POLISH ACADEMY OF SCIENCES - COMMITTEE OF MATERIALS SCIENCE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY

Conference Proceedings

12th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Experimental and numerical studies of spot welded thin-walled beams

E. Rusiński, A. Kopczyński, J. Czmochowski

Wrocław University of Technology, Mechanical Engineering Faculty, Institute of Machines Design and Operation, ul. Łukasiewicza 7/9, 50-371 Wrocław, Poland

Some findings from experimental and numerical studies of thin-walled spot welded beams subjected to axial compression are reported. The specimens were subjected to quasi-static loading. The effect of weld diameter and weld pitch on the amount of absorbed energy was studied. A discrete model was built for numerical studies. FEM strength computations were performed for physical and geometrical nonlinearity.

1. INTRODUCTION

Impact energy absorption is mainly determined by the sectional shape of the car's longitudinal members (beams) and the way in which they were made. The members can be made, for example, by spot welding two open top-hat steel sections together into one closed section. Such beams are built into the motor vehicle's front to absorb the impact energy during a crash. In the literature on the subject few results of symmetrical axial compression tests carried out on thin-walled sections made by spot welding are reported. One can obtain such information by running FEM-based simulations of the crushing of the beam.

Twenty specimens – beams with a rectangular cross-section formed by two thin-walled top-hat sections made from 1.5 mm thick steel sheet (DOCOL 800DP) – were prepared. The top-hat sections were joined by resistance spot welding. Four kinds of specimens (beams) were made: two with the spot welds respectively 4 mm and 8 mm in diameter and two differing in the distance between the welds (t = 25 mm and t = 50 mm).

The beams were subjected to quasi-static compression at a rate of 2 mm/s. Then discrete models of the same beams (with cramps: one movable and the other fixed) as above were built for FEM strength analysis using the ABAQUS/Explicit system.

2. NUMERICAL AND EXPERIMENTAL CRUSHING OF THIN-WALLED BEAMS

The numerical FEM determination of spot welded beams (Fig. 1) subjected to axial compression is a complex computational problem. In numerical FEM computations material physical nonlinearities (structural analysis after yield stress exceedance, large elastic-plastic strains), the friction of sheet folds against each other and geometrical nonlinearities (the buckling of the beam) must be taken into account [3, 4]. The tests carried out on the physical specimens (Fig. 2) showed that the spot welds were more resistant to shearing forces than to normal forces (table 1).

a) b)

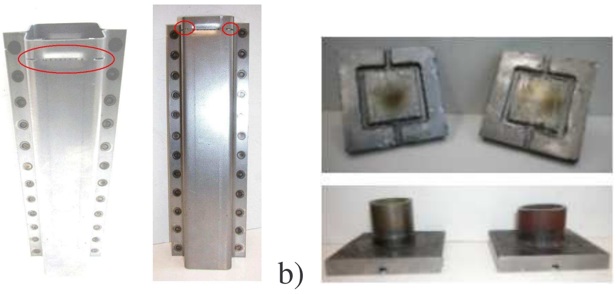


Fig. 1. Test specimens: a) beam with cut corners and overpress, b) cramps.

Table 1. Results of tests carried out on physical specimens.

Test	**Średnica zgrzeiny [mm]**	**Siła normalna [kN]**	**Siła ścinająca [kN]**
Test 1	4	11.0	13.2
Test 2	4	9.7	13.3
Test 3	4	10.6	13.3
Test 4	8	12.9	26.9
Test 5	8	14.1	26.8
Test 6	8	14.1	27.2

a) b)

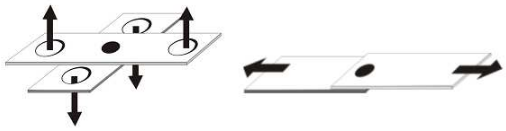


Fig. 2 Scheme of: a) cross-tension tests, b) shear tension tests

The results of numerical FEM computations showed that the largest energy absorption occurs for:

- the distance between welds equal to t = 25 mm (as compared with the results at t = 50 mm);
- welds with diameter d = 4 mm , but the difference between the energy absorbed at d = 4mm and the energy absorbed at d = 8 mm is very slight.

The largest energy absorption occurred for the weaker joint (d = 4 mm) but the crushing of the beam was much more stable at d = 8 mm.

The experimental determination of the strength of axially compressed spot welded beams [5] consisted of quasi-static compression tests (2 mm/s) carried out on the beams in the SSAB Tunnplåt laboratory (Sweden) [6]. Each beam had cut corners and an overpress at a distance of 23 mm from its highest edge (Fig. 2a) to ensure stable axial crushing. In addition, special cramps (Fig. 2b) for fixing the beams to prevent them from sliding in the crushing machine's clamps were made. The 300 mm long beams were crushed over a distance of 150 mm.

The experimental results show that the crushing of the beams with cut corners and an overpress is much more stable in comparison with the beams without them (Fig. 3).

a)

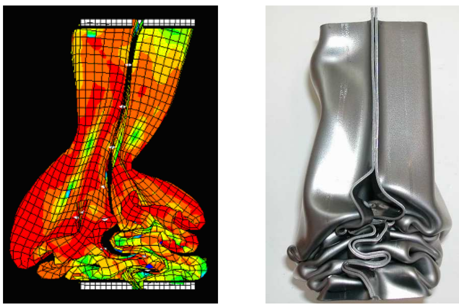
b)

Fig. 3. Assurance of stable crush by cutting corners; a) crushed beam without cut corners; b) crushed beam with cut corners

The results (Fig. 4) show that larger energy absorption occurs for the smaller distance between welds (t = 25 mm) and the larger diameter (d = 8 mm).

a)

b)



c)

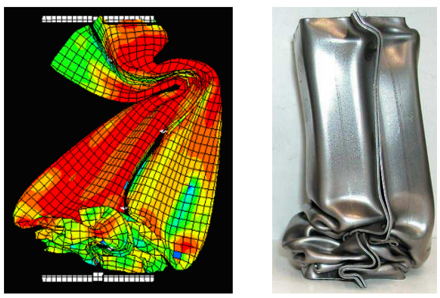


Fig. 4. Comparison of beam deformations obtained from numerical FEM simulations and laboratory tests: a) d = 8 mm, t = 25 mm, b) d = 4 mm, t = 25 mm, c) d = 8 mm, t = 50 mm.

The experimental crushed beam forms and the simulated ones are very similar in their weld failure, foldings and crush stability. An analysis of the experimental absorbed energy values and the ones obtained from computer simulations shows that the results are highly accurate as:

- for diameter d = 4 mm the difference between the experimental results and the simulation results amounts to 4.5% for interweld distance t = 25 mm and to 19.5% for t = 50 mm;
- for diameter d = 8 mm this difference amounts to 14% for interweld distance t = 25 mm and to 9.8% for t = 55 mm.

2. CONCLUSION

The results obtained from the numerical FEM simulations quite accurately reflect the actual strength of the welds and the energy absorption of the axially compressed beams (the measuring error amounts to 9.8÷14% for diameter d = 8 mm and to 4.5÷19.5% for diameter d = 4 mm). The spot weld diameter has turned out to be a significant indicator of the strength of the weld and the form of its potential fracture. The weld strengths obtained from the preceding tests were quite sufficient to determine the strength of the axially compressed spot welded beams.

The experimental results show that the largest energy absorption occurred for spot welds with diameter d = 8. Considering the distance between welds as an additional factor having an influence on energy absorption, it becomes apparent that the largest energy consumption occurred for interweld distance t = 25 mm in both the physical tests and the numerical simulations.

REFERENCES

1. O. C. Zienkiewicz, R.L. Taylor: The Finite Element Method. Fourth Edition, Vol. 1, Vol. 2. McGraw-Hill, Berkshire, England, 1991.
2. E. Rusiński, J. Czmochowski, T. Smolnicki: Advanced the Finite Element Method. The Publishing House of Wrocław University of Technology, Wrocław, 2000.
3. T. Smolnicki: Physical aspects of the coherence of the slewing bearing and deformable supporting structures. The Publishing House of Wrocław University of Technology, Wrocław, 2002.
4. A. Buchacz, A. Machura, M. Pasek: Hypergraphs in Modelling and Analysis of Complex Mechanical Systems. Systems Analysis Modelling Simulation. Vol. 43. No. 3, March 2003, New York: Taylor & Francis, p. 287-300
5. T.M. Mansour: Ultrasonic Inspection of Spot Welds in Thin-Gage Steel, Materials Evaluation, 46, (1988), pp.650-658.
6. Jan-Olof Sperle: High Strength Steel for Light Weight Structures. Report No 84-8, The Royal Institute of Technology, Stockholm, Sweden.