A Study on Smoke Behavior affected on Droplets of Sprinkler
- Velocities of the Droplets and Smoke Layer by PIV System -

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A sprinkler system is one of the most popular fire suppression systems in buildings, and well-known as a system which has high suppression performance. In addition, the sprinkler system has some other performance to a fire, such as an effect of cooling a compartment and materials, and reduction of the radiation from a fire. These are good effects. But, in addition, the water droplets disturb the stable smoke layer, and cause downward air flow from the smoke layer to the lower layer. This effect must negatively affect during initial stage of fire because of evacuation safety. This point was focused, and experimental studies about disturbing the smoke layer was carried out. Downward air flow is the flow that penetrates the boundary from smoke layer to lower layer since stable smoke layer disturbed by water droplets. In the past study, downward air flow was estimated by CO_2 concentration.

The purpose is to figure out the smoke behavior affected on water droplets of sprinkler. This study investigate mechanism of the smoke layer behavior by the physical phenomenon around the droplets, not by the CO_2 concentration. And this study investigate downward air flow rate by using Particle Image Verocimetry system. However, because of no precedent that 2 fluids are measured at the same time by PIV system, measurement procedure was studied at first. The velocities of air flow in the smoke layer and water droplets during water discharge were tried to obtain simultaneously. It must be an original methodology. The movement of smoke layer is analyzed by the movement of the tracer, though the velocity differs from water droplets. Therefore, by deleting radiants with greater brightness than certain level from the picture, improvements in the accuracy was accomplished.

The experiments were carried out by using a part of Full-Scale Compartment at Fire Research and Test Laboratory. Vertical temperature distributions were measured by thermocouples of type-K. The air flow rate was measured by PIV system. 4 kinds of nozzle (normal sprinkler head and 3 Ikeuchi), 2 types of fuel (methanol and normal-heptane) and 2 sizes of fuel pan were used. By this experiment, two components were obtained. The first, downward air flow rate is changing by character of the nozzles. And the second, the temperature difference inhibit the downward air flow rate. As the downward air flow rate depends on the nozzles such as distribution of droplet, droplet size and velocity. So, in addition to the experiment, the fundamental data of nozzles were measured. Sauter mean diameter was calculated from droplet diameter.

Then, from these fundamental data, the theoretical drag (D [N/m^3]) to the air by droplet is calculated by Newton's law because the shape of droplets is a sphere. And buoyancy force (B [N/m^3]) is calculated from temperature difference. Balance of D and B (D/B [-]) expresses stability of the smoke layer. Then, it was shown that values of D/B is related to the balance of downward air flow rate (v_s [m/s]) and droplet velocity (v_d [m/s]). As a result, in the stable region and the transition region, relationship of D/B and v_s / v_d is linear proportion, and a relational expression was provided.