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Investigation of drag coefficient in gas-liquid systems

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ABSTRACT

Computational fluid dynamics (CFD) is one of the methods in which the efficiency of fluids is examined in various ways; For these fluids, equations are considered that are specific to the fluid and its single-phase, biphasic and multi-phase. One of the equations used in these methods is the drag force which has a drag coefficient; The drag coefficient used here is for liquefied gas systems, systems in which the gas bubble and the liquid, which is usually water, come into contact at the separation surface and a slip occurs at this level, which is the drag force. To follow. Among the coordinates used for calculations, Euler-Euler, Euler-Lagrange and etc. The coordinates we are considering are Euler-Eulerian. The equations used in various CFD probes are for Newtonian fluids, usually for sieve trays and etcUsed. In this study, we review the drag coefficients that have been obtained by researchers in this framework over the years**.**

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1. Introduction

The model includes the flow of gas and liquid in the Euler-Euler structure where the opposing phases have separation transfer equations, so the Navier-Stokes equations with mean Reynolds (RANS) for the gas phase and the liquid phase are written as follows.

1- Equations of mass continuity

Gas phase:

$$\frac{\partial}{\partial t}(f_g \rho_g) + \nabla \times (f_g \rho_g v_g) = 0 \qquad 1$$

Liquid phase

f_k ، ρ_k And V_k are, in addition, volumetric, macroscopic density and velocity vectors for the K phase.

The sum of the volume of gas and liquid is thus obtained,

$$f_g + f_l = 1 \qquad 2$$

Motion size equations

Gas phase

$$\frac{\partial}{\partial t}(f_g \rho_g v_g) + \nabla \times (f_g \rho_g v_g v_g) = -f \nabla p_g + \nabla \times \left[f_g \mu_g (\nabla v_g + \nabla v_g^T) \right] M_{gl} + \rho_g f_g g \qquad 3$$

Liquid phase

$$\frac{\partial}{\partial t}(f_l \rho_l v_l) + \nabla \times (f_l \rho_l v_l v_l) = -f_l \nabla p_l + \nabla \times (f_l \mu_l^{eff} (\nabla v_l + \nabla v_l^T)) - M_{gl} + \rho_l f_l g \qquad 4$$

μ_K and g show the molecular viscosity and gravity vector of phase k, respectively.

P_k is the pressure field and has the same value for gas and liquid phases, $p_g = p_i$.

M_{lg} expresses the transfer of the amount of motion between the gas and liquid phases, and in addition the flux of the amount of motion is caused by fluctuations in velocity and turbulence, all of which are the same in the diffusion term.

The drag coefficients in gas-liquid were investigated by researchers [11]. The drag coefficient relationships in the tower for particles and bubbles have been investigated and drag coefficients were discovered by researchers. The governing equations for particles, energy and heat under different conditions have been presented [12-24]. Researchers have presented research on particle size and forces acting on particles, along with drag coefficients and governing energy, and how materials are transported[25-37].

Separation Level Transmission Motion Size

For the separation level, our momentum transfer includes momentum transfer due to the drag force. The drag force per unit volume is written as follows:

$$M_{gl} = \frac{3}{4} \frac{f_g \rho_l}{d_g} C_D \left| V_g - V_l \right| (V_g - V_l) \qquad 5$$

Where d_p is the bubble diameter and C_D is the posterior coefficient.

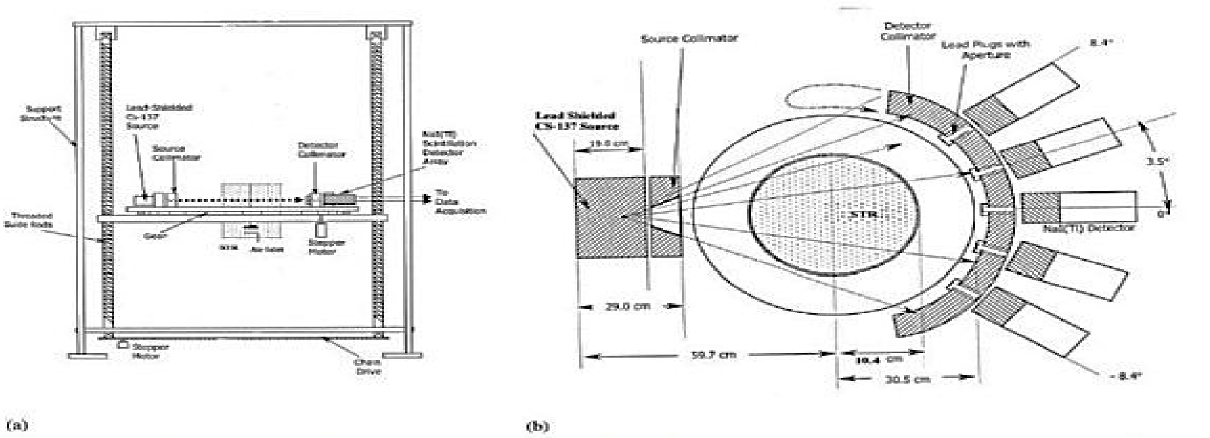

Fig. 2. Schematic of the CT scanner with the stirred vessel. (a) Front view, (b) top view, at one specific location of gantry plate (note that dimensions and angles are not to scale).

The C_D drag coefficient was estimated using the drag correlation of Krishna et al

$$C_D = \frac{4}{3} \frac{\rho_l - \rho_g}{\rho_l} g d_g \frac{1}{\left| v_g - v_l \right|^2} \qquad 6$$

[1], to raise bubbles sprayed in the turbulent area

In this equation, the relative velocity is between gas and liquid, and it can be estimated as a function of the surface velocity function of the gas velocity $U_g = Q_G / A_B$)، gas average holdup (، $f_g^{average}$, as follows:

Where f_g average is obtained from the equation of Bennett et al. [2],

$$f_g^{average} = 1 - \exp\left[-12.55 (U_g \sqrt{\frac{\rho_g}{\rho_l - \rho_g}})^{0.91} \right] \qquad 7$$

Use the separation surface in the proper form of CFD with the correct substitution in the momentum transfer equation [1] (van Baten and Krishna 1999):

$$M_{gl} = f_g(\rho_l - \rho_g)\left[\frac{1}{(U_g / f_g^{average})^2}\frac{1}{(1-f_g^{average})}\right] \quad 8$$

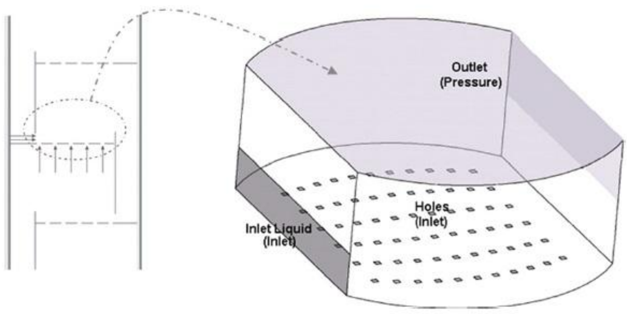

Fig. 1. Flow geometry and boundary conditions.

For the stock regime, we have [1]:

$$\mathrm{Re}_G = \frac{\rho_L U_G d_G}{\mu_L} \quad 9$$

$$C_D = \frac{24}{\mathrm{Re}_G} \quad 10$$

2. *Mathematical*

In another case of CFD application, the F_{qi} separation

To show another type of drag coefficient in computational fluid dynamics (CFD), we show the simulation of liquefied gas flow in a static helical mixer.

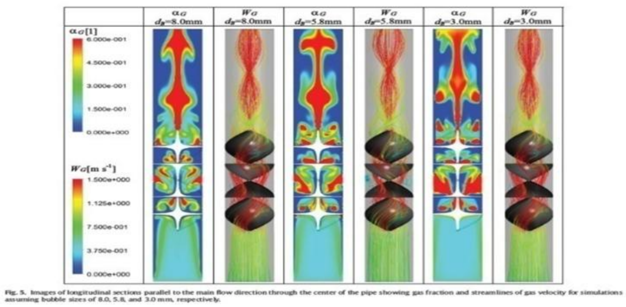

Figure2. *Proposed mechanism*

The drag coefficient depends specifically on the Reynolds number, and for larger Reynolds, where the bubbles have a metastructural ability and an elliptical structure, they depend on the EO number, but not on the MO number.

$$E_0 = \frac{(\rho_L - \rho_G) g d^2}{\sigma} \quad 13$$

level changes momentarily in the semester

It consists of four terms: exogenous force, virtual mass force, and post-separation force

In the agitated gas vessel, the drag coefficient of the CD separation surface is a complex function of the static fluid drag coefficient, f_g ^ average, and agitation, Lane et al. (2000) investigated the effects of turbulent flow on the drag coefficient (slip velocity). Based on a comparison of the gas volume fraction proposal with experimental data, a turbulent correlation factor was recommended by Brucato et al. (1998) but with a lower value than the correlation constant. We then used the correlation for the drag coefficient calculations.

$$\frac{C_D - C_{D_0}}{C_{D_0}} = K\left(\frac{d_b}{\lambda}\right)^3 \quad 11$$

$$C_{D_0} = \max\left\{\left(\frac{2.667E_0}{E_0 + 4.0}\right), \left(\frac{24}{\mathrm{Re}_b}(1 + 0.15\mathrm{Re}_b^{0.687})\right)\right\} \quad 12$$

The Kolmogorov longitudinal scale is d_p bubble diameter and K is an experimental constant obtained from 6 × 10^{-6}. Therefore, to increase the post-perturbation correlation due to perturbation is obtained [5].

$$M_O = \frac{(\rho_l - \rho_g) g \mu_L^4}{\rho_L^2 \sigma^3} \quad 14$$

A correlation distribution in the regimes of various structures in Reynolds numbers was proposed by Ishii and Zuber (1979) [6]:

$$C_D = \max(C_{D,Sphere} \min(C_{D,ellipse} C_{D,cap})) \quad 15$$

$$C_{D,sphere} = \frac{24}{\mathrm{Re}}(1 + 0.1\mathrm{Re}^{0.75}) \quad 16$$

$$C_{D,cap} = \frac{8}{3} \quad 17$$

The drag force resists the movement of the fluid body, the drag force on the body is written as follows.

$$F^D = \frac{1}{2}\rho_l U_{rel}^2 C_D A \quad 18$$

ρ fluid density and $U_{rel}$are the relative velocities between the mainstream and the body;

The drag coefficient indicates the effects of viscosity on the formula.

Grace (Grace et al. 1976) performed a dimensional analysis for single bubbles rising in a static liquid and concluded that their dynamics should be fully expressed with respect to dimensionless subgroups such as Re, EO, and MO. Has been:

Note that the number Re indicates the ratio of the retention force to the viscous post. σ is based on the surface tension between two phases.

The combination of these dimensionless numbers is as follows:

$$\mathrm{Re}^2 = \frac{4}{3C_D}\sqrt{\frac{E_0^3}{M_O}} \qquad 19$$

Schiller and Newman proposed the correlation coefficient of drag with the various flow classifications of its areas after careful study of bubble rising velocities in scattered flow and advanced equations useful for each part of the gas. Areas are separated into dense spherical particles, dense elliptical particles and dense spherical region of the cap.

The area of dense spherical particles

$$C_D(sphere) = \frac{24}{\mathrm{Re}_m}(1+0.15\,\mathrm{Re}_m^{0.687}) \qquad 20$$

Re_m is the Reynolds number of the mixture; μ_mThe viscosity of the mixture is expressed as follows:

$$\mathrm{Re}_m = \frac{\rho_l\left|\overline{U}_g - \overline{U}_l\right|D_b}{\mu_m} \qquad 21$$

In this equation, α_max expresses the maximum value for the mixture, which is equal to 0.52.

Dense elliptical particle area:

$$C_D(ellipse) = \frac{2}{3}\sqrt{E_0 E} \qquad 22$$

$$E = \frac{(1+17.67f^{6/7})}{18.67f} \qquad 23$$

In the area of dense spherical caps:

$$C_D(cap) = \frac{8}{3}E' \qquad 24$$

$$E' = (1-\alpha_g)^2 \qquad 25$$

The selection between the various flow zones is done as follows:

CD =

CD : (CD (spherical); CD (spherical) ≥ CD (elliptical) min (CD (elliptical), CD (spherical));

CD (spherical) <CD (elliptical))

This model is applicable to a range of Reynolds numbers [7]:

In the spherical region 0≤ Re <1000

In the elliptical and cap region Re ≥1000

Liquefied gas mixing model

In another example, the application of the drag coefficient was simulated using the Euler-Euler model.

It is assumed that the liquid phase and the gas phase share their relative volume space so that the sum of their relative volumes is as follows:

$$\alpha_l - \alpha_g = 1$$

Motion size equations

$$\frac{\partial}{\partial t}(\alpha_i \rho_i u_i) + \nabla(\alpha_i \rho_i u_i u_i) = -\alpha_i \nabla p + \nabla \tau_i + \alpha_i \rho_i g + F \qquad 26$$

The pressure is shared between the gas and the liquid. τ_i The shear stress of the liquid phase, F The drag force between the phases.

$$F = -\frac{3\rho_l \alpha_l \alpha_g C_D \left|u_g - u_l\right|(u_g - u_l)}{4d} \qquad 27$$

d The diameter of the adhesion bubble and the failure of the gas bubble can be neglected, and in fact the calculations are based on gas (hold-up) and flow field. The drag coefficient is calculated with the Schiller-Newman model.

Re_p is a relative Reynolds number that includes the effects of turbulent flow.

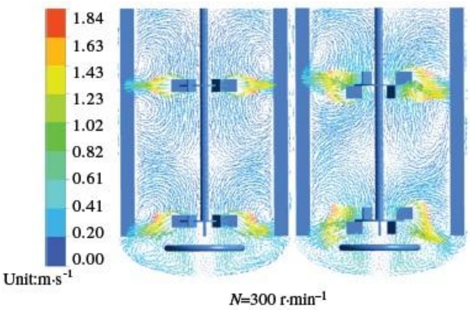

Figure 3. simulation of rector

In another form of CFD application where the simplified integrated equations for the simplified equations of the general system are summed in steady state, we experimentally calculate this problem by combining the following equations; The mean drag coefficient β and the mean drag force F_D and its use in biphasic and multiphase fluids are as follows.

$$F_D = \beta(u_l - u_g) \tag{28}$$

$$\beta = \frac{3}{4}\varepsilon_g \frac{C_D}{d_b}\rho_l \left|u_l - u_g\right| \tag{29}$$

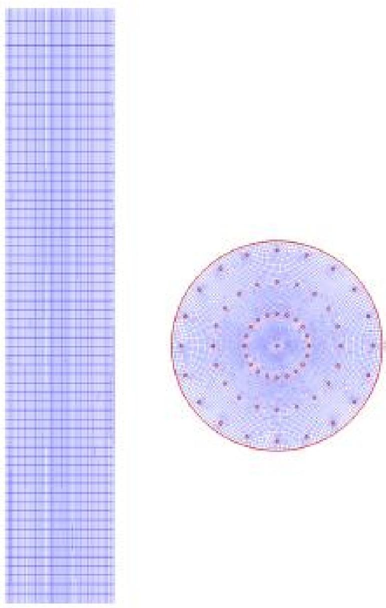

Figure 4; Data analysis in generated mesh

The effects of the drag coefficient for a bubble due to both stability factors of the bubble diameter variable d_b and the effects of the bubble spray are shown with a correction factor.

$$C_D = C_{D_0}(1-\varepsilon_g)^p \tag{30}$$

C_{D0}The standard drag coefficient is for a bubble without the effect of neighboring bubbles. The DBS model can compute an equilibrium $^{C_D}/_{d_b}$[9].

Tomiyama (1998)

$$C_{D_0} = \max\left\{\min\left[\frac{16}{Re}(1+0.15Re^{0.687}),\frac{48}{Re}\right],\frac{8}{3}\frac{E_0}{E_0+4}\right\} \tag{31}$$

White (1974)

$$C_D = 0.44 + \frac{24}{Re} + \frac{6}{1+\sqrt{Re}} \tag{32}$$

3. Result and discussion:

As you can see, in CFD and in various applications for two-phase liquids, gas and liquid, using the law of motion size and thus using the drag force, and especially the drag coefficient, various equations for the drag coefficient have been used, each with special accuracy. They have their own and are used for a specific area of fluid and are implemented. As you can see, each of these equations has its own methods of creation created by researchers. Some of these researchers have proven the equations. And some have fixed these equations to the extent that they depend on Reynolds and have increased their accuracy by changing the constant coefficients. Since the application of these coefficients in CFD is widespread, we have attempted to compile an article that covers almost all of these relationships in the liquefied petroleum gas system and in the Newtonian structure and in the Euler-Euler framework, because they are common in nature. We are dealing with them, it has a Newtonian structure and it is an environment that is visible to the viewer and the observer resides in it, thus responding to researchers who work in the field of computational fluid dynamics and under these conditions.

With the advancement of science and consequently industry and researchers turning to simulated work and the use of various software to get closer to industrial realities, especially the simulation of bubble towers, various relationships were used to use them. Each of which had its own degree of accuracy [10] and as the simulation became more realistic for the drag force and then the drag factor there is such an event that researchers seek to maximize the CFD studies in This paper has been applied to the process of working on the drag coefficient of Newtonian fluidized bubble towers in the Euler-Euler framework, and this process of realization will continue until the researc.

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