Trần, Ngọc Trình; **Staat, Manfred**

Direct plastic structural design under random strength and random load by chance constrained programming. (English) Zbl 1478.74014

Eur. J. Mech., A, Solids 85, Article ID 104106, 18 p. (2021).

Summary: A new formulation to calculate shakedown limit load of structures under stochastic conditions of strength and loading is developed. Direct structural reliability design is based on the required failure probabilities by chance constrained programming, which is an effective approach of stochastic programming if it can be formulated as an equivalent deterministic optimization problem.

MSC:

74C05 Small-strain, rate-independent theories of plasticity (including rigid-plastic and elasto-plastic materials)
74E35 Random structure in solid mechanics
74S60 Stochastic and other probabilistic methods applied to problems in solid mechanics
90C15 Stochastic programming

Keywords:

limit analysi; shakedown analysis; upper bound; lower bound; stochastic programming method; chance constrained programming; reliability

Full Text: DOI

References:

[1] Baravalle, M., Risk and Reliability Based Calibration of Structural Design Codes - Principles and Applications (2017), Norwegian University of Science and Technology: Norwegian University of Science and Technology Trondheim

[2] Belytschko, T., Plane stress shakedown analysis by finite elements, Int. J. Mech. Sci., 14, 619-625 (1972)

[3] Bernuzzi, C.; Cordova, B., Structural Steel Design to Eurocode 3 and AISC Specifications (2016), John Wiley \& Sons, Ltd: John Wiley \& Sons, Ltd Chichester, UK

[4] Bisbos, C. D.; Makrodimopoulos, A.; Pardalos, P. M., Second-order cone programming approaches to static shakedown analysis in steel plasticity, Optim. Methods Software, 20, 25-52 (2005) · Zbl 1068.90099

[5] Charnes, A.; Cooper, W. W., Chance-constrained programming, Manag. Sci., 6, 73-79 (1959) · Zbl 0995.90600

[6] Charnes, A.; Cooper, W. W.; Symonds, G. H., Cost horizons and certainty equivalents: an approach to stochastic programming of heating oil, Manag. Sci., 4, 235-263 (1958)

[7] Chen, H. F.; Ponter, A. R.S., Shakedown and limit analyses for 3-D structures using the linear matching method, Int. J. Pres. Ves. Pip., 78, 443-451 (2001)

[8] Corradi, L.; Zavelani, A., A linear programming approach to shakedown analysis of structures, Comput. Methods Appl. Mech. Eng., 3, 37-53 (1974)

[9] Dentcheva, D., Optimization models with probabilistic constraints, (Calafiore, G.; Dabbene, F., Probabilistic and Randomized Methods for Design under Uncertainty (2006), Springer-Verlag: Springer-Verlag London), 49-97 · Zbl 1181.90204

[10] Ditlevsen, O.; Madsen, H. O., Structural Reliability Methods (2007), Department of Mechanical Engineering Technical University of Denmark: Department of Mechanical Engineering Technical University of Denmark Lyngby

[11] Doorn, N.; Hansson, S. O., Should probabilistic design replace safety factors?, Philos. Technol., 24, 151-168 (2011)

[12] EN 13445-3, Unfired Pressure Vessels - Part 3: Design (2014), Comité Européen de Normalisation (CEN)

[13] Garcea, G.; Armentano, G.; Petrolo, S.; Casciaro, R., Finite element shakedown analysis of two-dimensional structures, Int. J. Numer. Methods Eng., 63, 1174-1202 (2005) · Zbl 1084.74052

[14] Gaydon, F. A.; McCrum, A. W., A theoretical investigation of the yield point loading of a square plate with a central circular hole, J. Mech. Phys. Solid., 2, 156-169 (1954)

[15] Geletu, A.; Hoffmann, A.; Li, P., Analytic approximation and differentiability of joint chance constraints, Optimization, 68, 1985-2023 (2019) · Zbl 1428.90104

[16] Genna, F., A nonlinear inequality, finite element approach to the direct computation of shakedown load safety factors, Int. J. Mech. Sci., 30, 769-789 (1988) · Zbl 0669.73027

[17] Groß-Weege, J., On the numerical assessment of the safety factor of elastic-plastic structures under variable loading, Int. J.

Mech. Sci., 39, 417-433 (1997) · Zbl 0891.73051

[18] Haneveld, W. K.K.; Vlerk, M. H.; Romeijnders, W., Stochastic Programming: Modeling Decision Problems under Uncertainty (2020), Springer: Springer Cham · Zbl 1446.90118

[19] Heitzer, M.; Pop, G.; Staat, M., Basis reduction for the shakedown problem for bounded kinematic hardening material, J. Global Optim., 17, 185-200 (2000) · Zbl 1011.74009

[20] Heitzer, M.; Staat, M., Direct FEM limit and shakedown analysis with uncertain data, (Oñate, E.; Bugeda, G.; Suarez, B., CD-ROM Proceedings of the European Congress on Computational Methods in Applied Sciences and Engineering, ECCOMAS 2000, Barcelona, Spain, 11-14 September 2000 (2000), ECCOMAS: ECCOMAS Barcelona), 1-13

[21] Heitzer, M.; Staat, M.; Reiners, H.; Schubert, F., Shakedown and ratchetting under tension-torsion loadings: analysis and experiments, Nucl. Eng. Des., 225, 11-26 (2003)

[22] General principles on reliability for structures (2015), International Organization for Standardization: International Organization for Standardization Geneve

[23] JCSS-OSTL/DIA/VROU-10-11-2000, Probabilistic Model Code, Part 1 - Basis of Design (2001), Joint Committee on Structural Safety, 12th draft

[24] Koiter, W. T., General theorems for elastic plastic solids, (Sneddon, I. N.; Hill, R., Progress in Solid Mechanics. North-Holland, Amsterdam (1969)), 165-221

[25] König, J. A., Shakedown of Elastic-Plastic Structures. North Holland, Amsterdam (1987)

[26] Mackenzie, D.; Boyle, J. T.; Hamilton, R., The elastic compensation method for limit and shakedown analysis: a review, J. Strain Anal. Eng. Des., 35, 171-188 (2000)

[27] Melan, E., Theorie statisch unbestimmter Systeme aus idealplastischem Baustoff. Sitzungsbericht der Akad. der Wissenschaften, 145, 195-218 (1936), IIa: IIa Wien, Abt · Zbl 62.1547.01

[28] Nadolski, V.; Rózsás, Á.; Sýkora, M., Calibrating partial factors – methodology, input data and case study of steel structures, Period. Polytech. Civ. Eng., 63, 222-242 (2019)

[29] Nowak, A. S.; Collins, K. R., Reliability of Structures (2012), CRC: CRC London

[30] Pagnetti, A.; Ezzaki, M.; Anqouda, I., Impact of wind power production in a European optimal power flow, Elec. Power Syst. Res., 152, 284-294 (2017)

[31] Phạm, P. T.; Staat, M., FEM-based shakedown analysis of hardening structures, Asia Pacific J. Comput. Eng., 1, 4 (2014)

[32] Pilkey, W. D.; Pilkey, D. F., Peterson's Stress Concentration Factors (2007), John Wiley \& Sons, Inc.: John Wiley \& Sons, Inc. Hoboken, NJ, USA

[33] Prékopa, A., Stochastic Programming (1995), Springer Netherlands: Springer Netherlands Dordrecht · Zbl 0834.90098

[34] Ri, J.-H.; Hong, H.-S., A basis reduction method using proper orthogonal decomposition for shakedown analysis of kinematic hardening material, Comput. Mech., 64, 1-13 (2019) · Zbl 1467.74016

[35] Sikorski, K. A.; Borkowski, A., Ultimate load analysis by stochastic programming, (Smith, L. D., Mathematical Programming Methods in Structural Plasticity (1990), Springer Vienna: Springer Vienna Vienna), 403-424 · Zbl 0819.73079

[36] Simon, J.-W.; Weichert, D., Shakedown analysis of engineering structures with limited kinematical hardening, Int. J. Solid Struct., 49, 2177-2186 (2012)

[37] Simon, J.-W.; Weichert, D., Numerical lower bound shakedown analysis of engineering structures, Comput. Methods Appl. Mech. Eng., 200, 2828-2839 (2011) · Zbl 1230.74046

[38] Staat, M., Limit and shakedown analysis under uncertainty, Int. J. Comput. Methods, 11, 1343008 (2014) · Zbl 1359.74350

[39] (Staat, M.; Heitzer, M., Numerical methods for limit and shakedown analysis. Deterministic and probabilistic problems, Publication Series of the John von Neumann Institute for Computing (NIC). Central Institute for Applied Mathematics (2003), Research Centre Jülich: Research Centre Jülich Jülich, Germany) · Zbl 1001.90024

[40] Staat, M.; Heitzer, M., Probabilistic limit and shakedown problems, (Staat, M.; Heitzer, M., Numerical Methods for Limit and Shakedown Analysis. Deterministic and Probabilistic Approach (2003), Publication Series of the John von Neumann Institute for Computing (NIC). Central Institute for Applied Mathematics, Research Centre Jülich: Publication Series of the John von Neumann Institute for Computing (NIC). Central Institute for Applied Mathematics, Research Centre Jülich Jülich, Germany), 217-268

[41] Staat, M.; Heitzer, M., LISA - a European project for FEM-based limit and shakedown analysis, Nucl. Eng. Des., 206, 151-166 (2001)

[42] Trần, N. T.; Staat, M., Direct plastic structural design under lognormally distributed strength by chance constrained programming, Optim. Eng., 21, 131-157 (2020) · Zbl 1433.90099

[43] Tran, N. T.; Tran, T. N.; Matthies, H. G.; Stavroulakis, G. E.; Staat, M., Shakedown analysis under stochastic uncertainty by chance constrained programming, (Barrera, O.; Cocks, A.; Ponter, A., Advances in Direct Methods for Materials and Structures (2018), Springer International Publishing: Springer International Publishing Cham), 85-103

[44] Tran, T. N.; Liu, G. R.; Nguyen-Xuan, H.; Nguyen-Thoi, T., An edge-based smoothed finite element method for primal-dual shakedown analysis of structures, Int. J. Numer. Methods Eng., 82, 917-938 (2009) · Zbl 1188.74073

[45] Trân, T. N.; Staat, M., An edge-based smoothed finite element method for primal-dual shakedown analysis of structures under uncertainties, (de Saxcé, G.; Oueslati, A.; Charkaluk, E.; Tritsch, J.-B., Limit State of Materials and Structures (2013), Springer Netherlands: Springer Netherlands Dordrecht), 89-102

[46] Vu, D. K.; Staat, M.; Tran, I. T., Analysis of pressure equipment by application of the primal-dual theory of shakedown,

Commun. Numer. Methods Eng., 23, 213-225 (2007) · Zbl 1107.74007

[47] Vu, D. K.; Yan, A. M.; Nguyen-Dang, H., A primal-dual for shakedown analysis of structures, Comput. Methods Appl. Mech. Eng., 193, 4663-4674 (2004), 10.1016/j.cma.2004.03.011 · Zbl 1112.74546

[48] (Weichert, D.; Maier, G., Inelastic Behaviour of Structures under Variable Repeated Loads (2002), Springer Vienna: Springer Vienna Vienna) · Zbl 1030.00039

[49] Zouain, N., Shakedown and safety assessment, (Stein, E.; de Borst, R.; Hughes, T. J.R., Encyclopedia of Computational Mechanics (2017), John Wiley \& Sons, Ltd: John Wiley \& Sons, Ltd Chichester, UK), 1-48