Technical Note

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POLLUTED WATER EFFLUENT IN THE SEA

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ABSTRACT

In this experimental study some measurements and their analysis are presented concerning the polluted water effluent disposal in the sea water. The wastes are disposed through the round openings of a submerged in the sea diffuser, in the form of turbulent jets which are mixing (diffusing) with the sea water. Three inclination angles (to the vertical) of the jets are examined, $\varphi=15°-45°-75°$, and at any angle three Froude numbers are also examined, $Fr_o=4.8-17-25.3$. The results are combined with previous results by the author for $90°\leq\varphi\leq150°$.

KEYWORDS: Sea, Environmental Hydraulics, Jet flow, Diffusers, Water Pollution

INTRODUCTION

The main hydraulic construction to dispose wastes in the sea water is the submerged multiport diffuser, with circular openings through which the liquid wastes (with density ϱ_o=const.) are issuing in the calm sea water (with density ϱ_s= const.), in the form of liquid jets. These jets have various angles φ to the vertical (h), and are diluting the waste, following the turbulent diffusion (or mixing) with the receiving water.

The study is based both, on previous papers by the author, such as by Demetriou (1984) or Demetriou and Noutsopoulos (1980), with $\varphi>75°$, and mainly on the presentation of more recent measurements for $\varphi=15°-45°-75°$, by Giannadakis and Gouroyannis (1996).

THE ISSUING BUOYANT JETS

Fig. 1 shows the typical configuration of steady turbulent buoyant jets (ϱ_o, kinematic viscosity ν_o) issuing from round openings (d_o, V_o) and mixing with the deep enough sea water (ϱ_s), for various inclination angles. The main flow parameters are, the Reynolds number $Re_o=V_o\cdot d_o/\nu_o$, and the Froude number $Fr_o=V_o\cdot(g'_o\cdot d_o)^{-1/2}$, where $g'_o=[(\varrho_s-\varrho_o)/\varrho_o]\cdot g$. The mass concentration at any point (x, y) is $c=(\varrho_s-\varrho)/(\varrho_s-\varrho_o)$ where ϱ=local density, while the concentration on jet trajectory (axis, x_m, y_m) is c_m. It is usual in the analysis to treat the experimental data in dimensionless form, such as $l'=(l/d_o)\cdot Fr_o^{-1}$, where l=any length (x, y, x_m, y_m), and $g'=c\cdot Fr_o$ (g'_m on the axis) where g' is the dimensionless concentration.

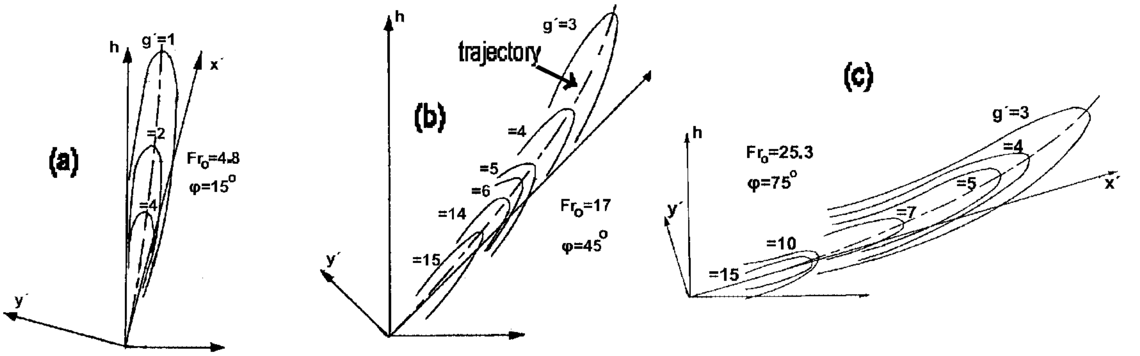

Figure 1. Iso - concentration curves for $\varphi=15°$-$Fr_o=4{,}8$(a), $\varphi=45°$-$Fr_o=17$(b), $\varphi=75°$-$Fr_o=25{,}3$(c)

THE MEASUREMENTS / ANALYSIS / DISCUSSION

A number of 3 groups of runs were organized, comprising 3 runs for jets with $\varphi=15°$, 3 runs for $\varphi=45°$ and 3 runs for $\varphi=75°$. In all groups of runs Fr_o had the values, $Fr_o=4.8$ -17 -25.3, while $Re_o>>100$, $\varrho_o= 1.000$ kg/m^3, $\varrho_s= 1.010$ kg/m^3. More details about the electronic equipment to measure ϱ can be found in Demetriou (1984) and Demetriou and Noutsopoulos (1980).

Figures 1a, b, c, present typical iso-concentration curves, g' =const., for $\varphi=15°$-$45°$-$75°$, and three Fr_o values, $Fr_o= 4.8$ -17 -25.3, in terms of dimensionless coordinates x' and y'. The trajectory (axial) points (x'_m, y'_m) are determined by local g' maxima ($=g'_m$). Figures 2a, b, show typical jet trajectories (axes) in terms of (x'_m, y'_m), for $\varphi=15°$ and 45°, in double logarithmic scales for all 3 values of Fr_o. From these figures it is concluded that the jet trajectories have the form

$$y'_m = A\cdot(x'_m)^B, \tag{1}$$

where A and B are determined from the measurements, for any angle φ. Another pair of A and B were also determined for $\varphi=75°$, while all (A, B) values are put in Fig. 3a, together with previous corresponding values for $\varphi=90°$-$112.5°$-$120°$-$135°$-$150°$, taken from older papers by Demetriou (1984), and Demetriou and Noutsopoulos (1980). From Fig. 3a three equations for $A=A(\varphi)$ and $B=B(\varphi)$, in the range $0.28<x'_m<1.5$ and φ in degrees, are concluded using the method of least squares' of best fit,

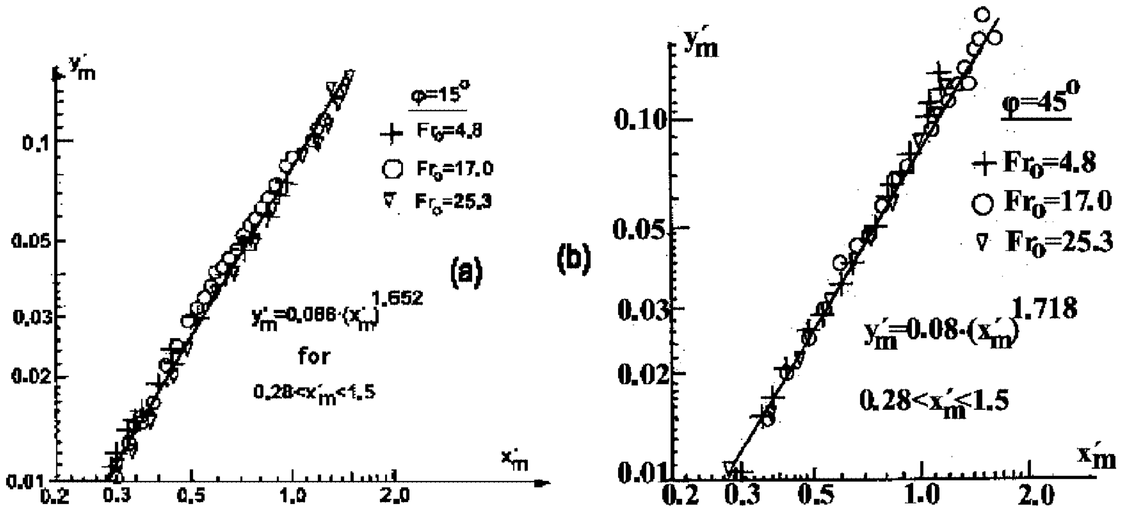

Figure 2. Jet trajectories for $\varphi=15°$ (a), and $\varphi=45°$ (b)

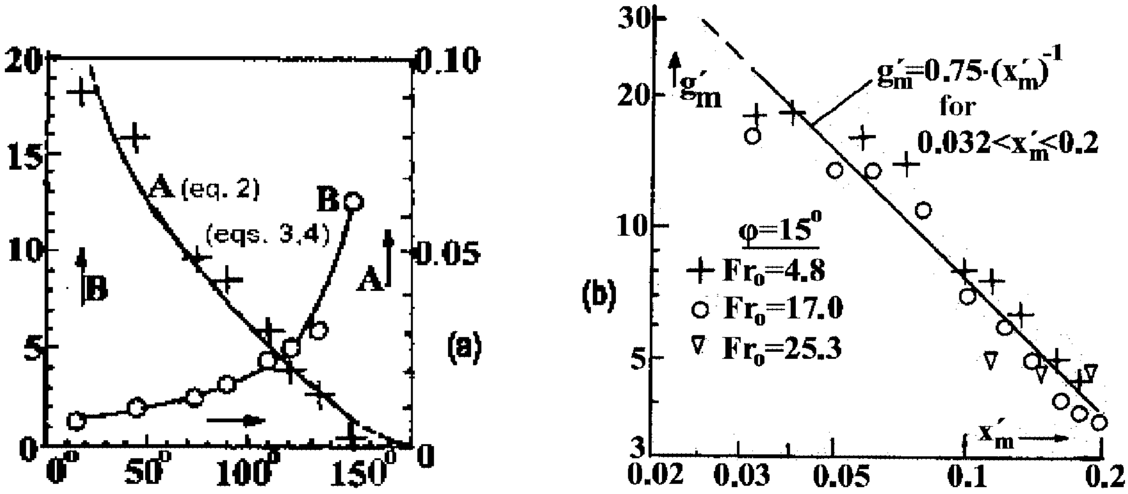

Figure 3. A and B values for 15°≤φ≤150° (a), and concentrations on axial trajectories for φ=15° (b)

$$A=8.37\cdot10^{-8}\cdot\varphi^{2}-2.16\cdot10^{-4}\cdot\varphi+1.718\cdot\varphi^{-1}+0.0316, \quad (2)$$

$$B=0.042\cdot\varphi^{0,973}, \text{ for } 15°\leq\varphi<112.5°, \quad (3)$$

$$B=4.17\cdot10^{-8}\cdot\varphi^{3.9}, \text{ for } 112.5°<\varphi\leq150°, \quad (4)$$

while corresponding curves are traced on Fig. 3a and B≅4.16 for φ=112.5°.

Based on eqs (1) to (4) the trajectories (axes) of all jets, for 15°≤φ≤150° and $0.28<x'_m<1.5$ may be calculated.

For dimensionless concentrations, g'_m, in the ranges 15°≤φ≤75° and $4.8\leq Fr_0\leq25.3$, equations of the form $g'_m=K\cdot(x'_m)^{-1}$, were determined from the measurements, where the arithmetic coefficients K have particular values depending on φ angles (in degrees). The 3 arithmetic K values were put in an auxiliary diagram (against 3 angles φ) and the simple expression $K=0.0307.\varphi^{1.18}$ was determined.

Thus, for 15°≤φ≤75°, the final equation for concentration on jets' axes is

$$g'_m = 0.0307 \cdot \varphi^{1.18} \cdot (x'_m)^{-1} \quad (5)$$

Fig. 3b shows, for φ=15° and $0.032\leq x'_m\leq0.2$, the line representing eq. (5), through the experimental points, for $4.8\leq Fr_0\leq25.3$, in double logarithmic scales x'_m, g'_m. The scatter of experimental points around the line given by corresponding eq. (5) (for φ=15°, *K*≅0.75) is not large, i.e. eq. (5) satisfactorily describes the dilutions along the jet axis. For φ=45° and φ=75° the corresponding eqs. (5) hold in the range $0.17\leq x'_m\leq 2$, as the present measurements have given.

CONCLUSIONS

In this study an experimental research is presented to determine or generalize a number of equations, concerning concentrations, jets' axes, geometry and trajectory concentrations, for liquid waste jet issuing from a round opening on submerged diffuser in sea water. Three angles of jet inclination φ are examined, φ=15°-45°-75°, and at each angle three Froude numbers are also examined, Fr_0=4.8-17-25.3. The results are combined with older data taken from previous papers by the author, and give the jet axes for 15°≤φ≤150°.

REFERENCES

Demetriou J. (1984), An Effort to Improve Simple Establishments of Marine Pollution, In: *Proceedings Int. Symposium on Maritime Structures in the Mediterranean Sea*, Athens, Sept. 1984, pp 3.29-3.38.

Demetriou J. and Noutsopoulos G. (1980), Geometry and Axial Dilutions in Round Turbulent Buoyant Jets, In: *Proceedings Congress of Wind Energy and Industrial Airdynamics*, Athens, Oct. 1980, pp. 4.41-4.56.

Giannadakis G. and Gouroyannis B. (1996), Inclined Buoyant Jets, Thesis Report, School of Civil Engineers, N.T.U.A.