Energy-absorbing characteristics of the re-entry vehicle landing gear crash box

© R.O. Lukovkin

Bauman Moscow State Technical University, Moscow, 105005, Russia

The article defines energy-absorbing characteristics of the thin-walled energy absorber (crash box) mounted on the advanced landing gear of the aerospace system's re-entry spacecraft. We consider verifying the parameters of the shell-type finite-element model of small dimension in the software package MSC Nastran SOL700. The work simulates a model problem of elasto-plastic crumpling of square aluminum samples of different thickness. We compare the simulation results with the experimental data. It has been established that the suggested mathematical model provides the tolerance of less than 10 percent for the samples having a width-to-thickness ratio C/s > 30. Based on the model's verified parameters we have obtained the main energy-absorbing characteristics of the basic square crash box of the landing gear, which was subjected to geometrical modifications in order to improve its damping capabilities. The results obtained can be used for studying the characteristics of the advanced landing gear containing energy-absorbing elements.

Keywords: *crash box, energy absorption, MSC Nastran SOL700, landing gear, computational simulation*

REFERENCES

[1] Abramowicz W. Thin-Walled Structures as Impact Energy Absorbers. *Thin-Walled Structures*, 2003, vol. 41 (2–3), pp. 91–107.

[2] Baroutaji A., Sajjia M., Olabi A.G. On the Crashworthiness Performance of Thin-Walled Energy Absorbers: Recent Advances and Future Developments. *Thin-Walled Structures*, 2017, vol. 118 (9), pp. 137–163.

[3] Alghamdi A.A.A. Collapsible Impact Energy Absorbers: An Overview. *Thin-Walled Structures*, 2001, vol. 39 (2), pp. 189–213.

[4] Airoldi A., Janszen G. A Design Solution for a Crashworthy Landing Gear with a New Triggering Mechanism for the Plastic Collapse of Metallic Tubes. *Aerospace Science and Technology*, 2005, vol. 9 (5), pp. 445–455.

[5] Johnson W., Walton A.C. An Experimental Investigation of the Energy Dissipation of a Number of Car Bumpers under Quasi-Static Lateral Loads. *International Journal of Impact Engineering*, 1983, vol. 1 (3), pp. 301–308.

[6] Husainov A.Sh., Nikitin A.N. *Vestnik UlGTU (Bulletin of Ulyanovsk State Technical University),* 2012, no. 4 (60), pp. 28–32.

[7] Husainov A.Sh., Kuzmin Yu.A. *Passivnaya bezopasnost avtomobilya* [Passive car safety]. Ulyanovsk, Ulyanovsk State Technical University Publ., 2011, 89 p.

[8] Shcheglov G.A., Lukovkin R.O. *Izvestiya vysshikh uchebnykh zavedeniy. Aviatsionnaya tekhnika — Russian Aeronautics*, 2017, no. 3, pp. 59–66.

[9] Lukovkin R.O., Shcheglov G.A. *Izvestiya vysshikh uchebnykh zavedeniy. Mashinostroenie — Proceedings of Higher Educational Institutions. Machine Building,* 2017, no. 12, pp. 77–87.

[10] Doelfs P., Neubauer I. *Using MSC.Nastran for Explicit FEM Simulations*. 3. LS-DYNA Anwenderforum, Bamberg 2004. Available at: https://www.dynamore.de/en/downloads/papers/04-forum/using-msc.nastran-for-explicit-fem-simulations/at_download/file (accessed June 5, 2018).

[11] Zhang X., Zhang H. Crush Resistance of Square Tubes with Various Thickness Configurations. *International Journal of Mechanical Sciences*, 2016, vol. 107, pp. 58–68.

[12] Du Bois P.A. *Crashworthiness Engineering: Course Notes*. Livermore Software Technology Corporation, 2004.

[13] Bala S., Day J. *General guidelines for crash analysis in LS-DYNA*. Livermore Software Technology Corporation, 2006. Available at: ftp.lstc.com/anonymous/outgoing/jday/faq/guidelines.pdf (accessed June 5, 2018).

[14] Otubushin A. Detailed Validation of a Non-Linear Finite Element Code Using Dynamic Axial Crushing of a Square Tube. *International Journal of Impact Engineering*, 1998, vol. 21 (5), pp. 349–368.

[15] Chung Kim Yuen S., Nurick G.N. The Energy-Absorbing Characteristics of Tubular Structures with Geometric and Material Modifications: an Overview. *Applied Mechanics Review*, vol. 61 (2), pp. 020802-1–020802-15.

[16] Jandaghi Shahi V., Marzbanrad J. Analytical and Experimental Studies on Quasi-Static Axial Crush Behavior of Thin-Walled Tailor-Made Aluminum Tubes. *Thin-Walled Structures*, 2012, vol. 60, pp. 24–37.

[17] DiPaolo B.P., Tom J.G. A Study on an Axial Crush Configuration Response of Thin-Wall, Steel Box Components: The Quasi-Static Experiments. *International Journal of Solids and Structures*, 2006, vol. 43 (25–26), pp. 7752–7775.

[18] Shalina R.E., ed. *Aviatsionnye materialy: spravochnik. V 9 t. T. 4. Alyuminievye i berillovye splavy* [Aircraft materials: reference book. In 9 volumes. Vol. 4. Aluminium and beryl alloys]. Moscow, ONTI Publ., 1982, 627 p.

Lukovkin R.O., post-graduate, Department of Aerospace Systems, Bauman Moscow State Technical University. e-mail: LukovkinRO@ya.ru

Crash landing occurs due to numerous circumstances. Significant problems and. their proportions were illustrated in Fig.1. Moreover, existences of deformable shock absorbers like aluminium. honeycomb and crushable carbon fibres in landing gears are not feasible for high scale mass and crewed landing, as a.Â Entry â€“ begins from entry preparation to hypersonic atmospheric entry, Descent â€“ begins from entry to parachute deployment, Landing â€“ begins from lander separation to touchdown. The lander remains active in case of soft-landing. 1.2. Hard landing.Â Because HIAD is emerging as one of the principal technology to faster aerocapture and landing large scale mass and crewed mission on the surface of Mars [15]. Currently NASAâ€™s Langley Research Centre is. â€“ The energy absorption for the crashed object is the product of the mean force and the crash length or the area under force displacement curve. The crash stroke of the crash box component is an important parameter for crash component design. During integrated bumper system design, improper placement of the connecting rim will affect the crash length and consequently the energy absorption of the system by blocking the progressive failure of the crash box. The relative position of the crash box and bumper beam rim needs to be optimized in order to get the intended target. â€“ The final factor con...Â Generally, a closed beam profile has better strength and energy-absorbing capacity than open beam profile. The article defines energy-absorbing characteristics of the thin-walled energy absorber (crash box) mounted on the advanced landing gear of the aerospace systemâ€™s re-entry spacecraft. We consider verifying the parameters of the shell-type finite-element model of small dimension in the software package MSC Nastran SOL700. The work simulates a model problem of elasto-plastic crumpling of square aluminum samples of different thickness. We compare the simulation results with the experimental data. It has been established that the suggested mathematical model provides the tolerance of less than 10