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Experimental Study of Energy Absorption of Square Column under Multi-Indentation Loading

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ABSTRACT: This research deals with experimental investigation on energy absorption and deformation of thin walled square columns under multi-indentation loading. The main goal of this research is to examine the effect of number and diameter of indenters and distance between them on the energy absorption parameters. First, square aluminum specimens with specific lengths were prepared and also an adjustable fixture for applying multi-indentation loading was fabricated. Then the indentation loading were applied on the specimens during a quasi-static condition with a constant loading rate. During loadings, the specimens were located between an almost rigid platen and the adjustable indenters. The load-displacement diagrams of specimens were obtained and the energy absorption parameters were calculated. The results indicate that the amount of absorbed energy in multi-indentation process increases significantly respect to single-indentation. By increasing the distance between indenters in multi-indentation loading, the load- displacement diagram shifts upward and moves toward the twice of single-indentation diagram. Also, by increment of diameter of indenters and distance between them, the amount of absorbed energy increases 20-60% due to formation of bigger plastic hinges.

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1- Introduction

Energy absorbers are the elements that transform apart or whole kinetic energy going through a component into other forms of energies. The transformed energy could be reversible or irreversible [1]. Thin-walled components have been known as one of the best energy absorption systems owing to their light weight, low cost, easily accessibility and suitable energy absorption parameters [2]. The main deformation mechanism of thin-walled energy absorbers are axial folding, flattening, indentation, axial splitting and inversion [2]. Energy absorbers have various applications in engineering structures like oil tankers [3], reactors [4], stroke guard in bridges and roads [5], and aerospace vehicles [6].

In this research in order to increase the energy absorption characteristics, the idea of multi-indentation loading is proposed. By using the experimental examinations, energy absorption parameters and shape deformation of thin-walled aluminum squared profiles under indentation loading by one and two indenters are investigated.

2- Materials and Experimental Examinations

The specimens were prepared from 35×35 mm square aluminum profiles. Their length was considered as 200 mm in order to investigate different distances between indenters. A fixture consisting of two adjustable indenters were fabricated as show in Fig. 1. The indenters were fabricated form two solid steel rods with diameter of 8, 12, 16 and 20 mm.

The specimens were compressed between a rigid platen and the adjustable indenters using universal test machine Zwick Z250 under quasi-static condition with constant loading rate of 5 mm/min and the load-displacement diagram of each test was obtained. In order to investigate the performance of energy absorbers, the important energy absorption parameters including "Crush Force Efficiency (CFE)", "Specific Absorbed Energy (SAE)", "Non-dimensional Load-carrying Capacity" and "Undulation of Load-carrying Capacity (ULC)" were calculated.

Fig. 1. The fixture of adjustable indenters.

3- Results and Discussion

Fig. 2 shows the load-displacement diagram of specimen S_{16} compressed on two indenters with 20 mm diameter (d=20 mm) which are 200 mm apart (D=200 mm). This figure has several regions. In region 1, main deformation is elastic which is reversible. In region 2, the diagram experiences an ascending trend up to the first peak load which is related to buckling of horizontal side of aluminum profile that is

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in contact with indenter. After buckling of horizontal side, the diagram has a descending trend in region 3 owing to the penetration of indenters in the specimen. The diagram in region 4 experiences an ascending trend due to shortening of lateral sides and crushing of upper part of profile. At the end of this region, the bucking of lateral sides of specimen leads to second peak load in the diagram. After occurrence of lateral sides buckling, the diagram again has a descending trend in region 5.

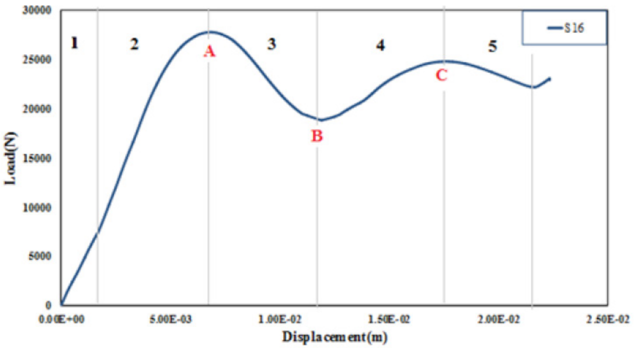

Fig. 2. Load-displacement waveform of sample S16.

The energy absorption parameters for single indentation loading are listed in Table 1. Then the double indentation loading were applied on specimens and results were compared with single indentation loading. The effect of indenter diameter and the distance between two indenters on energy absorption parameters are investigated in Fig. 3.

Table 1. The energy absorption parameters for single indentation loading.

Specimen	*d* (mm)	CFE	SAE	NLC	ULC
P_1	8	0.716	2145	118.1	0.156
P_2	12	0.715	2507	139.4	0.163
P_3	16	0.670	2510	135.3	0.178
P_4	20	0.673	2301	134.0	0.170

4- Conclusions

Under single indentation loading, the highest amount of CFE is related to indenter with 8 mm diameter. This amount of CFE is 6 percent higher than indenter with 16mm diameter. The NLC of test with indenter of 12 mm diameter is better than the other cases. This amount of NLC has 15 percent improvement compared to the test case with indenter of 8 mm diameters. The ULC has a fluctuating trend and maximum and minimum amounts are related to the tests with indenters of 16 and 8 mm diameters, respectively. By changing the number of indenters from one to two, the total absorbed energy (E_t) is increased due to formation of bigger plastic hinges and increasing the deformed region. The minimum increment of absorbed energy of double indentation increases is 14 to 25 percent respect to single indentation.

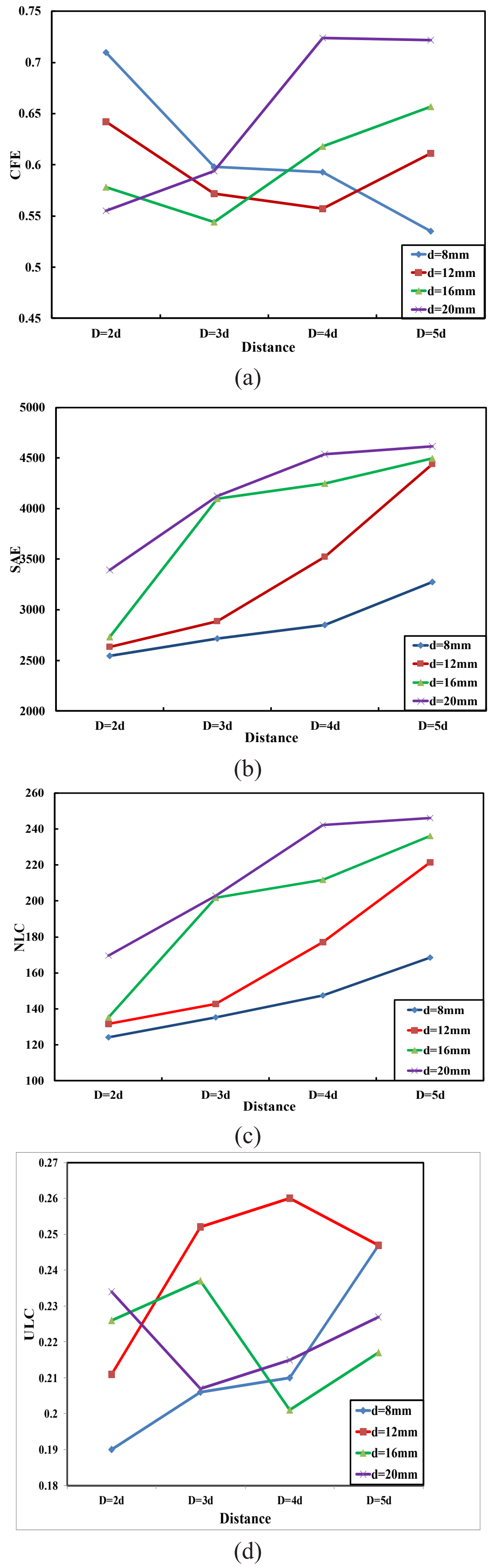

Fig. 3. The variation of energy absorption parameters by changing the diameter and distance between indenters.

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