Electrical and Pressure Characteristics of Wire Explosion for Various Wire Types to Simulate Reactivity Initiated Accident (RIA)

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1. Introduction

Reactivity Initiated Accident (RIA) occurs when fission rate and reactor power increase beyond the limit. It may cause failure at fuel pellet and fuel rod, and in severe cases, damage in nuclear reactor core may be occur [1].

To establish safety regulation for RIA, a number of experiments have been carried out since CABRI test in 1993, such as NSSR, TREAT, IGR [2]. However, these tests are experimental reactor test, which cost highly in respect of time and expenses. In Korea, since there is not test reactor for RIA, safety regulation on RIA based on RG 1.77 of Nuclear Regulatory Commission (NRC) in USA [3].

Recent work has suggested possibility of simulating mechanical behavior of cladding by lab-scale devices such as expansion due to compression test, ring test, burst test and magneto forming test [4-7]. However, these tests are insufficient in terms of controlling the reproduction of strain ratio in actual RIA situation.

As a part of a Nuclear Safety and Security Commission (NSSC) project, we are conducting wire-explosion test to imitate mechanical behavior of cladding during RIA situation. Wire-explosion is a way of generating plasma and accompanies shock waves [8]. Controlling electrical input results in difference in pressure shock wave, which is suitable for imitating mechanical behavior of cladding, especially pressure increase, during RIA situation. This paper describes pressure at wire-exploding experiment to simulate RIA under different wire, capacitance, and voltage.

2. Experimental Setup

In order to investigate the influence of wire material and thickness, Cu, Al and W wires of 100 um and 200 um were used with charging voltage 2 kV and capacitance 1.66 mF. Also, Cu wires of 100 um, 125 um and 200 um were used to investigate the influence of charging energy.

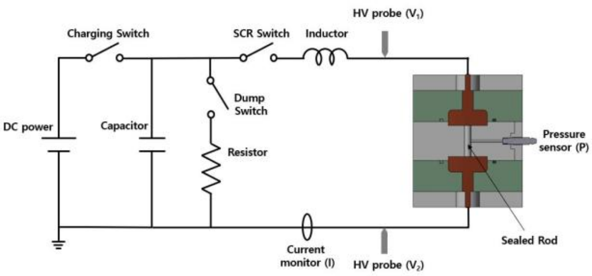

Fig. 1. Schematic diagram of pressure simulation instrument for RIA using pulsed plasma.

Figure 1 shows the schematic diagram of the electrical system and the pressure chamber. Electrical measurement was performed by current monitor (Model 3025, Pearson Electronics) and high voltage probe (P6015A, Tektronix). A pressure sensor (109C12, PCB Piezotronics) was installed 45 mm away from the discharge region. The current, voltage and pressure signal were recorded by an oscilloscope (MSO58 5-BW-2000, Tektronix).

3. Results and Discussion

Figures 2 and 3 show the current and pressure difference with changing the charging voltage for the same 100 um thick Cu wire and capacitance of 1.66 mF. In both cases, the higher charging voltage leads to the higher peak and faster rising time. The peak current is changed from 2.9 kA to 11.7 kA, with the voltage changing from 1 kV to 2 kV. Since the energy stored in the capacitor become 4 times higher when the voltage is doubled, this result suggests that the current is dependent on the stored energy. However, in Fig. 3, the pressure is slightly increased from 20.2 MPa to 28.1 MPa in spite of the voltage increase from 1 kV to 2 kV, indicating that the pressure does not depend linearly on the stored energy.

Figures 4 and 5 show the peak current and pressure dependency on various stored energies for different wire diameters (Cu 100 um, 125 um, 200 um) when the capacitance changes from 0.83 mF to 2.49 mF and voltage changes from 1 kV to 2.5 kV. This result shows both current and pressure have a positive correlation with the stored energy, as seen in Figs. 2 and 3. Also, in Fig. 4, thicker wire tends to have higher peak current at the same stored energy.

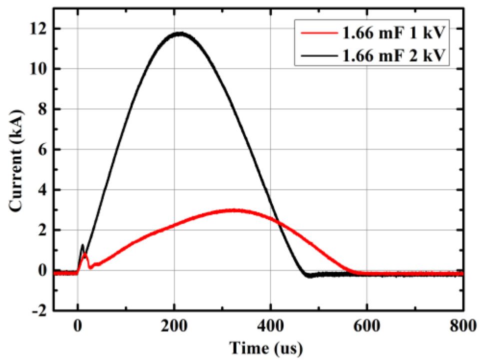

Fig. 2. Comparison of current at different charging voltage.

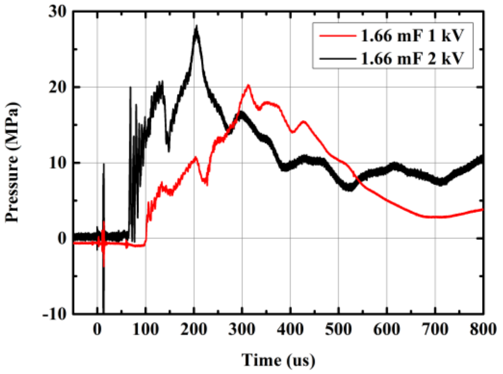

Fig. 3. Comparison of pressure at different charging voltage.

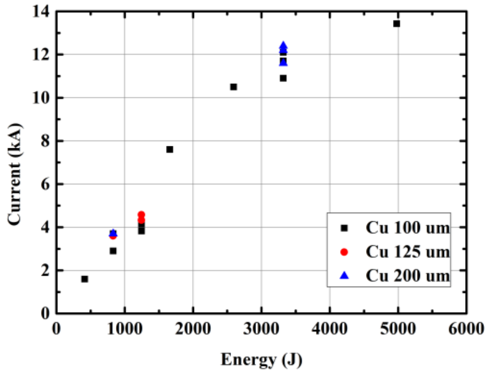

Fig. 4. Peak current dependence on stored energy.

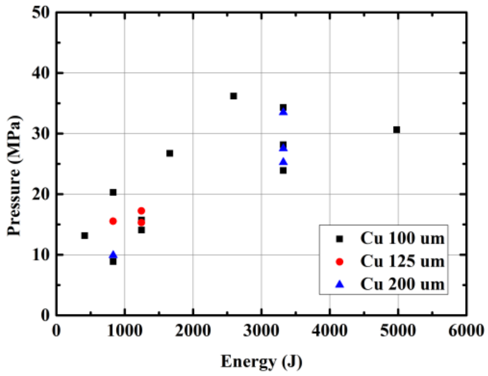

Fig. 5. Peak pressure dependence on stored energy.

Figures 6 - 8 show differences in the current, voltage and pressure waveforms when the wire material is changed. At the metal vaporization point, Cu has the highest peak in the current and voltage, followed by Al and W. However, overall shape of current and voltage waveforms is similar among Cu, W and Al. This similarity results in the similar delivered energy irrespective of the wire material. As a result, the peak pressure also does not show a significant difference among them, similar to the previous work [9].

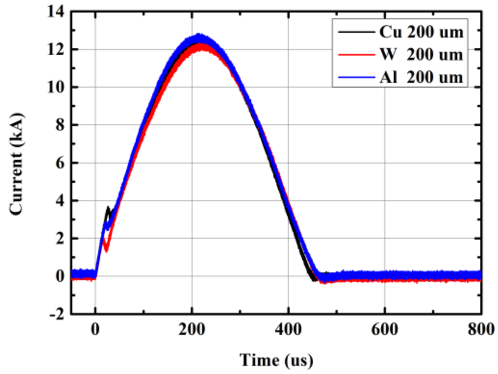

Fig. 6. Comparison of current shape at different material properties.

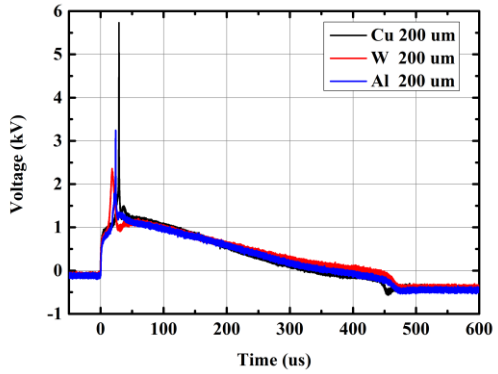

Fig. 7. Comparison of voltage shape at different material properties.

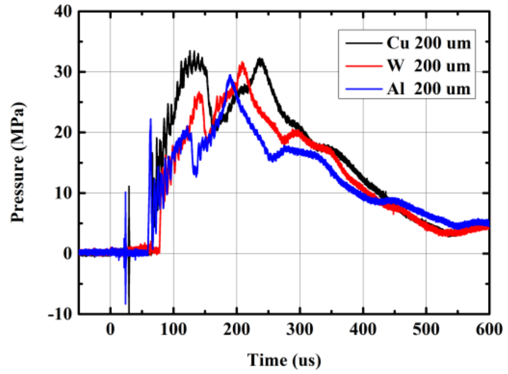

Fig. 8. Comparison of pressure shape at different material properties.

4. Conclusion

Experiments with various charging voltages and wire sizes show that the peak pressure is proportional to the stored energy. However, the change in the wire material does not show a clear change in the peak pressure. The results shown here will be used to improve the performance of the device for simulating RIA event.

ACKNOWLEDGEMENT

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