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Summary of:

NUMERICAL AND EXPERIMENTAL ANALYSIS OF POLY-DISPERSION EFFECTS ON PARTICLE-LADEN JETS

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Numerical and experimental analysis of poly-dispersion effects on particle-laden jets

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This paper gives a detail of the experiment and the computational method of polydisperse and monodisperse particle laden jets in a turbulent flow regime. This work can be considered to be a comparative study of the behavior of the monodisperse and polydisperse jet. The experimental set up is such that there is a turbulent particle laden jet with an inlet Re of 10,000 is issued into a weak co-flow and measurements are done using PIV and Nephelometry simultaneously. The Stokes number ranges from 0.003-25. The two-way coupled flow is considered in this study that shows that the particles with a lower stokes number are slowed down by the carrier phase flow, while those with a higher stokes are less affected. The study verifies that the velocity of smaller particles decay faster than the larger particles.

Based on the accuracy of the numerical simulation carried out in the previous works, the authors claim that the DNS method is not valid for the larger particles in the polydisperse flow as DNS is restricted to particle size below Kolmogorov's length, so LES is utilized. The computational method includes Stokes binning to progress to the next time step to classify the PDF-PDE and the LES-PDF-PDE which is a hybrid method that is employed in OpenFOAM. Implicit spatial and temporal second order LES solver is used. The numerical method includes a cylindrical domain. For the both annular and the central jet, time varying realistic boundary conditions are employed. The carrier phase is employed in the Eulerian framework while the disperse phase is employed in the Lagrangian framework leading to a Monte-Carlo PDF version of PBE. There is no interphase mass transfer so the source term in the transport equation is neglected.

The experimental setup is made in a careful manner by placing the jets in vertical position to avoid the gravity bias in the wind tunnel and the even using the crossflow velocity of the wind tunnels by matching to the co-annular jets' velocity. In every experiment, it is ensured that the volume fraction $(\alpha) > 10^{-6}$ so that the momentum exchange between the particles and the turbulence is high enough to alter the carrier phase and the turbulent behavior i.e; it has ensured the two-way coupling regime of the flow. Since, the previous literatures don't have a direct measurement or simulation results on the effect of stokes number in a turbulent, polydisperse, particle laden jet in the two-way coupling the experiment tries to fill that gap. Also, it tries to measure the particle velocity, number density and size in a simultaneous manner. The polydisperse spherical glass particles used in this particular experiment has a density of 480 Kg/m^3, and the co-flow jet velocity is fixed at $12:1$ with the bulk velocity of the pipe flow being $12m/s$. Furthermore, the particle-to-gas mass flow rate is fixed at 0.4, this loading is sufficient to cause a two-way coupling. The particles are chosen such that their Stokes number (St) lies in the range $0.003\ to\ 25$. During the experiments, it is noted that the calculated velocity using PIV is the aggregated value of the velocity within each interrogated window, which is as same as the area-weighted mean velocity. Also, it is observed that the larger particles influence the measured velocity from PIV due to the stronger scattering leading to a bias to the measurement.

PDF*: Probability Density Function*, **PBE***: Population Balance Equation*, **LES:** *Large Eddy Simulation,* **DNS:** *Direct Numerical Simulation*, $\boldsymbol{St_{in}}$:*Inlet Stokes Number,* **RMS:** *Root Mean Square,* $\boldsymbol{K_{1U}^{-1}}$:*Inverse velocity Decay coefficient*, $\boldsymbol{K_{1C}^{-1}}$*: Inverse Volume Fraction Decay Coefficient*

Based on the experiments for the single-phase jet, the maximum mean velocity along the centerline, the maximum axial RMS velocity is found to occur in the shear layer.

For the polydisperse jet, there is a good agreement between the numerical model and the experiments along the centerline. The effect of stokes are studied using only the PDF-PBE model as the experiment setup is not enough to study it. The following are observed:

1) Particles with higher St have a lower axial decay rate due to the less interaction with the carrier phase and the trend is opposite for the lower St.
2) Despite the mean velocity being similar in the near-field, the RMS velocity for different particle sizes vary with the peak RMS of the larger particles shifting downstream.
3) As the particle size decreases, the mean particle axial velocity decreases throughout the radial extent confirming the radial dispersion of larger particles are lesser compared to the smaller ones. Also, the volume fraction in the centerline is greatly influence by the St within the same jet.

Furthermore, the study provides a brief on the behavior of the mono-dispersed and poly-dispersed jets. $St_{in} = 0.3, 5.5, 9, 25$). The following are reported in the paper:

1) For both mono dispersed and poly dispersed case, the larger particles exceed the gas velocity in the far field due to inertia.
2) At $St_{in} = 0.3$, the monodispersed case approaches to the single-phase flow because the particles are very small and it follows the flow like a tracer particle. For a higher St_{in}, in the polydisperse flow, the axial decay rate increases as compared to the monodisperse flow.
3) The size-averaged velocity distribution in the polydisperse flow varied significantly compared to the monodispersed flow due to the influence of the larger particles on the gas-phase. In the mono-dispersed phased, due to the prominent RMS , there is a higher momentum transfer between the phases leading to the large scale mixing.
4) An increase in the St leads to the decrease of K_{1U}^{-1} . For both monodisperse jet and polydisperse jet, K_{1U}^{-1} is lower than the single phase that suggests that the particles reduces the decay rate.
5) K_{1C}^{-1} decreases with increasing St_{in} in both mono and polydisperse jets. For smaller St, K_{1C}^{-1} is higher for the polydisperse jet than the monodispersed jet.

Because of polydispersity there is decrease in the velocity decay rate of the low St_{in} particles and increase in the velocity decay rate of the larger St_{in} particles.

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