Praise Worthy Prize

International Review on
Modelling and Simulations
(IREMOS)

2D Simulation of Two-Phase Flow for Water Jet Cutting Processes with OpenFOAM®

Edwin Espinel[1*], Jhan Piero Rojas[2], Eder Florez[3]

[*] *Corresponding author*

Authors' affiliations

DOI: https://doi.org/10.15866/iremos.v14i4.19332

Abstract

Cold cutting processes are characterized to perform the kinetic energy needed to cut hard materials with little mechanical effort by means of the ultra-high flow pressure pumps, which produce water jets with a flow pressure value of around 90 ksi. These manufacturing processes may be studied considering the fluid mechanics' principles that describe the transport phenomena for inviscid, continuous, and incompressible laminar flows in order to obtain theoretical results approximated to the process conditions. In this sense, the numerical modeling techniques applied in the analysis of water jet cutting processes define an efficient solution of the processes due to the physical analysis of the partial differential equations, which quantify the abrasive flow particles into the system. Taking into account the above, this research proposes a numerical analysis of the physical phenomena through the two-phase flow simulation in steady state with OpenFOAM. Abrasive and liquid phases are quantified to study the turbulent values, which describe the water jet behavior under different working conditions. A 2D model has been computed and discretized, considering the nozzle features in order to visualize and predict the abrasive mixture and flow rejected by using a low computational effort. Therefore, this numerical approach has been validated with a mesh independency analysis developed to verify the relation between the numerical data and the finite number of nodes computed in order to discretize a computational domain and to solve analytically the system proposed until reaching a high approximation between the model and the experimental values obtained during the cutting process by means of abrasive flows.

Keywords

CFD; Flow Simulation; Turbulence Modeling; Two-Phase; Water Jet Cutting

Full Text:

PDF

References

Obregon, L., Valencia, G., Duarte Forero, J., Efficiency Optimization Study of a Centrifugal Pump for Industrial Dredging Applications Using CFD, (2019) International Review on Modelling and Simulations (IREMOS), 12 (4), pp. 245-252.
https://doi.org/10.15866/iremos.v12i4.18009

Orozco, T., Herrera, M., Duarte Forero, J., CFD Study of Heat Exchangers Applied in Brayton Cycles: a Case Study in Supercritical Condition Using Carbon Dioxide as Working Fluid, (2019) International Review on Modelling and Simulations (IREMOS), 12 (2), pp. 72-82.
https://doi.org/10.15866/iremos.v12i2.17221

R. Tripathi, S. Hloch, S. Chattopadhyaya, D. Klichová, J. Ščučka, and A. K. Das, Application of the pulsating and continous water jet for granite erosion, International Journal of Rock Mechanics and Mining Sciences, vol. 126, p. 104209, 2020.
https://doi.org/10.1016/j.ijrmms.2020.104209

U. Ashok Kumar, S. Mehtab Alam, and P. Laxminarayana, Influence of abrasive water jet cutting on glass fibre reinforced polymer (GFRP) composites, Materials Today: Proceedings, 2020.
https://doi.org/10.1016/j.matpr.2020.03.554

A. Polyakov, A. Zhabin, E. Averin, and A. Polyakov, Generalized equation for calculating rock cutting efficiency by pulsed water jets, Journal of Rock Mechanics and Geotechnical Engineering, vol. 11, no. 4, pp. 867-873, 2019.
https://doi.org/10.1016/j.jrmge.2018.11.009

Y. Natarajan, P. K. Murugesan, M. Mohan, and S. A. Liyakath Ali Khan, Abrasive Water Jet Machining process: A state of art of review, Journal of Manufacturing Processes, vol. 49, pp. 271-322, 2020.
https://doi.org/10.1016/j.jmapro.2019.11.030

Orozco, W., Acuña, N., Duarte Forero, J., Characterization of Emissions in Low Displacement Diesel Engines Using Biodiesel and Energy Recovery System, (2019) International Review of Mechanical Engineering (IREME), 13 (7), pp. 420-426.
https://doi.org/10.15866/ireme.v13i7.17389

R. Portaro, J. Sadek, and H. D. Ng, On the application of gas detonation-driven water jet for material surface treatment process, Manufacturing Letters, vol. 21, pp. 70-74, 2019.
https://doi.org/10.1016/j.mfglet.2019.09.004

Duarte Forero, J., Lopez Taborda, L., Bula Silvera, A.,

Characterization of the Performance of Centrifugal Pumps Powered by a Diesel Engine in Dredging Applications, (2019) International Review of Mechanical Engineering (IREME), 13 (1), pp. 11-20.
https://doi.org/10.15866/ireme.v13i1.16690

F. Consuegra, A. Bula, W. Guillín, J. Sánchez, and J. Duarte Forero, Instantaneous in-Cylinder Volume Considering Deformation and Clearance due to Lubricating Film in Reciprocating Internal Combustion Engines, Energies, vol. 12, no. 8, p. 1437, 2019.
https://doi.org/10.3390/en12081437

G. Valencia Ochoa, C. Isaza-Roldan, and J.D. Forero, Economic and Exergo-Advance Analysis of a Waste Heat Recovery System Based on Regenerative Organic Rankine Cycle under Organic Fluids with Low Global Warming Potential, Energies, vol. 13, no. 6, p.1317, 2020.
https://doi.org/10.3390/en13061317

G. Valencia, J. Duarte, and C. Isaza-Roldan, Thermoeconomic analysis of different exhaust waste-heat recovery systems for natural gas engine based on ORC, Applied Sciences, vol. 9, no. 19, p. 4017, 2019.
https://doi.org/10.3390/app9194017

M. Alibaba, R. Pourdarbani, M.H.K. Manesh, G.V. Ochoa and, J.D. Forero, Thermodynamic, exergo-economic and exergo-environmental analysis of hybrid geothermal-solar power plant based on ORC cycle using emergy concept, Heliyon, vol. 6, no. 4, p. e03758, 2020.
https://doi.org/10.1016/j.heliyon.2020.e03758

E. García-Ruiz et al., Effect of nozzle spacing in the formation of primary and secondary deposits in multi-nozzle inertial impactors part II: Numerical study., Journal of Aerosol Science, vol. 136, pp. 106-127, 2019.
https://doi.org/10.1016/j.jaerosci.2019.06.009

P. Dong, A. S. Kaiser, Z. Guan, X. Li, H. Gurgenci, and K. Hooman, A novel method to predict the transient start-up time for natural draft dry cooling towers in dispatchable power plants, International Journal of Heat and Mass Transfer, vol. 145, p. 118794, 2019.
https://doi.org/10.1016/j.ijheatmasstransfer.2019.118794

De la Hoz, J., Valencia, G., Duarte Forero, J., Reynolds Averaged Navier-Stokes Simulations of the Airflow in a Centrifugal Fan Using OpenFOAM, (2019) International Review on Modelling and Simulations (IREMOS), 12 (4), pp. 230-239.
https://doi.org/10.15866/iremos.v12i4.17802

W. Liu, Y. Kang, X. Wang, Q. Liu, and Z. Fang, Integrated CFD-aided theoretical demonstration of cavitation modulation in self-sustained oscillating jets, Applied Mathematical Modelling, vol. 79, pp. 521-543, 2020.
https://doi.org/10.1016/j.apm.2019.10.050

X. Long, X. Ruan, Q. Liu, Z. Chen, S. Xue, and Z. Wu, Numerical investigation on the internal flow and the particle movement in the abrasive waterjet nozzle, Power Technology, vol. 314, pp. 635-640, 2017.
https://doi.org/10.1016/j.powtec.2016.09.089

M. Slootweg, K. J. Craig, and J. P. Meyer, A computational approach to simulate the optical and thermal performance of a novel complex geometry solar tower molten salt cavity receiver, Solar Energy, vol. 187, pp. 13-29, 2019.
https://doi.org/10.1016/j.solener.2019.05.003

V. Dossena, N. Franchina, M. Savini, F. Marinoni, F. Cecchi, and F. Bassi, Reynolds number effects on the performance of safety valves operating with incompressible flows, Journal of Loss Prevention in the Process Industries, vol. 49, pp. 525-535, 2017.
https://doi.org/10.1016/j.jlp.2017.05.020

X. G. Song, L. T. Wang, Y. C. Park, and W. Sun, A Fluid-structure Interaction Analysis of the Spring-Loaded Pressure Safety Valve during Popping Off, Procedia Engineering, vol. 130, pp. 87-94, 2015.
https://doi.org/10.1016/j.proeng.2015.12.178

T. Ziegenhein, D. Lucas, G. Besagni, and F. Inzoli, Experimental study of the liquid velocity and turbulence in a large-scale air-water counter-current bubble column, Experimental Thermal and Fluid Science, vol. 111, no. October 2019, p. 109955, 2020.
https://doi.org/10.1016/j.expthermflusci.2019.109955

T. Ziegenhein, D. Lucas, G. Besagni, and F. Inzoli, Experimental study of the liquid velocity and turbulence in a large-scale air-water counter-current bubble column, Experimental Thermal and Fluid Science, vol. 111, no. October 2019, p. 109955, 2020.
https://doi.org/10.1016/j.expthermflusci.2019.109955

T. Beji, S. Ebrahimzadeh, G. Maragkos, and B. Merci, Numerical modelling of the interaction between water sprays and hot air jets - Part II: Two-phase flow simulations, Fire Safety Journal, vol. 96, pp. 143-152, 2018.
https://doi.org/10.1016/j.firesaf.2018.01.006

K. Ariafar, T. Cochrane, R. Malpress, and D. Buttsworth, Pitot and static pressure measurement and CFD simulation of a co-flowing steam jet, Experimental Thermal and Fluid Science, vol. 97, pp. 36-47, 2018.
https://doi.org/10.1016/j.expthermflusci.2018.04.004

A. Tabeei, A. Samimi, and D. Mohebbi-Kalhori, CFD modeling of an industrial scale two-fluid nozzle fluidized bed granulator, Chemical Engineering Research and Design, 2020.
https://doi.org/10.1016/j.cherd.2020.05.020

N. U. Aydemir, A. Trottier, T. Xu, M. Echlin, and T. Chin, Coupling of reactor transient simulations via the SALOME platform, Annals of Nuclear Energy, vol. 126, pp. 434-442, 2019.
https://doi.org/10.1016/j.anucene.2018.11.049

M. García Pérez and E. Vakkilainen, A comparison of turbulence models and two and three dimensional meshes for unsteady CFD ash deposition tools, Fuel, vol. 237, no. January 2018, pp. 806-811, 2019.
https://doi.org/10.1016/j.fuel.2018.10.066

Y. Wang and K. C. Smith, Numerical investigation of convective transport in redox flow battery tanks: Using baffles to increase utilization, Journal of Energy Storage, vol. 25, no. June, 2019.
https://doi.org/10.1016/j.est.2019.100840

J. Guo, Y. Zhang, Z. Chen, and Y. Feng, CFD-based multi-objective optimization of a waterjet-propelled trimaran, Ocean Engineering, vol. 195, p. 106755, 2020.
https://doi.org/10.1016/j.oceaneng.2019.106755

L. Wang, X. Yue, Q. Zhao, D. Chong, and J. Yan, Numerical investigation on the effects of steam and water parameters on steam jet condensation through a double-hole nozzle, International Journal of Heat and Mass Transfer, vol. 126, pp. 831-842, 2018.
https://doi.org/10.1016/j.ijheatmasstransfer.2018.05.090

Refbacks

There are currently no refbacks.