**Table A1** Numerical simulations of wellbore flow and heat transfer in SC-CO2 fracturing

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Fracturing technology | Well type | Heat transfer medium | Heat source | Friction coefficient | Heat transfer and flow state | Heat transfer description method between CO2 and formation | References |
| Tubing fracturing | Vertical well | CASF | Joule–Thomson effect | Chen (1979) | Steady & steady | Comprehensive heat transfer coefficient | Dou et al. (2013) |
| CTACSF | Friction heat | Chen (1979) | Unsteady & unsteady | Differential equation | Guo and Zeng (2015) |
| CTACSF | Joule–Thomson effect & friction heat | U | Unsteady & unsteady | Differential equation | Guo et al. (2015) |
| CASF | N | Jain (1976) | Unsteady & steady | Comprehensive heat transfer coefficient | Lv et al. (2015) |
| CTACSF | Joule–Thomson effect & friction heat & expansion/compression work | Wang et al. (2014) | Steady & steady | Comprehensive heat transfer coefficient | Li et al. (2018) |
| CTACSF | Joule–Thomson effect & friction heat | U | Unsteady & unsteady | Differential equation | Lyu et al. (2018a)  |
| CTACSF | Joule–Thomson effect & friction heat | Chen (1979) | Unsteady & unsteady | Differential equation | Lyu et al. (2018b)  |
| CTACSF | Friction heat | Wang and Touber (1991) | Unsteady & unsteady | Differential equation | Yang et al. (2018a)  |
| CTACSF | Friction heat | Churchill (1977) | Steady & steady | Comprehensive heat transfer coefficient | Yang et al. (2018b)  |
| CTACSF | Joule–Thomson effect | Wang et al. (2014) | Steady & steady | Comprehensive thermal resistance | Bai et al. (2019)  |
| CTACSF | Joule–Thomson effect & friction heat | U | Unsteady & unsteady | Differential equation | Gong et al. (2019a) |
| CTACSF | N | Wang et al. (2014) | Unsteady & unsteady | Differential equation | Wang et al. (2019a)  |
| Horizontal well | CTACSF | Joule–Thomson effect & friction heat | Zheng et al. (2017) | Unsteady & unsteady | Differential equation | Lyu et al. (2021) |
| Tubing and annulus co-injection fracturing | Vertical well | CTACSF | Joule–Thomson effect & friction heat | Chen (1979) | Unsteady & unsteady | Differential equation | Gong et al. (2019b)  |
| CTACSF | Joule–Thomson effect & friction heat & expansion/compression work | Chen (1979) | Unsteady & unsteady | Differential equation | Wu et al. (2021)  |
| Coiled tubing jet fracturing | Vertical well | CASF | N | U | Steady & steady | Comprehensive heat transfer coefficient | Cheng et al. (2014) |
| CTACSF | N | Wang et al. (2014) | Steady & steady | Heat transfer quantity for each medium | Song et al. (2017) |
| CTACSF | Friction heat | Churchill (1977) | Steady & steady | Comprehensive heat transfer coefficient | Yang et al. (2018c)  |
| CTACSF | Joule–Thomson effect & friction heat | Churchill (1977) | Unsteady & unsteady | Differential equation | Yi et al. (2019)  |

Note: CASF- Carbon dioxide, annulus, cement sheath, and formation, CTACSF- Carbon dioxide, tubing, annulus, casing, cement sheath, and formation, N- No, U- Unknow.

**Table A2** Numerical simulations of fracture initiation and propagation in SC-CO2 fracturing

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Method | Coupling | CO2 compressibility | Rock heterogeneity | Propagation criteria | Reservoir | Weak plane | Dimension | Physical model size (m) | Solution software/code | References |
| DEL | HM | Y | Y | Stress intensity factor K1 | Shale | N | 2D | 0.1×0.1 | COMSOL&MATLAB | Zhang et al. (2017a)  |
|
| HM | Y | Y | Maximum tensile stress criterion & Mohr-Coulomb criterion  | Shale | N | 2D | 1.9×1.9 | COMSOL&MATLAB | Liu et al. (2018)  |
| THM | Y | Y | Maximum tensile stress criterion & Mohr-Coulomb criterion  | Tight sandstone | N | 2D | 2×2 | COMSOL | Zhang et al. (2018) |
| HM | Y | Y | Maximum tensile stress criterion & Mohr-Coulomb criterion  | Shale | Bedding planes | 2D | 0.2×0.2 | COMSOL&MATLAB | Zhang et al. (2019)  |
| HM | Y | Y | Maximum tensile stress criterion & Mohr-Coulomb criterion  | U | N | 2D | 0.2×0.2 | COMSOL&MATLAB | Jia et al. (2020)  |
| HM | Y | Y | Stress intensity factor K1 Maximum tensile stress criterion & Mohr-Coulomb criterion  | Coalbed | N | 2D | 1×1 | COMSOL&MATLAB | Xue et al. (2021) |
| HM | Y | Y | Maximum tensile stress criterion & Mohr-Coulomb criterion  | Shale | Bedding planes | 2D | 0.2×0.2 | COMSOL&MATLAB | Zhang et al. (2021)  |
| HM | Y | Y | Maximum tensile stress criterion & Mohr-Coulomb criterion  | U | Natural fractures | 2D | 100×200 | U | Guo et al. (2022) |
| CZM | HM | N | N | U | U | Natural fractures | 2D | 30×30 | ABAQUS | Song et al. (2019)  |
| HM | N | Y | Maximum tensile stress criterion & Mohr-Coulomb criterion  | U | N | 2D | 0.2×0.2 | U | Liu et al. (2020)  |
| HM | N | Y | U | U | N | 2D | 25×25 | ABAQUS | Cai et al. (2021)  |
| HM | N | N | B-K criterion | Shale | N | 3D | R200×H15 | U | Song et al. (2021)  |
| HM | Y | Y | U | Coalbed | N | 2D | 0.05×0.05 | U | Yang et al. (2021)  |
| PFM | HM | Y | Y | Critical energy release rate criterion | U | N | 2D | 1×1 | U | Ha et al. (2018) |
| HM | Y | N | Critical energy release rate criterion | Shale | Natural fractures | 2D | 1×1 | U | Mollaali et al.(2019) |
| HM | Y | N | Critical energy release rate criterion | U | N | 2D | 4×4 (max) | U | Feng et al. (2021) |
| XEFM | HM | N | N | B-K criterion | Coalbed | N | 2D |  | ABAQUS | Yan et al. (2019) |
| HM | N | N | B-K criterion | Coalbed | N | 2D | 20×10 | ABAQUS & Fluent | Yan et al. (2020) |
| THM | Y | N | Critical energy release rate criterion | Shale | Bedding planes | 2D | 100×100 | U | Luo et al. (2021) |
| HM | N | N | B-K criterion | Coalbed | N | 2D | 20×20 | ABAQUS | Yan et al. (2021) |
| DDM | THM | Y | N | Stress intensity factor K1 | Shale | N | 3D | U | U | Li et al. (2019a) |
| THM | Y | N | Stress intensity factor K1 | U | N | 3D | U | U | He et al. (2020)  |
| HM | Y | N | U | U | Natural fractures | 3D | 500×500 | U | Zhao et al. (2021)  |
| FDM | THM | N | N | Tensile strength criteria | Tight sandstone | N | 3D | 2000 × 1000 × 2500 | FLAC3D | Liao (2020) |
| PFC | HM | N | Y | Tensile and shear strength criteria | Shale | Natural fractures | 3D | 0.1×0.1×0.1 | PFC3D | Peng et al. (2017)  |
| HM | N | Y | Tensile and shear strength criteria | Coalbed | N | 2D | 0.85mm×0.85mm (max) | PFC2D | Zhang et al. (2017b)  |
| HM | N | Y | Tensile and shear strength criteria | U | Natural fractures | 2D | 1×1 | PFC2D | Li et al. (2019b) |

Note: DEL- Damage evolution law, CZM- Cohesive zone model, PFM- Phase field method, XFEM- Extended finite element method, DDM- Displacement discontinuity method, FDM- Finite element method, PFC- Particle flow code, Y- Yes, N- No, U- Unknown.

**Table A3** Numerical simulations of proppant transport in SC-CO2 fracturing

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Method | Fracturepropagation | Fracturegeometry | Fracture size (m) | Inlet boundary conditions | Outlet boundary conditions | References |
| Computationalfluiddynamics | Euler-Euler method | N | Plane fracture | 2.07×0.495×0.009 | Constant mass flows and proppant volume fractions | Atmospheric pressure | Song et al. (2018)  |
| N | Plane fracture | 3×0.4×0.01 | Wang et al. (2018a) |
| N | Complex fracture | / | Wang et al. (2018b)  |
| N | Plane fracture | 2.4×6×0.006 | Xiao et al. (2018) |
| N | Complex fracture | / | Ge et al. (2019) |
| N | Plane fracture | 3×0.5×0.004 | Zheng et al. (2020a)  |
| N | Plane fracture | 60×6×0.02 | Zhou et al. (2020) |
| Euler-Lagrange method | N | Tortuous fracture | / | Xu et al. (2020) |
| N | Plane fracture | 0.7×0.1×0.002 | Zheng et al. (2020b) |
| N | Plane fracture | 0.5×0.15×0.002 | Zheng et al. (2021) |
| Proppantsettlement theory | Combing equilibrium velocity equation with proppant bank increment equation | Y | PKN-type fracture | / | Closure stress | Sun et al. (2018) |
| Y | PKN-type fracture | / | Wang et al. (2019b) |
| Based on the corrected Stokes settlement theory and considering the effects of proppant concentration and fracture wall | Y | Three-dimensional planar fracture | / | Liao (2020) |
| Based on the Dontsov model and considering the effects of proppant concentration and fracture width | Y | PKN-type fracture | / | Wang and Elsworth (2020) |

Note: Y- Yes, N- No

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