IMPACT BEHAVIOR OF PRISMATIC TUBES WITH DENTS

M. FERDYNUS
Department of Machine Construction & Mechatronics, Lublin University of Technology
Nadbystrzycka 36, 20-618 Lublin, Poland

M. KOTEŁKO, M. URBANIAK
Department of Strength of Materials, Łódź University of Technology
Stefanowskiego 1/15, 90-924 Łódź, Poland

1. INTRODUCTION

In the case of thin-walled members subjected to axial compression, which act as energy absorbers, a substantial issue is such a design, which promotes a progressive buckling mechanism, stimulating the highest energy absorption capacity. One of the possible design solutions is the application of a trigger (notch or dent), which releases the most desirable crushing mechanism. There are numerous published results of research concerning energy absorption of thin-walled tubes [1,2], however, very few deal with tubular structures with dents or other flaws. Objectives of the investigation were:- an extended parametric study into an influence of some geometrical parameters, mainly the dent's depth and distance of the dent to the base upon a crushing behavior and energy absorbing capacity of columns. Present publication is a continuation of the Finite Element numerical analysis performed by Ferdynus et al [3].

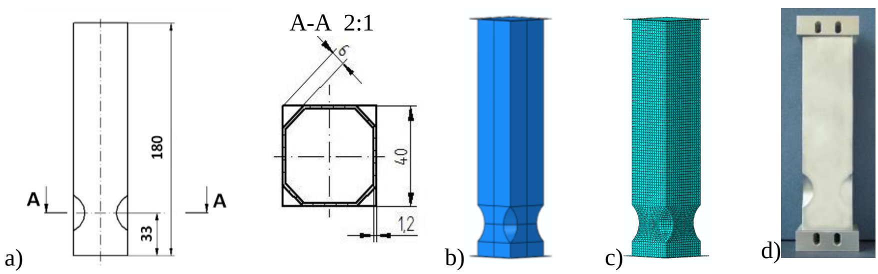

Fig. 1. Column models: a) general view, b) geometrical model in Abaqus FEM system, c) FE model, d) specimen A30 installed in blocs with vents

2. SUBJECT OF RESEARCH

The subject of investigation was a thin-walled square section aluminum tube with four dents in the corners, formed by means of cylindrical redrawing (Fig. 1). The tubes of dimensions □40x1.2 and height l = 180 mm, were made of aluminum alloy EN AW6060-T6 ($R_e = 175$ MPa, $R_m = 250$ MPa, $\nu = 0.33$). This material exhibits linear hardening during plastic flow ($E = 70000$MPa, $E_t = 937,5$MPa. The dent's geometry was characterized by the main radius R = 19 mm. The depth of the dent was 1,2,3…8 mm, what signify 5;10;15…40% of its side.

Dents were made at the bottom of the column (Fig. 1). The models were designated by the symbols from A05 to A40, where the number stands for the relative depth of the dent. The column with smooth walls was designated as SM.

3. NUMERICAL ANALYSIS - PARAMETRIC STUDY

A detailed parametric study into an optimal design of depth and position of the dents with respect to the column's energy absorption capability, namely crashworthiness indicators (CLE and STE), was performed on the basis of the FE simulations results. An impact of energy W = 1.47 kJ was assumed, which corresponds to the mass m = 60 kg dropping with the initial velocity V_0 = 7 m/s. A bi-linear material model was applied.

The results of the FE calculations reveal, that the failure mode of the investigated flawed columns depends mainly on the redrawing depth. Three following main modes of failure were observed: For the smallest values of the dent depth (A05), the crushing process was initiated at the center of the column. For medium values of dents depth (A10, A15), the crushing process was triggered by the local plastic mechanism situated just above the dent. For the largest values of dent depths (A20- A40), crushing was initiated by a local plastic mechanism situated exactly at the dent. Fig.2. shows the load-shortening diagram for columns A with different dent depths. The character of these diagrams is nearly the same. A significant decrease in the peak crushing force (PCF) is observed in comparison with the column without dents (SM). The values of stroke efficiency (STE) and crush load efficiency (CLE) are shown in Fig. 3. The most favorable parameters of energy efficiency indicators are provided by columns with a possibly deep dents. An experimental validation of the numerical FE model was carried out and the results will be presented at the conference.

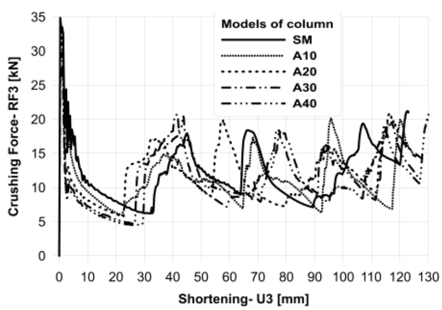

Fig. 2. Comparative load-shortening diagram

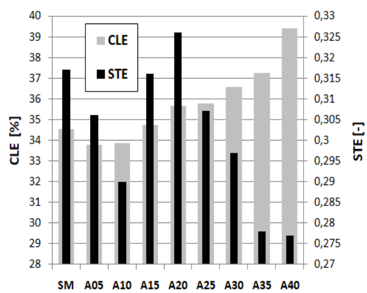

Fig. 3. Energy absorption indicators diagram

REFERENCES

[1] Hamouda AMS, Saied RO, Shuaeib FM. Energy absorption of square tubular structures. Journal of Achievements in Materials and Manufacturing Engineering 2007; 24: 36-42.

[2] Langseth M, Hopperstad OS, Hanssen AG. Crash Behaviour of Thin-Walled Aluminium Members. Thin Walled Structures 1998; 32:127-150.

[3] Ferdynus M. Kotełko M. and Kral J., Energy absorption capability numerical analysis of thin-walled prismatic tubes with corner dents under axial impact, Eksploatacja i Niezawodność-Maintenance and Reliability, 20 (2), 252-259, 2018.