Measurement of the Liquid-Sodium Velocity with Electromagnetic Flowmeters

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1. Introduction

The conventional types of Electromagnetic Flowmeters(EMF) have traditionally been used to measure the mean velocity of the liquid metal system owing to a rapid response and a simple geometry. However, EMF has some uncertainties when impurities are accumulated in the near vicinity of the electrodes. The AC-EMFs were newly designed to overcome several problems in the EMF and previously calibrated together with the EMFs in the sodium circulation loop to develop the systematic signal processor. The AC-EMF shows lots of electrical noises originated from the unknown sources.

2. Design of EM-Flowmeters and Results

2.1 Design of EM-Flowmeters

Shercliff derived the electromagnetic flowmeter theory for the flow measurement of liquid metal. The distribution of the potential U inside the flowtube of the magnetic flowmeter is described by the Poisson type equation (Shercliff, 1954, 1962; Bevir, 1970).

$$\nabla^2 U = \mathrm{div}\left(\mathrm{v} \times \mathrm{B}\right) \quad (1)$$

Here, **v** is the velocity vector and **B** the magnetic flux density vector. Making an assumption of a rectilinear flow and a uniform magnetic field, Shercliff (1962) derived a solution to equation (1) for the non-conducting wall and homogeneous liquid.

$$\Delta U_{AB} = KB\,\mathrm{v}_{\mathrm{m}}\, d \quad (2)$$

Where ΔU_{AB} and d are the potential difference and distance between electrode A and electrode B in Figure 1, respectively. The notation $\mathrm{v_m}$ and K is the average velocity in the cross section and the correction factor, respectively. He also developed the idea of weight function that represented the degree of fluid velocity profile's contribution to the flow signal in the cross section. Due to this function, the effect of velocity is strong near the electrodes and decreases with increasing distances from the electrodes. Thus, sensitivity depends on the weight function, which is determined by the distribution of the magnetic flux, and the relative positions of the electrodes and the liquid. Thus, the conventional type of Permanent Electro Magnetic Flowmeter(PEMF) has a weak point for the contamination in the vicinity of electrode and the asymmetric velocity profile and fluctuation as well as the magnet aging problem with temperature.

Figure 2 shows the conceptual diagram to measure the liquid-metal velocity with AC EM-Flowmeters(AC-EMF). Two-types of AC-EMFs were designed, which were distinguished with the arrangement of the exciting and the sensing coils and each coil was composed of the solenoid magnet. The electromagnet of AC-EMF was sinusoidally excited by the AC power which was controlled by a frequency converter(112AMX, Pacific Power Source) and Uninterruptible Power System(UPS).

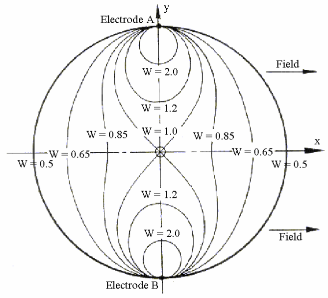

Figure 1. Weighting function of EM-flowmeter

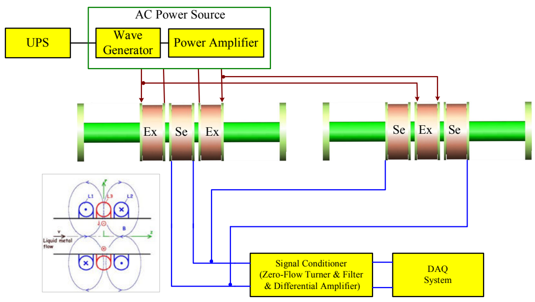

Figure 2. Conceptual diagram of AC EM-flowmeters

The general measuring principle is that the motion of an electrically conducting fluid in an imposed field B produces an induced field B' which is proportional to the flowrate in the first order. The magnitude of the RMS value in the sensing coil is proportional to the magneric Reynolds number of the fluid flow R_{em} in the Equation (3), where μ is the magentic permeability and σ the specific electric conductivity of the fluid.

$$\Delta U \propto \mathrm{Re}_m = \mu\sigma\,\mathrm{v}_m\, d \quad (3)$$

The exciting coil of AC-EMF was designed to lower the inductance of magnet in order to reduce the noise effect and endure the high temperature. The bobbin was made by the combination of the PTFE(Teflon) and the ceramic materials. The wire diameter and the winding number of the exciting coil are 2mm and 220 turns, respectively. The sensing coil was made by the diameter 1.0mm copper wire winding with 800(400, 600 selective) turns.

Figure 3 shows the penetration depth of the electromagnetic field with the exciting frequency, which was calculated at 200^{o}C sodium. In case of 1000Hz, the flowtube is limited within around 1 inch stainless steel pipe. The electrical characteristics of the AC-EMF magnets are depicted in the Figure 4. The axial magnetic field is around 15gauss in the center of the magnet within a measuring range and the inductances of the double exciting and the single coils are 2.3mH and 5.2mH, respectively.

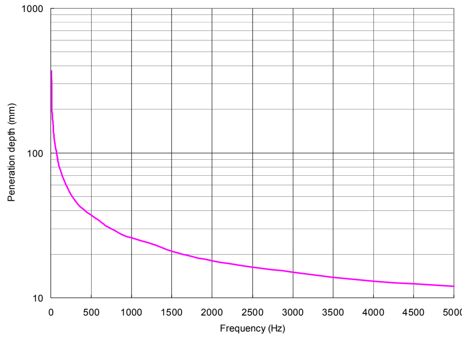

Figure 3. Penetration depth with the exciting frequency

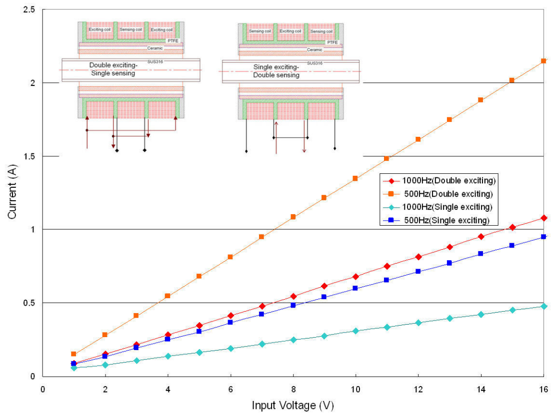

Figure 4. Electrical characteristics of AC-Flowmeters

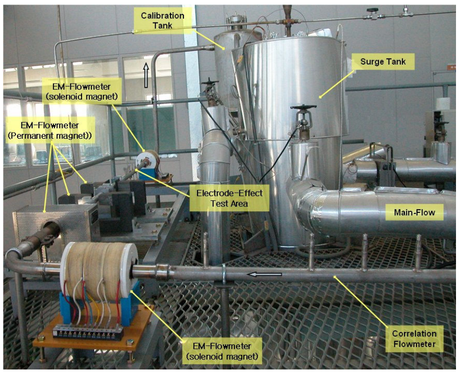

Figure 5. Sodium facility for the flowmeter calibration

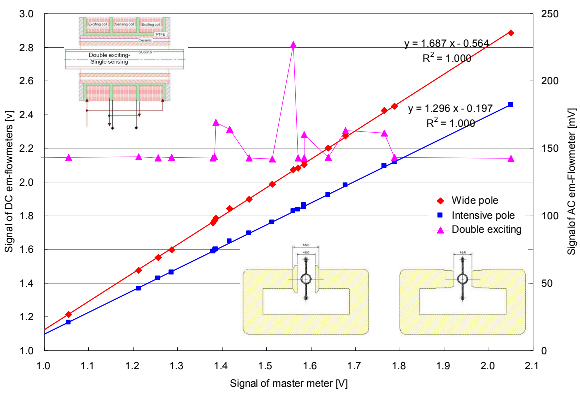

Figure 6. Calibration data of the EM-flowmeters

2.2 Experimental results

The experiment was conducted by changing the EM-pump input voltage over the range from 0 to around 200 volt with a variable voltage controller. The liquid sodium temperature was maintained around 180°C.

Figure 5 shows the sodium facility to calibrate the flowmeters, which was recently modified using the sodium MHD-loop at KAERI. All flowmeters were serially mounted along the bypass line from the previous sodium flow-line and a calibration tank of around 50 liter was attached its end to measure the volume charging interval. A PEMF made by Framatome was also installed in the calibration line to compare the sodium flowrate as a master meter and its sensitivity 1.18 m^3/hr/mV.

Figure 6 shows the calibration data which was sampled at 5000Hz with the data acquisition system of DT-3001 board (Data-Translation, 12bit, 330kS/s). The signal outputs of PEMF were sampled after then converting from voltage to current to reduce the noise effect through the signal transmission line of the long distance. The signal of AC-EMF was directly collected to study the noise effect on the signal transmission for the design of signal processor. The exciting frequency and input voltage of the AC-EMF was 1000Hz and 10V, respectively. The calibration data of PEMF designed by KAERI with ALNICO-VIII magnet showed the good linearity and repeatability. However, the AC-EMF signal did not show any tendency for the flowrate due to the noise incursion of several sources such as electrical devices.

3. Summary

The AC-EMFs were newly designed to avoid the inherent problems of the conventional EMF and previously calibrated together with the PEMFs in the sodium loop. Whereas the PEMFs show the good linearity and repeatability, the AC-EMF shows lots of electrical noise originated from the unknown sources.

Acknowledgement

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