

REGULAR WAVE EFFECTS ON NEGATIVELY BUOYANT JETS

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INTRODUCTION

Seawater desalination is an increasingly important technology in the supply of potable water to municipal communities. Brine created by this process is typically released back to the ocean via a nearshore diffuser into a wave-exposed climate. Despite this, little work has been published on the effect of waves on negatively buoyant jets. In this paper we outline the literature on this topic and the results of a series of computational fluid dynamics (CFD) simulations that address the role of regular waves on negatively buoyant jets.

METHODS

A CFD model was created using OpenFOAM® v1812. The model simulates the nonlinear interaction of two miscible fluids (sea water and brine) with the free surface violation by solving 3D Navier-Stokes equations using a volume of fluid (VOF) technique to capture the free surface. A new wave generation boundary condition is applied to generate and absorb waves at the inlet and outlet boundaries, making the model computationally effective.

RESULTS

We define u_{max} as the maximum horizontal wave-induced velocity at the discharge port and u_j as the discharge velocity.

The effect of regular waves on positively buoyant discharges emanating from wastewater plants was well-described by Chin (1987). He found for conditions typical for ocean outfalls, that the discharges are plume-like for the majority of the rise height. Dilution (S) was measured at the plume surface and was found to be a linearly increasing function of u_{max}/u_j , ie $S/S_0 = 5.35 u_{max}/u_j + 1$ ($r^2=0.86$), where S_0 is the dilution under the no-wave case (Figure 1).

We re-analysed the laboratory results published by Ferrari et al (2018) for negatively buoyant discharges at 67° to the horizontal and plot dilution as a function of u_{max}/u_j (Figure 1). The location of the dilution measurement is not reported, but we assume based on experimental configuration and data that it is measured at the impact point. Data is available for two Froude numbers, and clearly indicates a decreasing trend of dilution with increasing u_{max}/u_j . There are four instances of the dilution ratio S/S_0 exceeding unity, which we have no physical explanation for and can only attribute to experimental error and/or measurement uncertainty. A linear function fitted to these data with an intercept of zero and ignoring data where S/S_0 exceeds unity gives $S/S_0 = -2.05 u_{max}/u_j + 1$ ($r^2=0.97$) for $Fr = 18$ and $S/S_0 = -3.59 u_{max}/u_j + 1$ ($r^2=0.73$) for $Fr = 28$.

To provide additional design guidance we also report S/S_0 from our CFD experiments, where dilution was measured at the impact point of the negatively buoyant plume on the bed. Our results confirm that the effect of waves is to decrease dilution relative to the stagnant case, and that the decreases are greater for larger waves. Work is currently underway to improve these results so that they asymptote to unity under the no-wave case and will be reported during the conference.

CONCLUSIONS

We have demonstrated that unlike for positively buoyant discharges, the effect of waves on negatively buoyant discharges is to decrease dilution. This is important as it is non-conservative with respect to the current design guidance which ignores the effects of waves. This omission has not been based on knowledge but on lack thereof.

Whilst some uncertainties exist in both the laboratory results (by others) and our own CFD results, which are currently being investigated, we felt it important to publish this information as-is given that it demonstrates current design practice is non-conservative. Results will be updated for the ICCE conference.

Additional work is underway to better formulate the design conditions (port angles, Froude numbers, wave attack angles, port and diffuser layout) that may reduce the effects of waves on dilution.

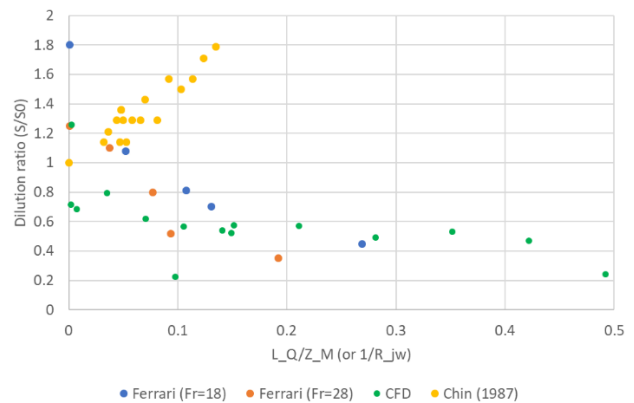


Figure 1 - Dilution ratio as a function of u_{max}/u_j for positively and negatively buoyant jets.

REFERENCES

Chin (1987): Influence of surface waves on outfall dilution, J. Hydraulic. Eng. 113(8), 1006-1018.

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