Measurement of contact force-deformation relation between two identical spheres during elastic-plastic impact

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Introduction. Dynamic contact force-deformation relations between spheres are interested in impact engineering applications, such as identification of material properties, wear resistance, and so on. They can be obtained by numerical simulations such as FEM (Finite Element Method)\textsuperscript{(1),(2)}. However, it is not easy to obtain experimentally in general. The purpose of this paper is to measure the elastic-plastic contact force-deformation relation between two identical spheres experimentally. To this end, two identical steel spheres were collided by a pendular motion. The velocities of spheres during impact were measured using two Laser-Doppler-Vibrometers (LDVs). The contact force and the deformation of the spheres were calculated from the velocity signals. Then, the elastic-plastic contact force-deformation relation between two identical spheres were obtained experimentally.

Impact experiments and FEM simulations. Figure 1 shows the pendular experimental set-up. The diameter of the used spheres were 17/32 in. Commercial spheres for journal bearing were annealed before the experiment. So, they can be regarded as elastic-plastic spheres. The experiments were conducted for three kinds of impact speeds: about 0.5 m/s, 0.75 m/s, and 1.0 m/s. The material properties of the spheres were obtained from static and dynamic material tests. The finite element simulations were carried out by the commercial software, LS-DYNA. Figure 2 shows the mesh division used in the FEM.

Results and Discussions. Because some fluctuations were observed in the contact forces, the derived contact force-deformation curves were smoothed by adjacent average. The elastic-plastic contact force-deformation relations were agreed reasonably with those from the FEM simulations. Figure 3 shows the contact force - deformation diagrams for the case of impact speed 1.0m/s. The elastic curve from Hertzian contact theory\textsuperscript{(3),(4)} was also shown in the figure. The experimental result and the FEM result agree well except around the maximum contact force, where the experimental result shows the higher contact force than the FEM. The same degree of reasonable agreement were seen for the other two impact speeds.

This method may be applied for the other spherical collisions such as spheres with dissimilar size and material. It is thought that this measurement technique could valid as long as the assumption of the local deformation of the spheres holds.

Fig. 1 Schematic view of the experimental setup.

Fig. 2 Finite element mesh.

Fig. 3 Contact force - relative displacement diagram.

References.