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BLOCKAGE EFFECT FOR SINGLE ROWS OF BLUFF BODIES

by

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S U M M A R Y

Interference effects for flow past single bluff bodies and rows of bluff bodies are similar in character. It is shown that the vortex shedding frequency on these two configurations can be normalised effectively by adopting the mean gap velocity u_1 and the contracted jet velocity u_j as the relevant velocity scales to form the Strouhal number.

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INTRODUCTION

Two-dimensional flow past a bluff body can be constrained under two important circumstances. For single models, the side walls of a testing facility can impose a constraint on the flow past the model. On the other hand, for single row configurations the adjacent members impose a constraint on the flow past an intermediate member of the row (Fig. 1). Both these effects are a consequence of boundary interference.

Constraint or blockage for two-dimensional flow is defined as the ratio of the model width to the test section width. For single rows of bodies, the width of the test section has to be replaced by the spacing between adjacent bodies, while computing blockage.

Both the vortex shedding frequency and drag coefficient of bluff bodies are influenced by interference effects. Realising the limitations of Maskell's original blockage correction formula for drag [1], Modi [2] modified it to improve the correlation of his experimental data related to the drag of single cylinders subject to severely constrained flow. Shaw [3,4] and Toebes [5] have proposed the contracted jet velocity u_j (Fig. 1a) as the velocity scale characterising constrained flow past bluff bodies. Existing test data [3,5,6] upholds this view for flows which are at least moderately constrained.

The interference effects for multiple body configurations have been examined by Borges [7]. He states that the Strouhal number S_1 based on the mean gap velocity u_1 was nearly constant for single cylinder rows up to a blockage of 0.5. Beyond this range of blockage, he observes that the flow becomes unstable.

In the present investigation, boundary interference associated with flow past single rows of cylinders and symmetric equilateral prisms (Fig.1) are studied. Specifically the study is related to the vortex shedding frequency of single rows of bluff bodies.

EXPERIMENTAL EQUIPMENT AND PROCEDURES

Test Bodies: The models were generally made of 10" long machined metallic cylinders and symmetric equilateral triangular prisms (Fig. 1d). They were rigidly mounted in the test section (25.4 cm x 35.6 cm) of a wind tunnel. The vortex shedding frequency of the rows of bodies were determined from wake surveys conducted with the help of a hot wire anemometer. The pressure coefficient C_{ps} at the separation point was determined to get an estimate of the empirical constant $k(=u_s/u_\infty)$ and the separation velocity u_s. The latter was assumed to be equal to the contracted jet velocity u_j (Fig. 1).

DISCUSSION OF RESULTS

Velocity Scales - Single Row Bodies: The Strouhal numbers S, S_1 and S_j for the single rows of cylinders and prisms shown in Figures 2 to 4 are based respectively on the undisturbed mean velocity u, the gap velocity u_1 and the contracted jet velocity u_j. In all cases, S increased with blockage. In the lower range of blockage, S_1 is nearly constant for the single rows of prisms at 60^o and cylinders.

S_l for the single rows of prisms at 0^o indicated a marked increase with blockage. S_j was nearly constant up to a blockage of 0.3 (Fig. 2). These trends are similar to the characteristics displayed by single prisms subject to comparable blockage. As blockage is increased to 0.5, vortex shedding for single rows of cylinders and prisms occurs at more than one frequency (Figs. 2,4). For single cylinder rows, Borges [7] too has reported the existence of multiple vortex shedding frequencies at higher blockages. Even for flow past twin cylinders of diameter d, the flow characteristics have been observed to change distinctly [8] when the gap between the cylinders is reduced to the order of d. In the present tests, the hot wire signals for single row bodies consisted of a larger number of harmonics when the blockage was increased beyond 0.5.

Velocity Scales-Single Bodies: Some of the existing vortex shedding frequency data given by Shaw for single bluff bodies is regrouped using u_l and u_j as the reference velocities. Table 1 shows that the vortex shedding frequency for flow past normal plates and gates [9] can be effectively grouped to yield a nearly constant value of S_j for each set of configurations. The contracted jet velocity u_j was used to normalise the vortex shedding frequency of the plate and gate.

CONCLUSIONS

The following conclusion can be drawn based on the discussion of results.

From the point of view of vortex shedding frequency the interference effects for flow past single rows of bluff bodies (cylinders and prisms) are similar to the interference of side walls on single bluff bodies. For both configurations, the vortex shedding frequency can be effectively normalised by adopting u_l and u_j (Fig. 2) as the reference velocities.

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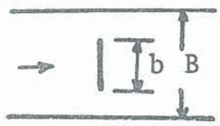
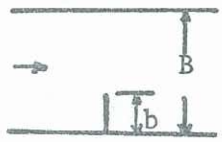
TABLE 1

S, S_1 and S_j for Single Plates and Gates, Towing Tank Test

b/B	S	S_1	S_j	Source	Flow Configuration
.06	.143	.145	.123	Shaw [8]	
.11	.176	.156	.120		
.17	.197	.164	.121		
.22	.210	.162	.118		
.06	.160	.151	.128	Shaw [8]	
.11	.188	.167	.129		
.17	.205	.171	.126		
.22	.216	.168	.121		

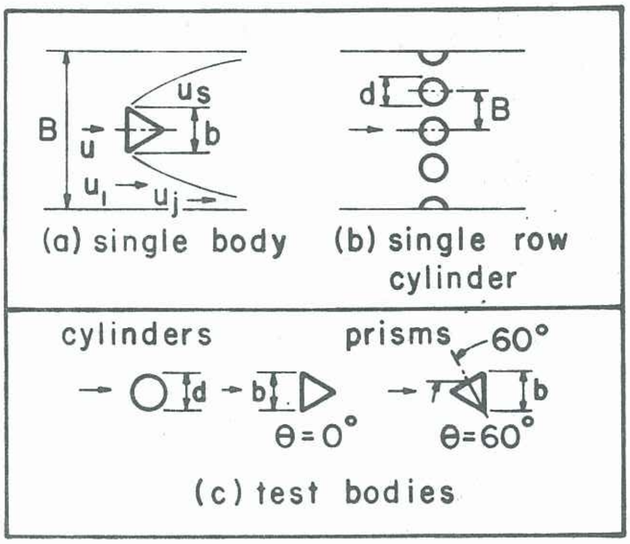


FIG. 1 CONSTRAINED FLOW

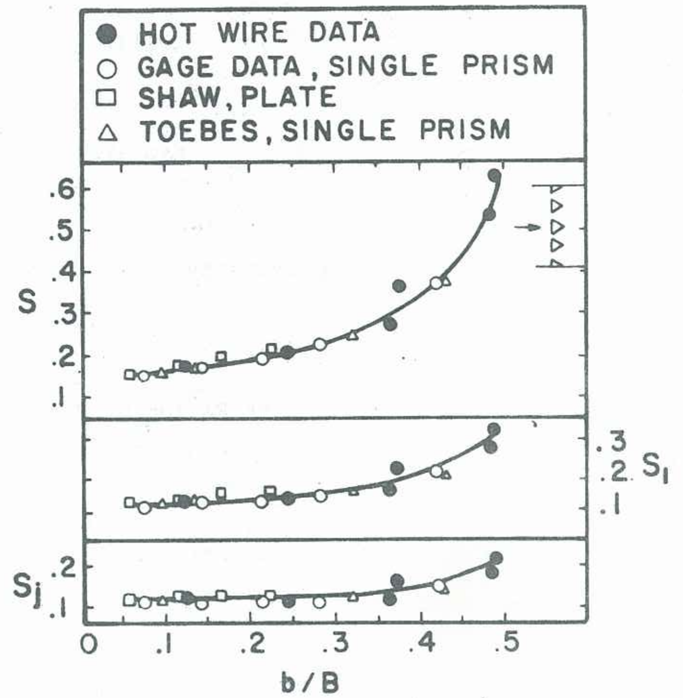


FIG. 2 S, S_1, S_j, Vs. b / B
MULTIPLE PRISMS (θ = 0°)

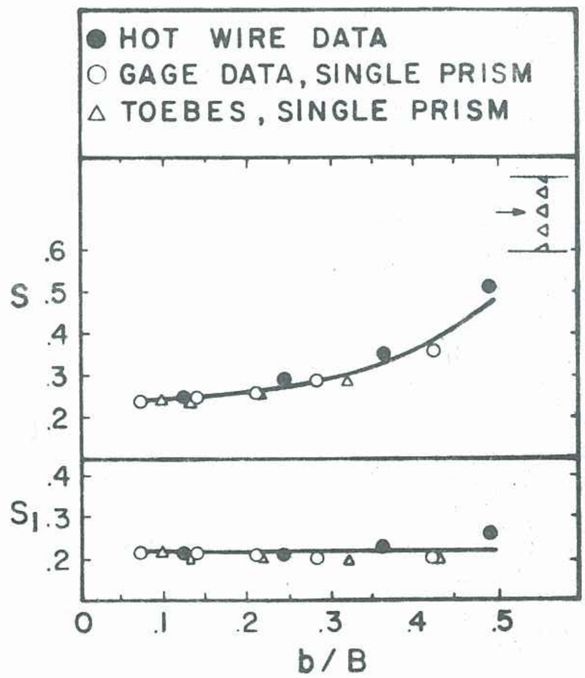


FIG. 3 S, S_1 Vs. b / B
MULTIPLE PRISMS
(θ = 60°)

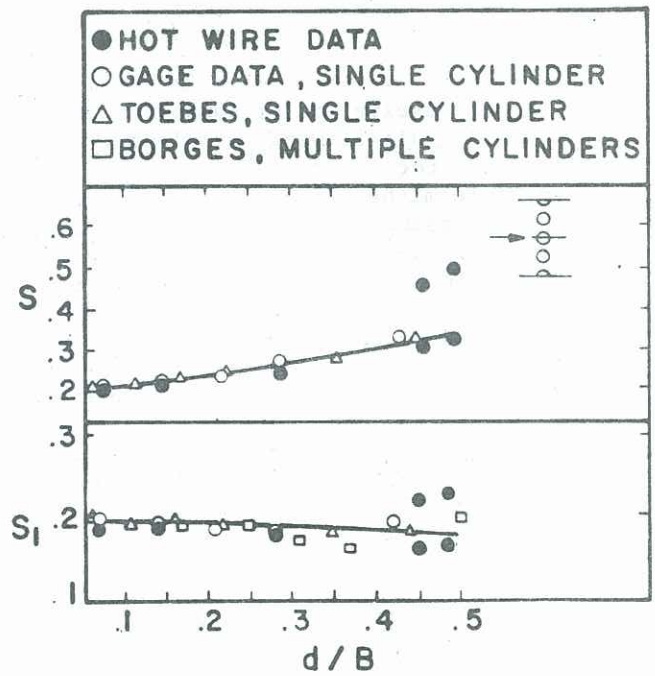


FIG. 4 S, S_1, Vs. d / B
MULTIPLE CYLINDERS