DOI: 10.34854/ICPAF.52.2025.1.1.172

MATHEMATICAL MODELING OF PLASMA-ARC EJECTOR *)

[1,2]Petrenko P.I., [2]Stepanenko A.A., [1]Pereslavtsev A.B., [1]Artemov A.V., [1]Voshchinin S.A., [1]Chemodanov N.S.

[1]National Research Center "Kurchatov Institute", Moscow, Russia, petrenko_pi@nrcki.ru
[2]National Research Nuclear University "MEPhI", Moscow, Russia.

To solve the problems of waste utilization in far districts it is essential to use plasma waste processing units on a mobile platform (railway car, sea and sea ship). One promising solution to this problem is the use of plasma-arc ejector.

The aim of this work is to develop a mathematical model of a plasma-arc ejector as the main component of a mobile plasma unit.

Based on literature analysis [1, 2] and calculations of material and heat balances, a mathematical model of the plasma-arc ejector will be developed in order to determine its the main characteristics of this unit.

In order to model the flow dynamics in the combustion zone, was used a system of two equations k-ε turbulence model. This model consists of two equations: one for turbulence kinetic energy (k) and another for turbulent energy dissipation (ε).

$$\frac{\partial}{\partial t}(\rho_m k) + \nabla(\rho_m \vec{v}_m k) = \nabla\left(\frac{\mu_{t,m}}{\sigma_k}\nabla k\right) + G_{k,m} - \rho_m \epsilon$$

$$\frac{\partial}{\partial t}(\rho_m \epsilon) + \nabla(\rho_m \vec{v}_m \epsilon) = \nabla\left(\frac{\mu_{t,m}}{\sigma_k}\nabla \epsilon\right) + \frac{\epsilon}{k}\left(C_{1\epsilon} G_{k,m} - C_{2\epsilon}\rho_m \epsilon\right)$$

The equation for k describes the energy carried by the turbulent eddies, while the equation for ε describes the rate of dissipation this energy.

A mathematical model of ejector vortex dispersion was developed based on the material and heat balance calculations performed. The dynamic model was calculated for a feed of 40 kg/h of polyethylene particles with water supply to the cooling system at an interval of 5 seconds.

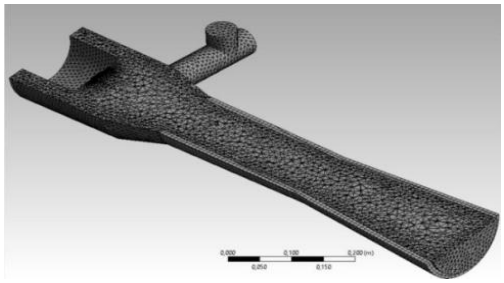

Figure 1. Geometry of the plasma-arc ejector for processing granular waste and its breakdown into elements

To simulate the decomposition of polyethylene, was used the Species Transport model in combination with the turbulent chemical model Finite Rate/Eddy-Dissipation.

Similar calculations were performed for the simulation of liquid chlorine waste disposal, using the Species Transport model combined with Non-Premixed Combustion for a detailed study of the decomposition of various substances and their mixtures.

Based on this model, the distributions of temperature, velocity and gas current lines were calculated. We plan to develop a plasma-arc ejector for experimental work on the «Prometheus» bench.

References

[1]. Wood S. et al. Review of state-of-the-art waste-to-energy technologies //Stage Two Report-Case studies, WSP, London, UK. 2013.

[2]. P. Carabin, E. Palumbo and T. Alexakis, "Two-stage plasma gasification of waste", Proc. 23rd Int. Conf. Incineration Therm. Treatment Technol., 2004.

*) abstracts of this report in Russian