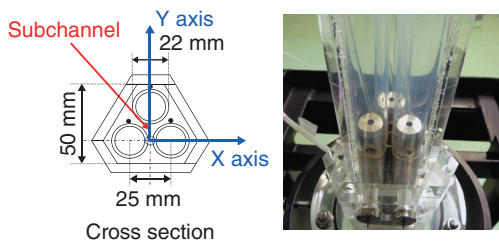


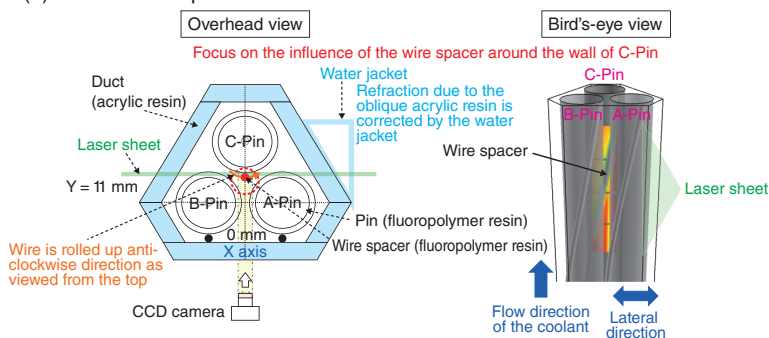
# 7-3 Visualizing the Coolant Flow in the Fuel Assembly

## — Achieving Highly Accurate PIV Measurement through Index Matching —

(a) Photo of the test apparatus



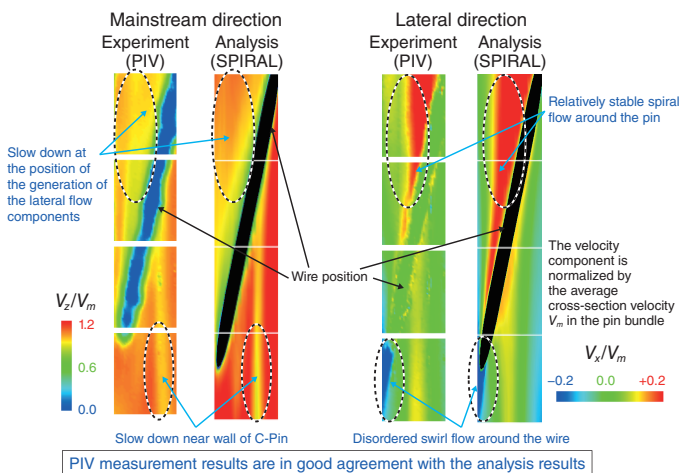
(b) Measurement position



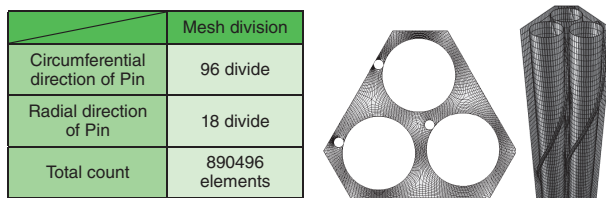
**Fig.7-8 Three-pin bundle water experiment system**

The distortion of a laser through the pin and wire were eliminated by fabricating them from clear fluoropolymer resin with a refractive index close to that of water (index matching). As a result, highly accurate visualization of flow in the narrow complex flow path has been achieved.

(c) The average flow velocity distribution in 6 s



(d) Mesh division of SPIRAL analysis



**Fig.7-9 Comparison between PIV measurement results and analytical results**

The average flow velocity obtained by PIV measurement was in good agreement with the analytical results of SPIRAL (finite element mesh code) over 6 s in the flow direction and the lateral direction (which was normalized by the  $V_m$ -averaged cross-section flow rate) near the wire.

Fuel pins are generally densely arranged in equilateral triangles in the fuel subassemblies of sodium-cooled fast reactors. The spiral wire spacers are adopted to maintain gaps in the fuel pins and to ensure cooling because they can be relatively flexible to deformation of fuel pins caused by neutron irradiation. However, the coolant flow path between the fuel pins might become a narrow, complex shape due to the installation of the wire spacer. Then, the fuel pin could be damaged if a mismatch between the output and the flow rate occurred by some event such as deformation of the coolant flow path for the high burn-up. To evaluate the structural integrity of the fuel pins, it is important to clarify the flow field in this narrow and complex flow path. However, no techniques have been developed for visualizing such a narrow and complex area to obtain the verification data of the analysis codes in past studies.

The flow field was measured by particle image velocimetry (PIV) in the subchannel around the wrapping wire of the three-pin bundle water model (Fig.7-8(a)), which simulated the simplest system of the fuel pins (Fig.7-8(b)) in this study.

The test section comprised an irregular hexagonal acrylic duct tube and fluoropolymer resin pins that had nearly the

same refractive index as that of water and had a high light-transmission rate. This refractive index matching enabled us to visualize the inner subchannel through the outer pins with a high degree of accuracy.

As a result, two types of characterized flow field data (the flow velocity distribution and fluctuation intensity) were successfully obtained. One is a relatively stable spiral flow around the pin and the other is a disordered swirl flow around the wire. As an example, the experimental (Fig.7-9(c)) and analytical results obtained by SPIRAL (a finite element analysis code) (Fig.7-9(d)) for the flow velocity distribution near the wire wound on the C-Pin are compared. The two results are in good agreement, and are hence considered to have verified the efficacy of this code.

Verification and validation (V&V) research has focused on the development of a safety assessment analysis code for nuclear power facilities, especially in recent years. Standardization of V&V has been underway in Japan and overseas.

In this way, the results of this study contribute to the promotion of fast reactor development by helping to validate analysis codes as basic technology and to the establishment of a standard for V&V.

**Reference**

Nishimura, M. et al., Study on Flow in the Subchannels of Pin Bundle with Wrapping Wire, Proceedings of 9th Korea-Japan Symposium on Nuclear Thermal Hydraulics and Safety (NTHAS-9), Buyeo, Korea, 2014, paper N9P0087, 7p., in CD-ROM.