Preliminary Single-Phase Mixing Test using Wire Mesh System in a wire-wrapped 37-rod Bundle

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1. Introduction

A wire mesh sensor and system have been traditionally used to measure the void fraction of a two-phase flow field with gas and liquid [1]. Recently, Ylönen et al. [2] successfully designed and commissioned a measurement system for a single-phase flow using a wire mesh sensor. In this paper, preliminary tests of the wire-mesh sensor are introduced before measuring of mixing coefficient in the wire-wrapped 37-pin fuel assembly for a sodium-cooled fast reactor [3]. Through this preliminary test, it was confirmed that city water can be used as a tracer for de-mineralized water as a base.

2. Methods and Results

2.1 Wire Mesh Sensor and System

A Wire Mesh System consists of two parts, a sensor and an electronic. The sensor has a transmitting electrode layer and receiving electrode layer with a short distance. The wires of each layer are aligned at an angle of 90^o. As a driving voltage is supplied to the transmitting electrode layer, a current is derived in the receiving electrode layer. According to the electric conductivity of the liquid between two layers, the derived currents may be varied. Using this principle, a difference in the electric conductivity of the liquid in the local area can be measured.

A wire mesh system has a high time resolution through a quick response time. It has a good benefit for intuitively investigating the specific flow field where the sensor is installed even if the flow area is disturbed by the wire sensor.

The wire mesh sensor will be set up in the wire-wrapped 37-pin fuel assembly for a sodium-cooled fast reactor, as shown in Fig. 1. A cross point of the wires is fabricated to be located at the center or beside each subchannel. Active transmitting and receiving electrode wires consist of 16 × 16 channels, respectively. The actual 256 measurement points in the wire mesh are shown in Fig. 2. A schematic of the wire mesh sensor is shown in Fig. 3.

The data acquisition system consists of a main device, transmitter unit, receiver unit, and connection cables. The main device contains several cards such as a power supply card, input/output card, slave card, and maser card. The IO card is connected with the receiver unit. The slave card receives the data stream from the receivers and stores the data on a compact flash card (CF card). Measured data are stored in a CF card of the slave card as integer valves from 0 to 4079.

The master card controls the measurement and the communication with the PC over a USB connection. Sixteen transmitting electrodes have a measuring frequency of up to 10 kHz. A receiver unit contains the preamplifier, main amplifier, analogue-digital converter (ADC), and a control unit.

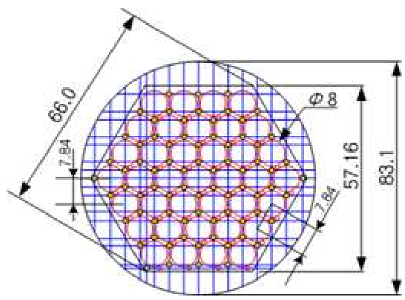


Fig. 1. Schematic diagram of the wire-wrapped 37-pin fuel assembly and active wires (blue lines)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128
129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176
177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208
209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224
225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256

Fig. 2. Measuring points: Each numbered measuring point belongs to one crossing point of WMS inside the pipe diameter. The yellow color marks the points of interest (related to the rod bundle), while the grey points are out of the circular range of the WMS.

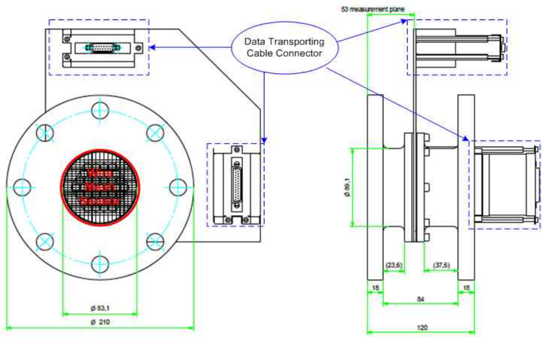


Fig. 3. Fabrication drawing of wire mesh sensor

2.2 Preliminary Test and Uncertainty

A blank flange is mounted on the bottom flange of the wire mesh sensor. The inside of the wire mesh sensor is filled with de-mineralized water and connected with a thermocouple, which is used to measure the temperature of the de-mineralized water. The conductivity and temperature of the de-mineralized water were measured and recorded during the tests. The conductivity of de-mineralized water at all cross points was measured for 5 seconds with a frequency of 100 Hz.

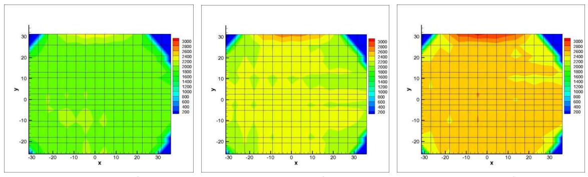
A test carried out for different temperatures of de-mineralized water and city water, since these two kinds of water will be used in the mixing cross test as a base and tracer, respectively. The plane image of the wire mesh for the de-mineralized water is shown in Fig. 4. By increasing the temperature, the valves of the ADC are linearly increased for temperatures of 40 ^{o}C to 60 ^{o}C. Figs. 5 and 6 show the time-averaged value of the plane image based on the temperature of the de-mineralized water and city water. The time-averaged value of city water is more than 10-times that of de-mineralized water under the same conditions. This means that the city water can be used as a tracer for de-mineralized water as a base.

The standard deviation of these averaged values is listed in Table III. All of the low values of standard deviation mean that the wire mesh sensor has high reliability.

Table III: Average and standard deviations of plane image

Temp	DMW$^{(*)}$ 100 %		DMW 90 % + CW 10%		CW$^{(**)}$ 100%	
^{o}C	AVG.	SD	AVG.	SD	AVG.	SD
30	1.699	0.027	-	-	-	-
40	4.665	0.041	28.634	0.052	263.049	0.087
50	8.488	0.237	33.236	0.058	313.874	0.095
60	11.977	0.051	37.891	0.054	371.388	0.160

(*) DMW: de-mineralized water
(**) CW: city water



(a) 40 ^{o}C (b) 50 ^{o}C (c) 60 ^{o}C

Fig. 4. Contour image of wire mesh for the de-mineralized water by temperature

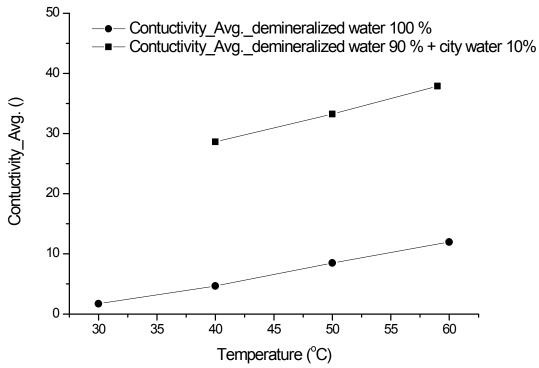


Fig. 5. Average valve of cross points in wire mesh for 100 % de-mineralized water, and mixture of 90 % demineralized water and 10 % city water

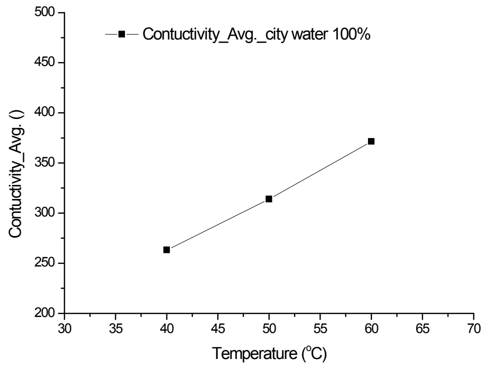


Fig. 6. Average valve of cross points in wire mesh for 100 % city water

3. Conclusions

A simple test was performed to evaluate the characteristics of a wire mesh with of a short pipe shape. Electrical conductivity was measured for various temperatures.

1. The conductivity of de-mineralized water and city water is linearly increased for the limited temperature ranges as the temperature is increased.
2. The reliability of the wire mesh sensor was estimated based on the averages and standard deviations of the plane image using the cross points. A wire mesh sensor is suitable to apply to a single-phase flow measurement for a mixture with de-mineralized water and city water.

ACKNOWLEDGMENTS

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REFERENCES

[1] A. Ylönen, W.-M. Bissels, and H.-M. Prasser, Single-Phase Cross-Mixing Measurements in a 4X4 Rod Bundle, Nuclear Engineering and Design, Vol.241, p.2484, 2011.
[2] H.-M. Prasser, A. Böttger, and J. Zschau, A New Electrode-Mesh Tomograph for Gas-Liquid Flows, Flow Measurement and Instrument, Vol.9, p. 111, 1998.
[3] S.K. Chang, D.J. Euh, H. Bae, H.Y. Lee, and S.R. Choi, Design of the Wire Wrapped 37-Pin Fuel Assembly for Measurements of the Flow Characteristics in a SFR, The Sixth Korea-China Workshop on Nuclear Reactor Thermal-Hydraulics(WORTH-6), April 11-13, 2013, Busan, Republic of Korea.