ANALYSIS AND OPTIMIZATION OF CYCLONE SEPARATORS BY USING RANS

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ABSTRACT

Many types of particulate matter collectors are used in the industry to separate particulate matter from the gaseous streams. Among various type of particulate collectors, cyclone separators are one of the most extensively used gas cleaning equipment because of they are inexpensive; easier to fabricate, and could be designed to stand under harsh operating conditions.

Due to this extensive usage in the industry, many theoretical and experimental studies have been carried out and empirical models were developed to predict cyclone separator's most important operational parameters. These models have many limitations of illustrating flow behavior properly due to the complex nature of the cyclone gas–solid flow behavior. Computational Fluid Dynamic (CFD) simulation could be useful to predict cyclone performance as an alternative approach.

This work represents a CFD simulation of a Lapple cyclone separator using OpenFOAM software. Cyclone simulations have been carried out using turbulence models associated with the Reynolds Average Navier Stokes (RANS) equations. Multiphase Particle in Cell (MPPIC) method was used for the particle modeling, in which particle interactions with other particles were represented by models. The perditions of simulations have been compared both mutually and to literature in terms of cyclone pressure drop, gas-solid flow pattern and collection efficiency.

RANS model fairly predict the gas-solid flow pattern of the cyclone. Pressure drop and collection efficiency of cyclone well fitted to the experimental results in the literature.

Optimum values for inlet gas-solid velocity and particulate loading rate for the Lapple cyclone were obtained by RANS analysis. Pressure drop variation with gas-solid inlet velocity which has been obtained by this analysis could be useful to minimize the energy requirement while maintaining the required collection efficiency.

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Abbreviation	Description
β	constants
δ_{ij}	Kronecker delta
Δ	lattice spacing constant
ΔP	static pressure drop
Δt	residence time of gas
θ_{cp}	close pack volume fraction
λ_{mix}	mixing length of the sub grid scale
μ	viscosity of gas
μ_t	eddy (turbulent) viscosity
ν_e	eddy viscosity
ε	dissipation of turbulent kinetic energy
ρ	density
ρ_g	density of gas
ρ_g	density of gas
ρ_p	density of particle
τ	particle stress
φ	a property of a flow
Φ	the mean property
Ω_p	particle volume at position x and time t
ω_k	rotational vector
A	particle acceleration
B_c	cyclone inlet width
C_μ	dimensionless constant
C_s	a constant
D_p	diameter of the particle
D, D_c	diameter of the cyclone

D_e	diameter of gas exit
d_p	diameter of the particle
d_{pc}	diameter of the particle collected with 50% efficiency
F	Particle phase and gas phase momentum exchange rate
H_c	cyclone inlet height
H_c	cyclone inlet height
H_v	the pressure drop, which is given in terms of number of inlet velocity heads
J_c	diameter of dust outlet
K	constant, function of cyclone design and operating parameters
k	turbulent kinetic energy
L_c	height of cylindrical section
L_c	length of cylindrical body
N_e	number of effective revolutions in the outer vortex
n	vortex exponent
n_1	vortex component at 283K
n_2	vortex component operating temperature
P	total pressure in the cyclone
P_s	constant
R	radius of the cyclone body
R_{ij}	Reynolds stress $(u_i' u_j')$
r	radial distance from center axis (m)
S_c	length of vortex finder from inlet width
S^2	squared resolved deformation rate
T_1	283K
T_2	operating temperature
U	mean velocity of flow
U_x	tangential gas velocity
U_y	radial gas velocity

U_z	axial gas velocity
u	three dimensional velocities
u'	instantaneous fluctuating velocity component
u_p	particle velocity
V_i	gas inlet velocity
V_{ct}	tangential gas velocity component (m/s)
Vt	terminal velocity
Z_c	height of conical section
Z_c	length of cone

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