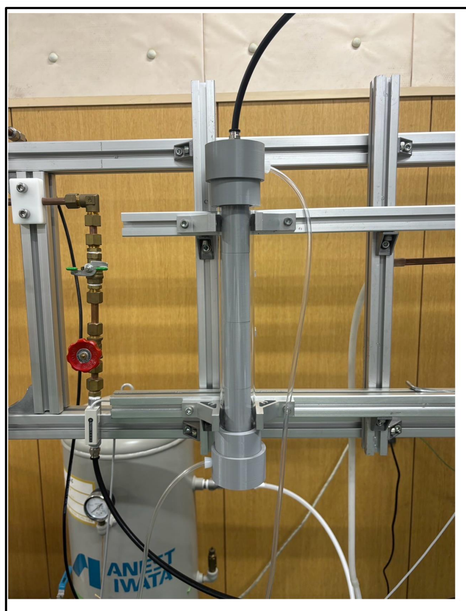


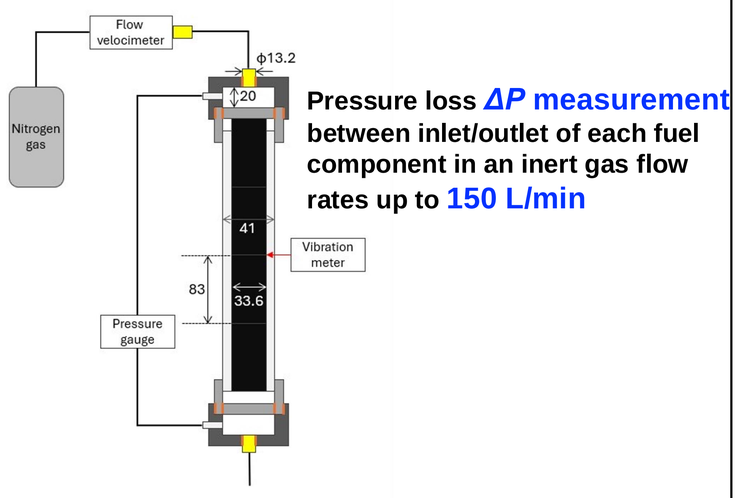
[ref. 2]

To ensure structural integrity and optimize the fuel spacers design

EXPERIMENTAL

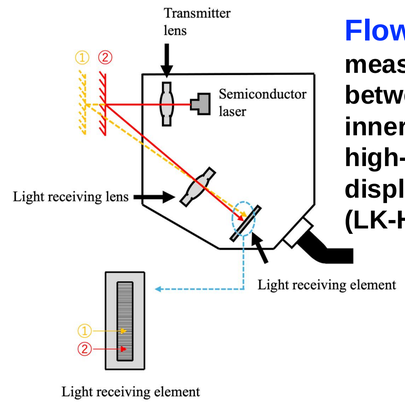
Fig. 2. CAD model and dimensions for each fuel component including ring-type and helical wire-wrapped fuel spacers design with varied structures and configurations





Pressure loss *ΔP* measurement between inlet/outlet of each fuel component in an inert gas flow rates up to 150 L/min

Fig. 3. Experimental facility of the pressure loss measurements (left) and illustration of the measurement system (right).



Flow induced vibration measuring the displacement between outer acrylic pipe and inner fuel compact using high-precision laser displacement sensor (LK-H020 KEYENCE, JAPAN)

Fig. 4. Measurement of the displacement in the gas flow (left) and measurement technique using the high-precision laser (right).

RESULTS & DISCUSSION

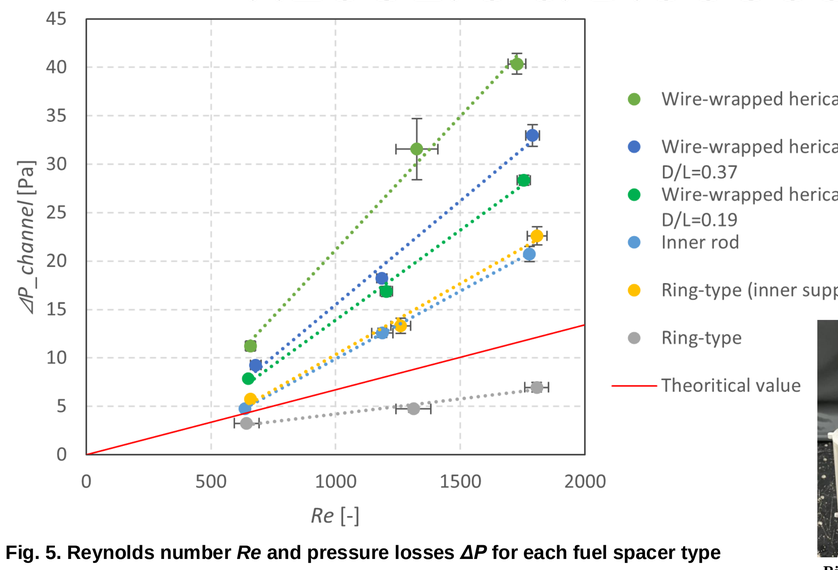
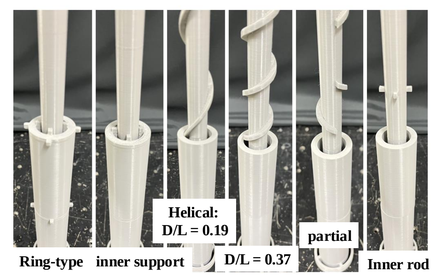


Fig. 5. Reynolds number *Re* and pressure losses *ΔP* for each fuel spacer type



Helical pitch *D/L*: ratio of inner rod diameter *D* and rotation length *L

- **Ring-type spacers cause lower pressure losses: while helical-type spacers higher**
- **Larger helical pitch *D/L*, higher pressure loss**

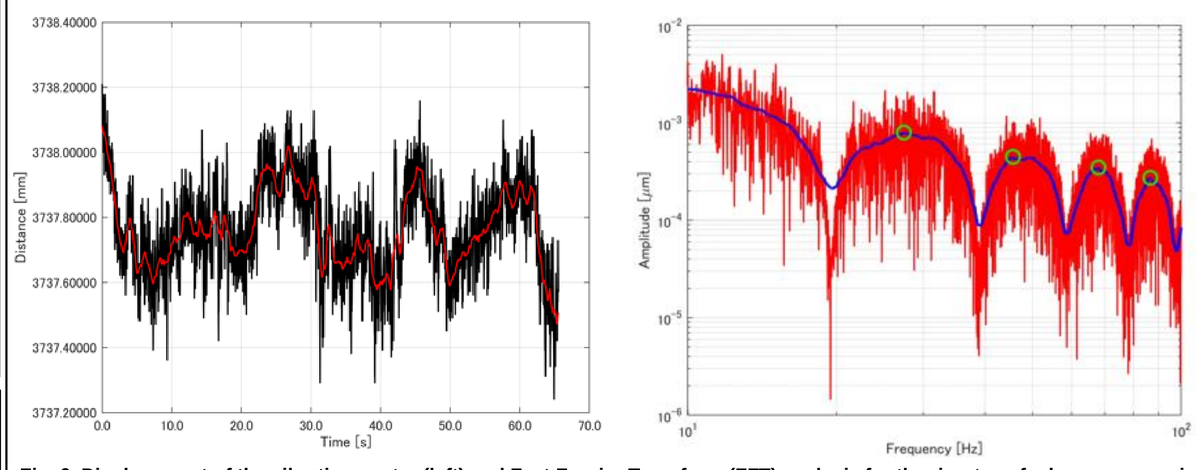


Fig. 6. Displacement of the vibration center (left) and Fast Fourier Transform (FFT) analysis for the ring-type fuel spacer experiment in *Re* = 1800 (right).

- ***No significant vibration* in the laminar flow regime (*Re*~1800) for ring-type spacers**
- **The dominant (1st order) frequency is much lower than structural frequency of HTGR**

CONCLUSION

- **Designed several types of fuel spacers for the sleeveless core of HTGR**
- **Ring-type fuel spacers exhibit lower pressure loss in laminar flow regime**
- **Each fuel spacer design effectively supports the entire components**
- **Further investigation needed in turbulent flow regime**

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[ref. 1] S. Okita et al., Proceedings of the 30th International Conference on Nuclear Engineering, May 2023, Kyoto, Japan. https://doi.org/10.1299/jsmeicone.2023.30.1119

[ref. 2] Y. Yamazaki, et al., NURETH-21, August 2025, Busan, Korea.