Pan, Xiaofei; **Wu, C. T.**; **Hu, Wei**; **Wu, Youcai**

A momentum-consistent stabilization algorithm for Lagrangian particle methods in the thermo-mechanical friction drilling analysis. (English) Zbl 07099894

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Summary: This paper introduces a new stabilization algorithm to Lagrangian particle methods for the coupled thermal mechanical analysis in the friction drilling simulation. Different from the conventional penalty method which utilizes a direct smoothing of velocity fields in the weak formulation, the proposed algorithm introduces the smoothed velocity fields through linear momentum equations for stabilization. Particle approximations are used for the discretization of coupled thermal mechanical discrete equations. The coupled system is solved by the explicit and staggered time marching scheme. In comparison to the conventional penalty method which requires at least one extra integration point for stabilization, the proposed algorithm needs only one integration point per particle in computation. The essential features of linear and angular momentum conservations are preserved in the explicit dynamic analysis. A bridging scheme is also developed to couple the particle formulation with finite element formulation for practical industrial applications. Several benchmark tests are performed to examine the effectiveness of this new method. Furthermore, a friction drilling application is studied, and the results are compared with the experimental data.

MSC:

74 Mechanics of deformable solids

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particle formulation; stabilization; direct nodal integration (DNI); momentum-consistent (MC); thermal mechanical

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References:

[1] Miller, SF; Shih, AJ; Blau, PJ, Microstructural alterations associated with friction drilling of steel, aluminum, and titanium, J Mater Eng Perform, 15, 647-653, (2005)

[2] Miller, SF; Shih, AJ, Thermo-mechanical finite element modeling of the friction drilling process, J Manuf Sci Eng, 129, 531-538, (2007)

[3] Belytschko T, Liu WK, Moran B, Elkhodary KI (2014) Nonlinear finite elements for continua and structures, 2nd edn. Wiley, London · Zbl 1279.74002

[4] Raju, BP; Swamy, MK, Finite element simulation of a friction drilling procedure using Deform-3D, Int J Eng Res Technol, 2, 716-721, (2012)

[5] Gopichand, A.; Brahmam, MV; Bhanuprakash, D., Numerical simulation and analysis of friction drilling process for aluminum alloy using Ansys, Int J Eng Res Technol, 3, 602-607, (2014)

[6] Buffa, G.; Hua, J.; Shivpuri, R.; Fratini, L., A continuum based fem model for friction stir welding—model development, Mater Sci Eng, A, 419, 389-396, (2006)

[7] Meyghani, B.; Awang, MB; Emamian, SS; Mohd Nor, MKB; Pedapati, SR, A comparison of different finite element methods in the thermal analysis of friction stir welding (FSW), Metals, 7, 450, (2017)

[8] Chen, JS; Pan, C.; Wu, CT; Liu, WK, Reproducing kernel particle methods for large deformation analysis of non-linear structures, Comput Methods Appl Mech Eng, 139, 195-227, (1996) · Zbl 0918.73330

[9] Rabczuk, T.; Belytschko, T., Cracking particles: a simplified meshfree method for arbitrary evolving cracks, Int J Numer Methods Eng, 61, 2316-2343, (2004) · Zbl 1075.74703

[10] Simkins, DC; Li, S., Meshfree simulation of thermo-mechanical ductile fracture, Comput Mech, 38, 235-249, (2006) · Zbl 1162.74052

[11] Li S, Liu WK (2004) Meshfree particle method. Springer, Berlin

[12] Wang, DD; Chen, JS, Locking free stabilized conforming nodal integration for meshfree Mindlin-Reissner plate formulation, Comput Methods Appl Mech Eng, 193, 1065-1083, (2004) · Zbl 1060.74675

[13] Gingold, RA; Monaghan, JJ, Smoothed particle hydrodynamics—theory and application to non-spherical stars, Mon Not R Astron Soc, 181, 375-389, (1977) · Zbl 0421.76032

[14] Lucy, LB, A numerical approach to the testing of the fission hypothesis, Astron J, 82, 1013-1024, (1977)

[15] Libersky, LD; Petschek, AG, Smooth particle hydrodynamics with strength of materials, Lect Notes Phys, 395, 248-257, (1990)

[16] Shadloo, MS; Oger, G.; Touzé, DL, Smoothed particle hydrodynamics method for fluid flows, towards industrial applications: motivations, current state, and challenges, Comput Fluid, 136, 11-34, (2016) · Zbl 1390.76764

[17] Swegle, W.; Hicks, DL; Attaway, SW, Smoothed particle hydrodynamics stability analysis, Comput Mech, 116, 123-134, (1995) · Zbl 0818.76071

[18] Belytschko, T.; Guo, Y.; Liu, WK; Xiao, SP, A unified stability analysis of meshless particle methods, Int J Numer Methods Eng, 48, 1359-1400, (2000) · Zbl 0972.74078

[19] Wu, CT; Ma, N.; Takada, K.; Okada, H., A meshfree continuous-discontinuous approach for the ductile fracture modeling in explicit dynamics analysis, Comput Mech, 58, 391-409, (2016) · Zbl 1398.74480

[20] Rabczuk, T.; Belytschko, T.; Xiao, SP, Stable particle methods based on Lagrangian kernels, Comput Methods Appl Mech Eng, 193, 1035-1063, (2004) · Zbl 1060.74672

[21] Dyka, CT; Randles, PW; Ingel, RP, Stress points for tension instability in SPH, Int J Numer Methods Eng, 40, 2325-2341, (1997) · Zbl 0890.73077

[22] Beissel, S.; Belytschko, T., Nodal integration of the element-free Galerkin method, Comput Methods Appl Mech Eng, 139, 49-74, (1996) · Zbl 0918.73329

[23] Wu, CT; Koishi, M.; Hu, W., A displacement smoothing induced strain gradient stabilization for the meshfree Galerkin nodal integration method, Comput Mech, 56, 19-37, (2016) · Zbl 1329.74292

[24] Hillman, M.; Chen, JS, An accelerated, convergent, and stable nodal integration in Galerkin meshfree methods for linear and nonlinear mechanics, Int J Numer Methods Eng, 107, 603-630, (2016) · Zbl 1352.74119

[25] Chen, JS; Wu, CT; Yoon, S.; You, Y., A stabilized conforming nodal integration for Galerkin Meshfree methods, Int J Numer Methods Eng, 50, 435-466, (2001) · Zbl 1011.74081

[26] Hillman, M.; Chen, JS; Chi, SW, Stabilized and variationally consistent nodal integration for meshfree modeling of impact problems, Comput Particle Mech, 1, 245-256, (2014)

[27] Guan, PC; Chen, JS; Wu, Y.; Tang, H.; Gaidos, J.; Hofstetter, K.; Alsaleh, M., Semi-Lagrangian reproducing kernel formulation and application to modeling earth moving operations, Mech Mater, 41, 670-683, (2009)

[28] Wu, CT; Chi, SW; Koishi, M.; Wu, Y., Strain gradient stabilization with dual stress points for the meshfree nodal integration method in inelastic analysis, Int J Numer Methods Eng, 107, 3-30, (2016) · Zbl 1352.74060

[29] Wu, CT; Wu, Y.; Crawford, JE; Magallanes, JM, Three-dimensional concrete impact and penetration simulations using the smoothed particle Galerkin method, Int J Impact Eng, 106, 1-17, (2017)

[30] Chen, JS; Zhang, X.; Belytschko, T., An implicit gradient model by a reproducing kernel strain regularization in strain localization problems, Comput Methods Appl Mech Eng, 193, 2827-2844, (2014) · Zbl 1067.74564

[31] Wu, CT; Wu, Y.; Liu, Z.; Wang, D., A stable and convergent Lagrangian particle method with multiple nodal stress points for large strain and material failure analyses in manufacturing processes, Finite Elem Anal Des, 146, 96-106, (2018)

[32] Silling, SA; Askari, E., A meshfree method based on the peridynamic model of solid mechanics, Comput Struct, 83, 1526-1535, (2005)

[33] Wu, CT; Bui, TQ; Wu, YC; Luo, TL; Wang, M.; Liao, CC; Chen, PY; Lai, YS, Numerical and experimental validation of a particle Gakerkin method for metal grinding simulation, Comput Mech, 61, 383, (2018) · Zbl 06876201

[34] Felippa, CA; Park, KC, Staggered transient analysis procedures for coupled dynamic systems, Comput Methods Appl Mech Eng, 26, 61-112, (1980) · Zbl 0453.73091

[35] Hughes TJR (2000) The finite element method. Prentice-Hall, Englewood Cliffs · Zbl 1191.74002

[36] Hallquist JO (2006) LS-DYNA® keyword user's manual. Livermore Software Technology Corporation, Livermore

[37] Liu, WK; Chen, Y., Wavelet and multiple scale reproducing kernel particle methods, Int J Numer Methods Fluid Dyn, 21, 901-931, (1995) · Zbl 0885.76078

[38] Liu, WK; Uras, RA; Chen, Y., Enrichment of the finite element method with reproducing kernel particle method, J Appl Mech, 135, 143-166, (1997) · Zbl 0920.73366

[39] Belytschko, T.; Organ, D.; Krongauz, Y., A coupled finite element-element-free Galerkin method, Comput Mech, 17, 186-195, (1995) · Zbl 0840.73058

[40] Sulsky, D.; Schreyer, HL, Axisymmetric form of the material point method with application to upsetting and Taylor impact problems, Comput Methods Appl Mech Eng, 139, 409-429, (1996) · Zbl 0918.73332

[41] Johnson, GR; Holmquist, TJ, Evaluation of Cylinder-impact test data for constitutive model constants, J Appl Phys, 64, 3901-3910, (1988)

[42] Krasauskas, P.; Kilikevičius, S.; Česnavičius, R.; Pačenga, D., Experimental analysis and numerical simulation of the stainless AISI 304 steel friction drilling process, Mechanika, 20, 590-595, (2014)

[43] Chow, HM; Lee, SM; Yang, LD, Machining characteristic study of friction drilling on AISI 304 stainless steel, J Mater Process Technol, 207, 180-186, (2018)

[44] Lee, SM; Chow, HM; Huang, FY; Yan, BH, Friction drilling of austenitic stainless steel by uncoated and PVD AlCrN- and TiAlN-coated tungsten carbide tools, Int J Mach Tools Manuf, 49, 81-88, (2009)

[45] Johnson GR, Cook WH (1983) A constitutive model and data for metals subjected to large strains, high strain rates, and high temperatures. In: Proceedings of the 7th international symposium on ballistics (1983), pp 541-547, The Hague, Netherlands

[46] Belytschko, T.; Lu, YY; Gu, L., Element-free Galerkin Methods, Int J Numer Methods Eng, 37, 229-256, (1994) · Zbl 0796.73077

[47] Liu, WK; Jun, S.; Li, S.; Adee, J.; Belytschko, T., Reproducing kernel particle methods for structural dynamics, Int J Numer Methods Eng, 38, 1655-1679, (1995) · Zbl 0840.73078