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The Effect of Circular Disc One Cylinder Drag Force

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Abstract

Placing two or more bluff bodies in tandem in flow stream is known to lead, in certain cases, to configurations with relatively low over- all drag.

The present experimental study concerns with the reduction of drag forces of tandem positioned bluff bodies, by employing suitable sizing to these bodies, and selecting a proper gap separating them. For this purpose an ax symmetric. Combination was build, consisting a cylinder whose axis is aligned to the stream, as a rear body, and discs of different diameters as a fore-body. The tests were performed for Reynolds number based on rear body diameter in the range of $1.0*10^5$ to $2.2*10^5$.

Experimental investigations shows that; a significant drag reductions was achieved and up to 42.5% lower than that of cylinder alone , when placing a proper sized disc at an optimum distance ahead of the cylinder.

Keywords; _ Circular disc, Cylinder, Drag force.

Notation

d_1	Front body diameter (disc diameter), mm
d_2	Rear body diameter (cylinder diameter),mm.
g	Gap length , mm
g/d_2	Gap ratio
μ	Air dynamic viscosity,Kg./s.m
ρ_a ρ_a	Air density, Kg/m^3.
C_D C_D	Drag coefficient
D	Drag ,N
Re	Reynolds number
U_∞	Free stream velocity, m /s

Introduction

In recent years more work has been carried out to study the effect of flow around groups of bluff bodies in different arrangement (i.e. staggered, side by side and tandem). To solve practical problems concerned applications in various areas of engineering and science, problems were first encountered in aeronautical engineering in the early use of twin struts to support wings [1]. In mechanical engineering the problems were connecting with the vibrations of heat exchanger tubes [2, 3, and 4] and the effect of gaps on the aerodynamic drag of tractor-trailer truck combinations [5, 6]. In civil engineering groups of building [7], chimney stacks, and offshore structures in high seas were typical problem areas. However, Zdravkovich [1] has given a brief review of some of this problem in different fields of engineering, concerning round bodies. Morel, T. and Bohn, M. [8] studied the flow over two circler discs in tandem having different diameter ratios. For two discs of equal diameter, they found that the system drag coefficient reached a minimum value of (C_D=0.85) when g/d_2 is about 1.55, which is 26% below the single disc value. Roshko and koening [5], investigate the interference between bluff bodies of simpler geometry then those of the real road trucks. Such as semi- infinite half body circular cylinder with flat face. They found that, the minimum dissipation condition, in which the separation stream surface just matches the rear body. Lee and Fowler [9], investigated the interference effect of a pair of square prisms on their mean lift and drag. They found that if the pair of prisms placed parallel to the stream, the drag of the upstream prism is less than that of an isolated prism until the gap size of 10 d. Bearman and Trueman [10] show that, maximum value of drag coefficient for a rectangular cylinder is 2.94 when g/h =0.62 . The increased drag coefficient was completely eliminated by introduction of a splitter plat having a suitable height into the wake.

The aim of the present study is to investigate the effects of transversal gap on cylindrical bluff body whose axis is aligned to the stream, by circular discs of different diameter in close tandem

with the cylinder. And to find the optimum gap ratio, based on the cylinder diameter, which cause the minimum drag.

Experiential work and measurements

All tests were carried out in aerodynamic laboratory at military engineering college Baghdad , using an open type wind tunnel [11] ,see fig.(1- A) . The tunnel was constructed mainly of aluminum. The air is drawn through the tunnel by an axial fan, driven by 3-phase electric motor of 5kw power consumption. Different Reynolds's number was a chivied at test section by means of double butter fly valve. The test section is constructed from heavy gauge Perspex material offering clear visibility, having a dimension of 305 mm by 305 mm.

The drag forces for each combination were measured, by means of a calibrated three component balance type (TE 81/ A) supplied with the tunnel. Each test was carried out at various Reynolds number for each gap ratio. Every tested combination was mounted in the midpoint with zero incidence angles at the test section, from one of the side walls by means of a 12.7mm diameter stem attached, to the three component balance see fig. (1- B).

The balance frame work comprises of the base plate, which is screwed to the wind tunnel testing section by three studs, and carries a triangular force plate. These two plates are attached to each other, by a spherical universal joint, providing the balance with the necessary freedom.

The forces acting on the force plate are balanced by three springs of cantilever form, i, e; (drag spring, and two lift spring), deflections of the drag spring and hence drag forces, are measured by means of a drag micrometer.

The mean velocity of the free-stream was measured by means of a standard pitot-static tube of 4mm outside diameter located in test section at a distance of (500) mm upstream of the test model. The pitot static leads were connected to an electrical micro manometer having a range of o to 100 mm water head. The air flow temperature was measured by means of thermal resistance probe.

The atmospheric pressure, air temperature, and relative humidity inside the test room were measured by calibrated standard instrument.

Each test was performed for different Reynolds number; this was achieved by changing the mass flow rate passing the experimental model, by means of the butterfly valve. The flowing data were recording after achieving steady running condition:

1-Room temperature, atmospheric pressure, and relative humidity.

2-Total (stagnation) pressure head in mm water up stream the model.

3- Static heads up & down stream of the model in mm water.

4- The reading of drag micrometer in mm.

5-Free stream air temperature in degree cent grate.

The accuracy of drag measurement based on frequent calibration of drag instrument, i.e., the three component balance, which mean the accuracy of the micrometer & the drag dial gauge used for measuring the deflection of the drag spring. This accuracy was within (± 0.1365) Newton. Figure (1 – C), represent the calibration curve of the micrometer.

The accuracy of air velocity head measurement was about o.02 mm water. The measurement of the g/d2 ratio was accurate within ± o.oo7.

Results and discussion

The experimental results are presented in term of drag coefficient (C_D), as a function of Reynolds number for different combination of frontal-body to rear body diameter rations (i .e.,d1/d2, where d1, disc diameter and d2 is the cylinder diameter). For each combination different gaps to rear body diameter were selected and tested (i-e; g/d2= gap ratio). The Reynolds number which is based on cylinder diameter (d2) is varied from $0.9* 10^5$ to $2.23* 10^5$ the following combinations, were tested:-

A- Disc diameter equal to cylinder diameter:

The test results are shown in figurers 2 to 5 where the gap ratio (g/d2) varied from 0.05 to 1.25. An interesting behavior was observed; the drag coefficient increased slightly at gap ratio 0.05, reaching a value of C_D =1.0, which higher than the drag coefficient of the cylinder (C_D for cylinder = 0.87 when tested). As gap ratio increasing the drag coefficient decreasing to values lower than the value of single cylinder.

B- Disc diameter equal to 0.75 cylinder diameter:

Figure 6, 7 and 8 shows the results of increasing gap ratio from 0.05 to 1.5. when g/d2 =0.05, the drag coefficient is less than that of the cylinder alone by 13.7%, a sharp decrease in drag coefficient accompanied with increasing of g/d2 was achieved. The minimum was observed at $0.25 \leq g/d2 \leq 0.325$ where $C_D = 0. 5$, which is 42.5% 1ower than that of cylinder alone. Further increasing in gap ratio causes a sharp increasing in drag coefficient reaching a max. value of $C_D = 0.85$ at g/d2= 1.5, but this value is still lower than the value of cylinder alone.

C- Disc diameter equal to 0.65 cylinder diameter

Further investigations were carried out using a disc diameter equal to 0.65 cylinder diameters. The results are presented in figs 9 and 10. The behavior of drag coefficient for this combination seems to be similar to the behavior of the previous combination (i.e. d1/d2=0.75), but the trend of curves for this group is much smooth along the whole range of Reynolds number, also the values of C_D is higher by small amount. The minimum drag was obtained at gap ratio =0.3, which have an average valve of 0.53. At larger gaps ratios between 0.5 to 1.5, the drag coefficient in this range starts to increased gradually above the minimum value obtained above, but even that these values are still lower than the values of single cylinder.

D- Disc diameter equal to 0.525 cylinder diameter

The results of this combination are presented in figures 11, 12, 13, &14. The tests were carried out over $0.05 \leq g/d2 \leq 1.5$, in general little gain for drag reduction was achieved in this combination, and the minimum was obtained at two different values of g/d2 (i.e. at 0.2 and 0.75).

E- Disc diameter equal to 0.45 cylinder diameter:

In general smaller disc does not give a good optimum configuration, but the value of drag coefficient is still within the value of a single cylinder. See figs 15 and 16.

F- Disc diameter equal to 0.3 and 0.2 cylinder diameter

The results are shown in figs. 17, 18, 19 and 20. It could be concluded that no further reduction in drag could be achieved for these combinations either for small gaps or larger gaps.

The reduction in drag is achieved for most of the combinations tested in present study, and the works of previous investigators [5, 8, 10, 12, 13, and 14] could be due to one or more of the following reasons.

a-Reducing the reattachment of the separated shear layers from the fore- body on the rear body causing high base pressure behind it. This higher base pressure accounts for the lower drag actually observed. The reattached shear layer also constitutes a turbulent boundary layer on the surface of the rear cylinder, which also accounts for a lower skin- friction drag.

b-Presence of ax symmetric divergent fluid flow across the gap may help to from a narrow wake behind the body and hence reduce the effect of bluffness.

c-The separated surface (shear layers) at the optimum diameter ratio could capture the cylinder perimeter smoothly and skin over it forming a turbulent layer over the cylinder as far as possible.

Conclusions

1- Experiments with discs having different diameters placed in tandem with a cylinder at a proper distance, shows a significant reduction in drag force as compared to that of either disc, or cylinder. When a proper sizing is selected.

2- The most significant drag reduction was achieved and up to 42.5% lower than that of cylinder alone , for a combinations of disc diameter to cylinder diameter ; (d1/d2) between 0.65 to 0.75 .

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تاثير قرص دائري على قوه الكبح لاسطوانه

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الخلاصه:

وضع جسمين غير انسيابين احدهما خلف الاخر في مجرى هواء ,سوف يؤدي في بعض الحالات الى ان قوه الكبح الكليه للمجموعه ستكون قليله نسبيا

ان البحث الحالي هو بحث تجريبي يتناول تقليل قوه الكبح لجسمين غير انسيابين موضوعين احدهما خلف الاخر وذلك با اختيار الاحجام(الاقطار)المناسبه لهذه الاجسام والمسافه المثاليه الفاصله بينهما . لذا تم تصنيع مجموعه من الاجسام تتضمن اسطوانه وضعت بصوره موازيه لمسار الريح كجسم خلفي واقراص دائريه ذات اقطار مختلفه كاجسام اماميه تم اجراء التجارب لعدد رينولودز يتراوح بين $1.0*10^5$الى $2.2*10^5$

ان نتائج تجارب أظهرت بأن قوة الكبح التي تم الحصول عليها قد قلت بصورة كبيره ولغايه 42.5% وهي اقل من قوه كبح الاسطوانة المفرده عند اختيار قطر القرص المناسب والمسافة المثالية امام الاسطوانة.

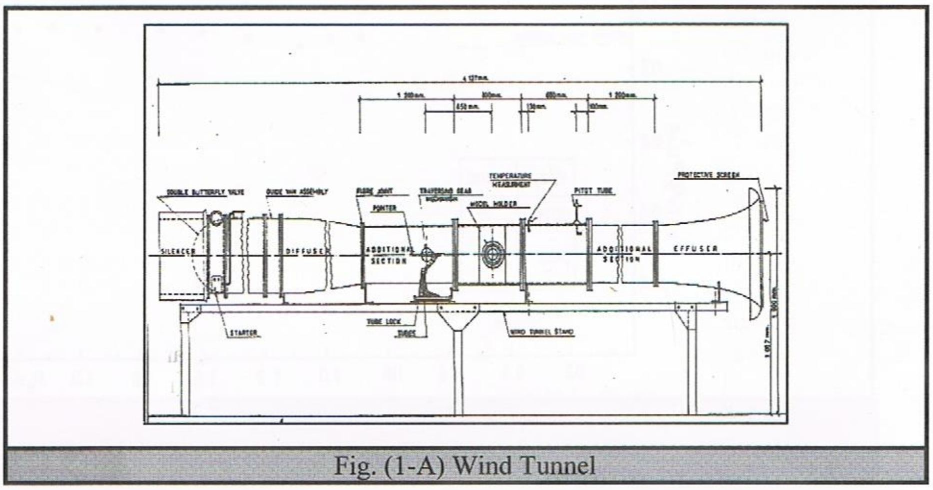

Fig. (1-A) Wind Tunnel

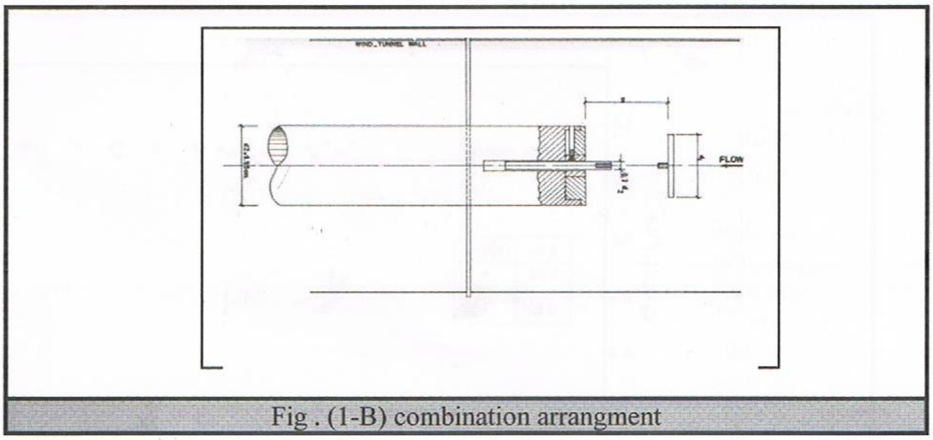

Fig . (1-B) combination arrangment

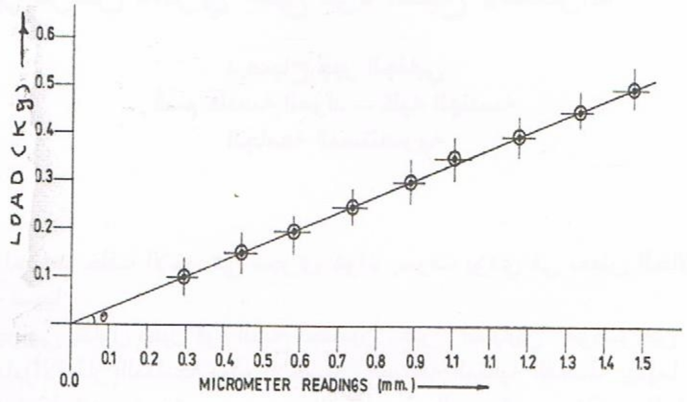

Fig.(1-C) Micrometer calibration

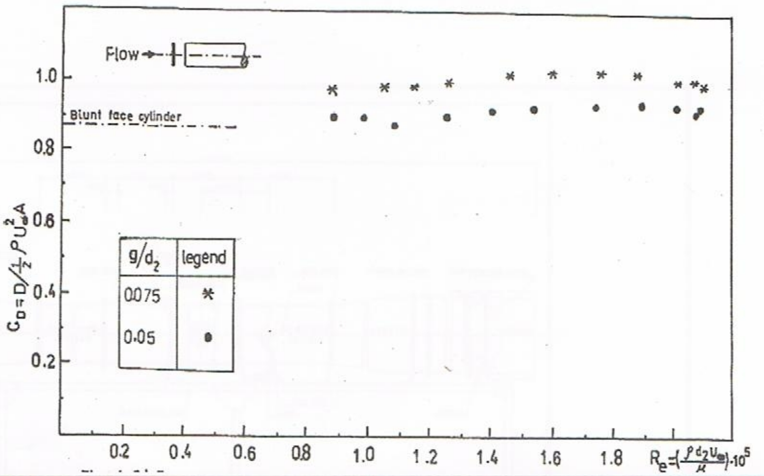

Fig. (2).Drag coefficient versus Reynolds number for configuration, disc in tandem with the cylinder, $d_1/d_2=1.0$

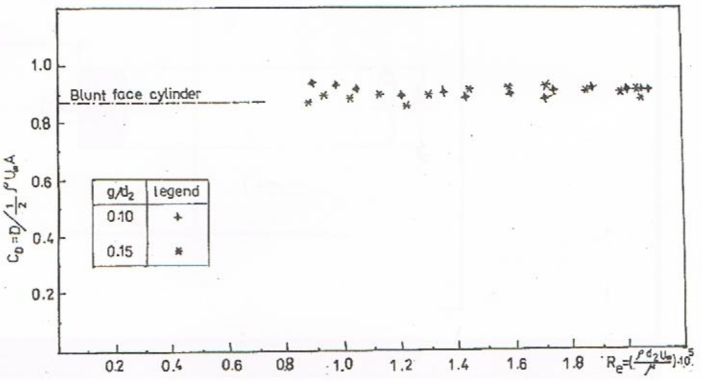

Fig (3) Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, $d_1/d_2=1.0$

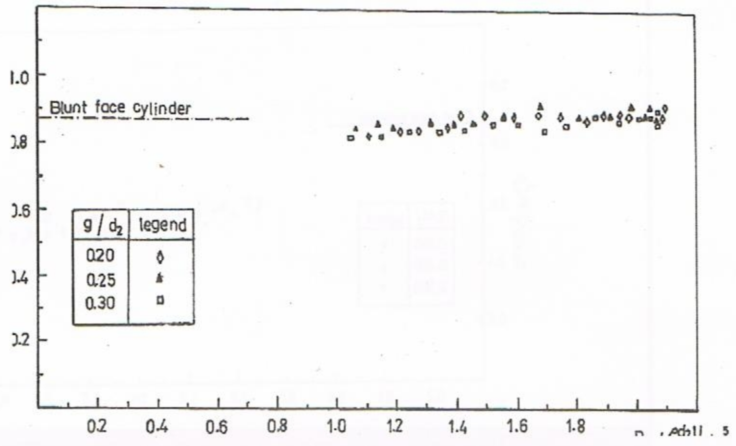

Fig. (4) .Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, d_1/d_2=1.0

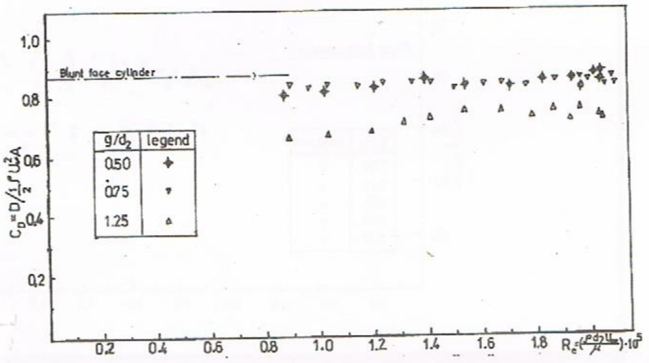

Fig. (5). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, d_1/d_2=1.0

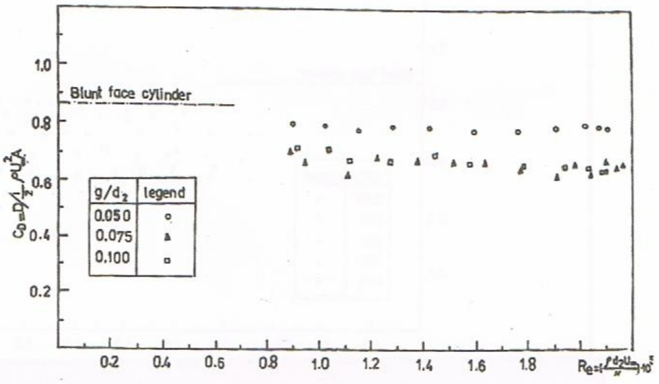

Fig. (6).Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder , d_1/d_2=0.75

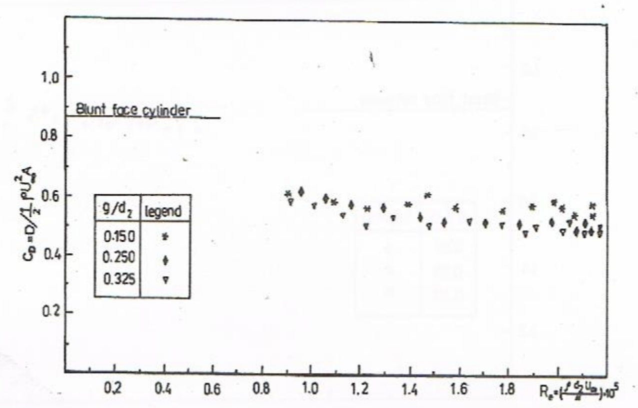

Fig. (7). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder , $d_1/d_2 = 0.75$

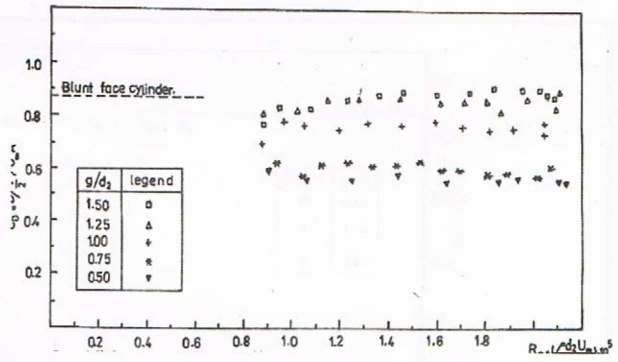

Fig. (8). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, $d_1/d_2 = 0.75$

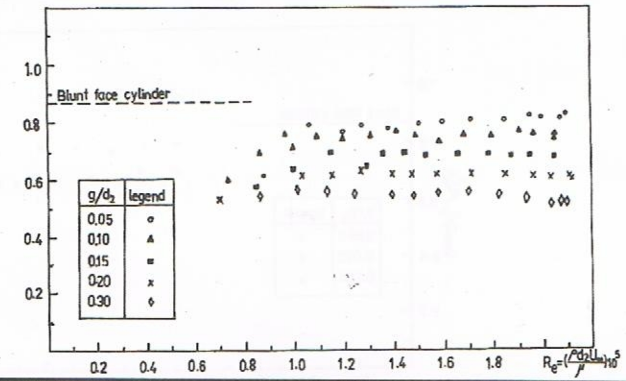

Fig. (9) . Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder , $d_1 / d_2 = 0.65$

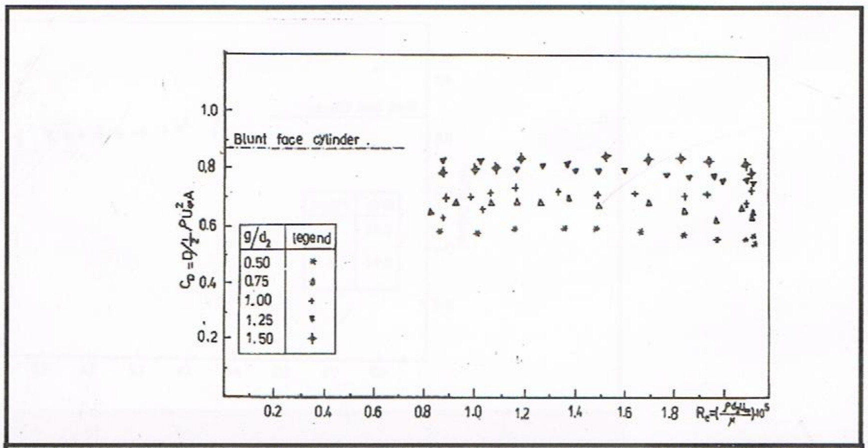

Fig. (10). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, $d_1/d_2=0.65$

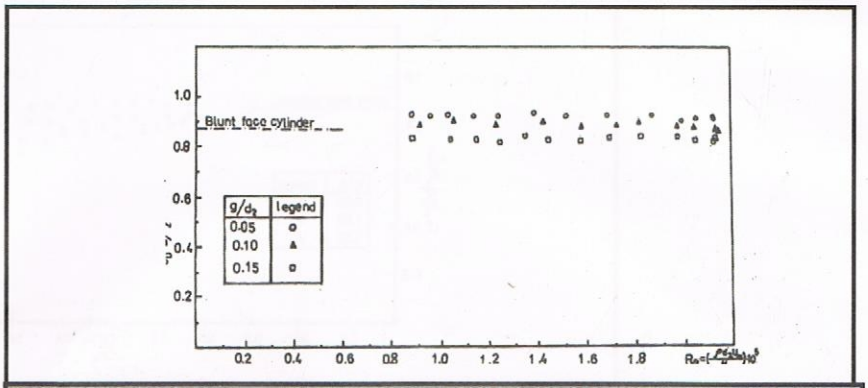

Fig. (11). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, $d_1/d_2=0.525$

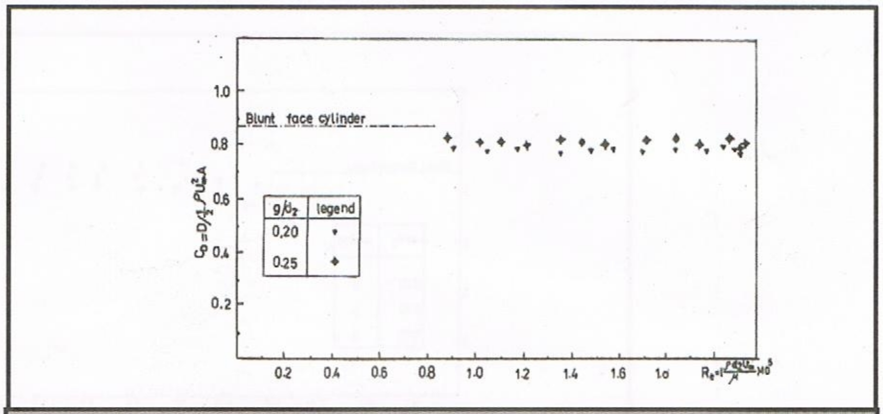

Fig. (12). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, $d_1/d_2=0.525$

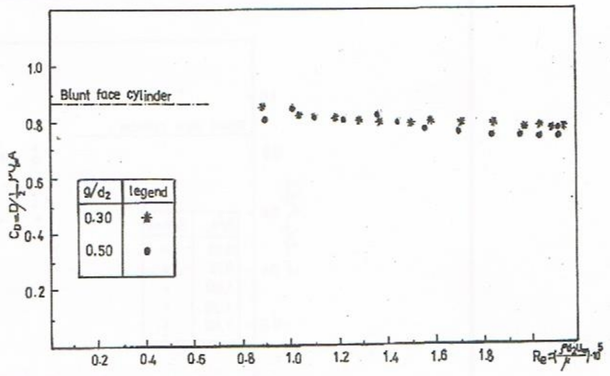

Fig (13) Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder , $d_1/d_2=0.525$

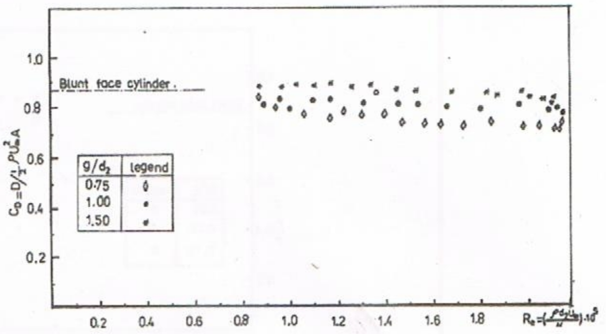

Fig. (14) . Drag coeffioient versus Reynolds number for the configuration disc in tandem with the cylinder, d_1/d_2=0525

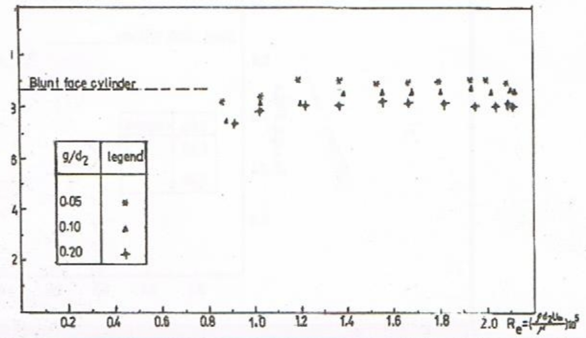

Fig (15) Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder , d_1/d_2 =045

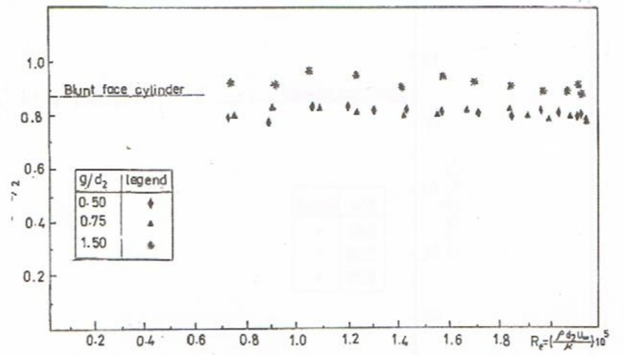

Fig. (16). Drag coefficient versus Reynolds number for the configuration disc in tandem with cylinder, $d_1/d_2=0.45$

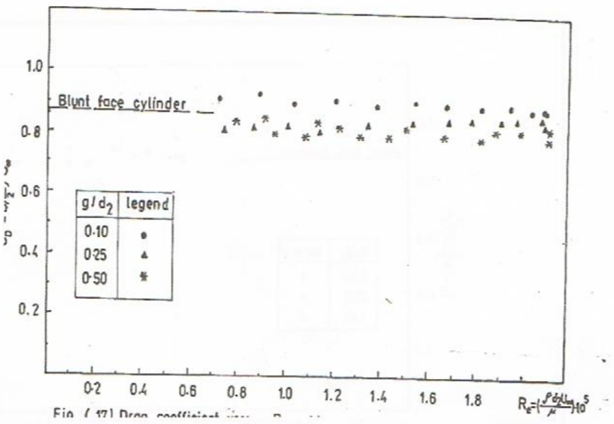

Fig. (17). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, $d_1/d_2 = 0.3$

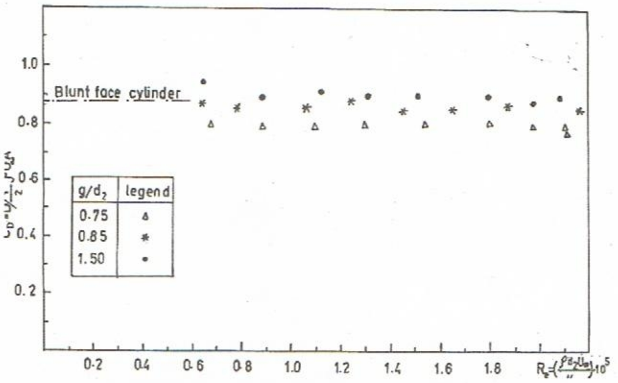

Fig (18). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, $d_1/d_2 = 0.3$

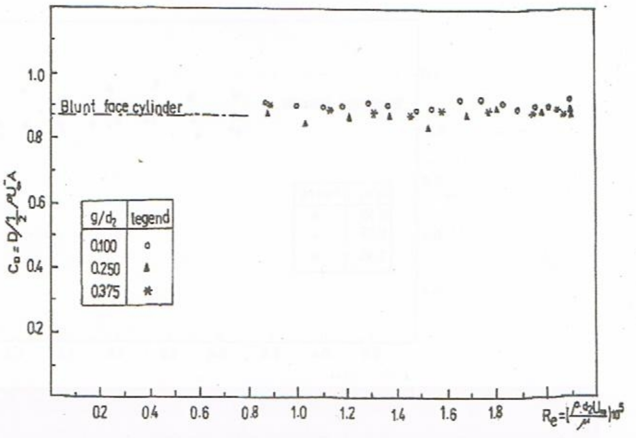

Fig. (19). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, d_1/d_2=0.2

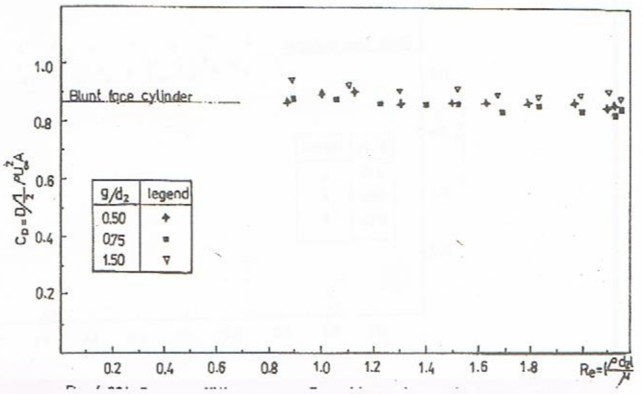

Fig. (20). Drag coefficient versus Reynolds number for the configuration disc in tandem with the cylinder, d_1/d_2=0.2