In situ X-ray Radiography for Compression Test of Foam Aluminum

In recent years, it has become increasingly important to reduce the weight of automobiles because of energy and environmental problems. Moreover, the popularization of aluminum use in automobiles is expected to improve human safety. Foam aluminum has features such as lightness, a high modulus of rigidity, and high crashworthiness (shock resistance), etc. Particularly, foam aluminum has several excellent properties for both reducing vehicle weight and improving human safety. However, neither the technology for evaluating its mechanical properties nor the technologies for its practical use in car parts have yet been established for foam aluminum. Therefore, practical uses of foam aluminum have stalled. In recent years, however, some examples on foam aluminum characterization using synchrotron radiation have been reported in Europe and the U.S.A [1-3]. This report includes its first use in Japan in an X-ray phase-contrast imaging experiments with synchrotron radiation. The results will be used to develop in situ technology for determining the high-speed distortion of the porous structure in foam aluminum [4]. This research is expected to lead to the establishment of a basic structural design of automotive material with foam aluminum and the improvement of its crushability properties. In this study, we aimed to take pictures of the *in situ* image of the porous structure, and also aimed to clarify how the porous structure influence on the pressure-displacement curve. Once the basic information has been obtained, it can be fed back to a basic structural design and be incorporated into structural materials for automobiles.

The *in situ* experiment on X-ray phase-contrast imaging of the foam aluminum cause by the reflection effect was done in the third hutch of beamline **BL19B2**. A continuous X-ray from the synchrotron radiation source was monochromatized by an Si(311) double crystal monochromator to 33 keV. The X-ray detector adopted was a 1280 × 1024 pixel CCD camera with a 6.7-μm pixel size (C4742-95, Hamamatsu photonics K.K). The distance between the sample and the camera was

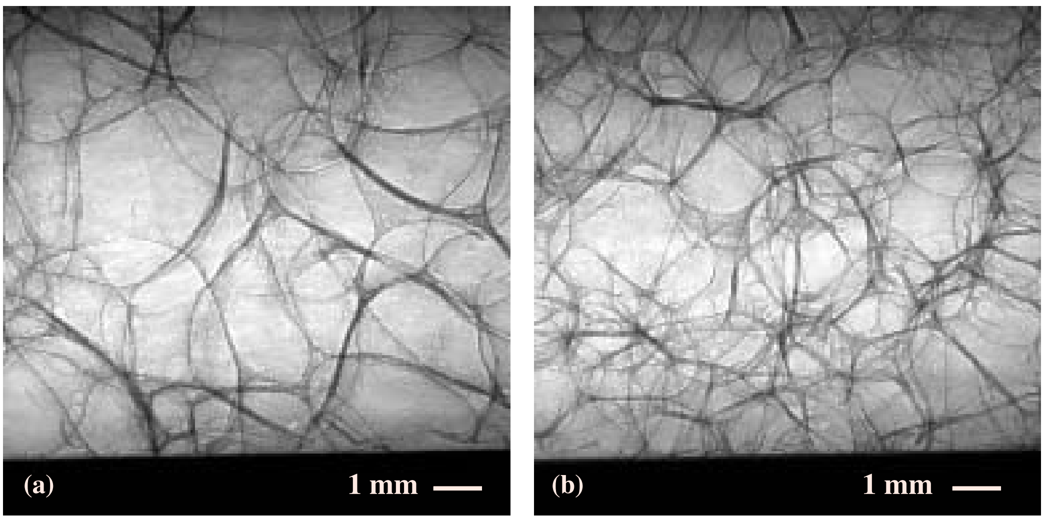

*Fig. 1. Static image of two types of foam aluminum by X-ray radiography. The foam size is about 5.0 mm in **(a)** and about 1.7 mm in **(b)**. The foam size of both types can be clearly distinguished.*

determined to be about 3 m by using the equation $L = D^2 / \lambda$, where L the distance from the sample to the detector, D the space resolution of detection, and λ the X-rays wavelength. The X-ray imaging data was stored in the process of compressing the sample with the speed of 1 mm/min, using the compression testing machine (AGS-H Shimadze Co. Ltd.) onto a PC (DOS/V, Windows 2000), one by one every two seconds. Static images of two kinds of foam aluminum with foam sizes of 5.0 and 1.7 mm are shown in Fig. 1(a) and (b), respectively. The difference in foam size could be identified by comparing each X-ray image. Figure 2 (a-c) shows three *in situ* images for a compression test. The foam with a size of $15^l \times 15^w \times 10^h$ mm^3 begins to collapse from both top and bottom edges of the sample. The sample center keeps its shape for a while. It is understood that the foam collapse once catastrophically, and then the remaining form collapses again.

In the sample with small-scale foam, it is understood that the stress induced under the transformation decreases and the displacement to complete destruction increases. In addition, it was observed that there were two types of processes operating in the destruction of the foam as seen in the movie of the foam aluminum impact test. One was buckling destruction and the other was an explosion. The compression speed of the sample was estimated at 1 mm/min in the actual experiment, taking into account the X-ray intensity and space resolution. Base d on the results of the actual experiment, we are planning to speed up the CCD camera's reading speed from seconds to milliseconds to record the destruction of the foam. That type of data will be of practical use for developing automotive materials from foam aluminum. In the near future, we plan to do further compression tests, bending tests, and modulus of rigidity tests on foam aluminum, which will help to increase the variety of applications for the material.

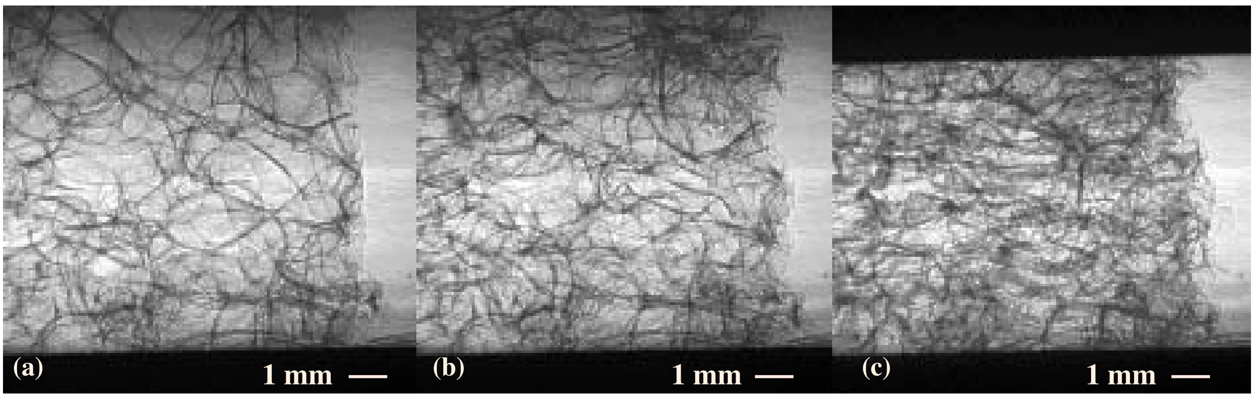

Fig. 2. Three scenes of an in situ image monitored by X-ray radiography when a compression test is done on foam aluminum. ***(a)*** *Foam aluminium begins to collapse at top and bottom.* ***(b)*** *Foam aluminium is collapsing. The center keeps its shape.* ***(c)*** *All the foams seem to be almost destroyed.*

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