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Deformation behavior of axially compressed aluminum polygonal tube

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Abstract

Aluminum tubes are efficient energy absorbing components and are widely used as framework and reinforcement members of structures. This paper deals with the influence of the axial length, cross-sectional shape and reinforcing rib on a dynamic axially compressed aluminum polygonal tube in order to obtain basic data on buckling. The axial impact test of an aluminum square tube was carried out with a drop-hammer testing machine. The dynamic deformation process of a polygonal tube was analyzed by a finite element method. The specimen used in this analysis is an aluminum polygonal tube (square, hexagonal, octagonal and decagonal). The result shows that even when the axial length was changed, there was no difference in the trend of the compressive load-time curve in each cross-sectional shape. The trend of the compressive load-time curve was affected by the reinforcing ribs. The buckling was generated partially in each axial length and cross-sectional shape. In the case of a square tube without ribs, the deformation shape was concave-convex in adjoining surfaces, and crushed in a bellows-like manner. As for the deformation shape, the experimental results approximately agreed with those of the finite element method analysis.

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Keywords: Plastic buckling; Impact load; Axial load; Dynamic deformation; Numerical analysis

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1. Introduction

Square or polygonal tubes have been widely used as framework and reinforcement members of structures. Many studies on the deformation of a circular tube have been carried out. For example, static and quasi-static compressive tests have been carried out to predict the deformation process. There are also many research reports on square or polygonal tube deformation behavior, such as experiments of dynamic buckling [1-5]. The axial impact behavior of elastic and plastic stress waves propagating in a square tube have been investigated [6]. Compared with common steel materials, the specific tensile strength of an aluminum alloy is high, and its density is as light as one-third that of iron. There is much interest in the aluminum tube having these special features as the frame timber having the function of high strength and weight reduction of automobile bodies [7].The Young's modulus of aluminum is one-third that of steel, so it is necessary to examine the cross-sectional shape, such as the thickness of the tube, to ensure the same rigidity as steel materials. However, the whole buckles become large when thickness is increased, and it becomes axial compression deformation, which cannot effectively absorb collision energy [8]. During buckling of the square tube, the torsional rigidity in the corner seems to contribute greatly to the deformation shape [9]. In a previous report [10], the authors experimentally examined square tubes with ribs positioned cross sectionally by the axial impact squeezing test. The influence of the cross-sectional shape on polygonal tube (square, pentagonal, hexagonal, heptagonal and octagonal) was also investigated by numerical analysis [11]. In the case of the tubes without opposite faces, it was found that deviation occurred during deformation and such tubes are not suitable for energy absorption. However, there are only a few reports on the axial length and cross-sectional shape of aluminum tubes. This paper deals with the influence of the axial length, polygonal shape and reinforcing rib on dynamic axially compressed aluminum polygonal tubes with opposite faces.

2. Experiment

The axial impact test of extruded aluminum square tubes (JIS A6063-T5, 40 mm width, 100, 150, 200 and 300 mm length) without a rib (Type-A) and with a rib (Type-B) was carried out with a drop-hammer testing machine, as shown in Fig. 1. The thickness of the aluminum tubes of Type-A and Type-B are about 1.1 and 1.5 mm, respectively. The reinforcing rib connects the middle portions of one face and the opposite face. The weight of the hammer is 15.0 kg. The impact velocity is 10 m/s and depends on the falling height of the weight. The ends of the specimen are fixed into the grooves on the steel plate. For the measurement of compressive load, the load cell was placed under the steel base.

(a)

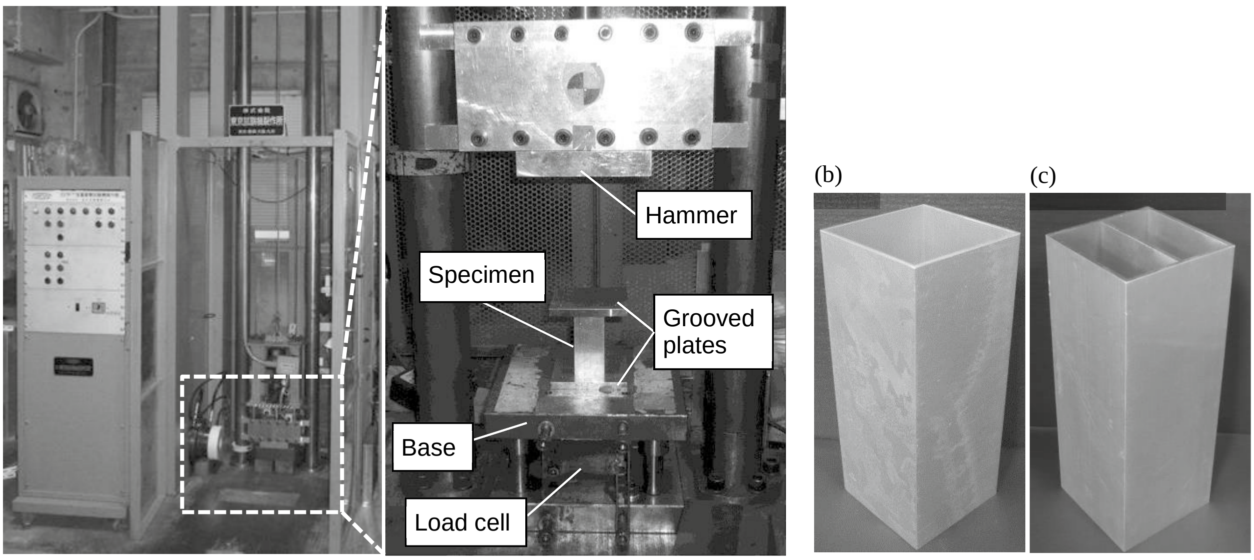

Fig. 1. Drop-hammer testing machine and tested specimen. (a) Drop-hammer testing machine, (b) Type-A specimen and (c) Type-B specimen.