Interference between two circular cylinders for side by side arrangement

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1. Introduction and experimental arrangement

Although flow interference between two circular cylinders for side by side arrangement has been studied by a number of researchers, such as Zdravkovich(1), Bearman(2), Kiya(3) and Biermann(4) etc, there are still many aspects of this topic to be studied. Since time mean forces and pressures have been the main research subjects in the past, the results for fluctuating forces and pressures are limited. Most of the previous work has been conducted at low Reynolds numbers(of the order of 10^3 to 10^4) in smooth flow. To attain further information in this field , comprehensive studies on interference between circular cylinders in both smooth and turbulent flows have been carried out at Monash University. Some of the results obtained in smooth flow are presented in this paper.

The experiments were conducted in the $2m \times 1m$ working section of the 450KW wind tunnel. The cylinders were made of thin aluminium tubes with a diameter of 0.1m and a length of 0.8m. The relative surface roughness, K/D, was of the order of 10^{-6}, where D was the cylinder diameter and K was the averaged height of surface roughness. The cylinders were placed horizontally across the working section which has a width of 1m. To keep the flow close to two-dimensional, two square end plates with a length of 1.82m were used. For the smooth flow measurements, the turbulence intensity was 0.4% and the Reynolds number was in the range of 1.0×10^5 to 2.0×10^5.

The experiments consisted of force and pressure measurements. For the force measurement, a two dimensional force balance was used, which measured alongwind and crosswind forces. For the pressure measurement, eight pressure transducers were used to get the pressure distribution. The pressure tappings were positioned at the mid span of the cylinders. A pressure transducer tubing system was selected to achieve the optimum frequency response, up to 120Hz for a given length of tubing. All the signals were digitized with a sampling frequency of 1000Hz and processed by a mini-computer from which time mean, standard deviation and peaks were obtained based on 35 seconds averaging time. For other analyses, a wave form analyzer was used.

2. Results and discussions

Figure 1 gives the variations of the pressure coefficients at different tapping positions as functions of cylinder arrangements. The interference force coefficients for time mean forces and interference factors for fluctuating forces are presented in Figures 2. The interference factor is defined as the ratio of force coefficient on the cylinder in the presence of the interference cylinder to that of the cylinder in isolation for the same free stream condition. The interference force is defined as the difference between the force coefficient on the cylinder in the presence of the interference cylinder to that of the cylinder in isolation for the same free stream condition.

It can be seen that for $Y/D > 4$ the flow interference is not very prominent. The two cylinders experience more or less the same pressure and forces. As Y/D is decreased from 4 to about 1.9, the flow interference becomes more noticeable. The time mean drag increases due to the drop of the base pressure. Also, a repulsive lift force appears due to the shift of the stagnation points. Furthermore, a moderate increase in fluctuating forces can be seen from Figure 2. This is caused by coupling between the two separate vortex shedding processes behind the cylinders, which results in an increase in the fluctuating pressure and spanwise correlation.

As Y/D is reduced to about 1.9, normal vortex shedding from both cylinders is disrupted and the flow becomes unstable and fluctuates at low frequency. As a result of the disrupted vortex shedding processes, the fluctuating pressure remains low. Hence, the fluctuating forces, especially the lift force, are small. This lasts until Y/D reaches about 1.12 where a single vortex street starts to form. As a result of this, the Strouhal number is halved and the correlation between the fluctuating pressures on the inner sides of the cylinders is changed from being negative to almost 1. The form of the single vortex street has a large effect on the pressures and forces acting on the cylinders. The time mean drag coefficient increases sharply and almost doubles its value as a single cylinder when the cylinders are in contact. The same trend can be observed for the time mean lift coefficient, which reaches its minimum value of about -1. While the increase of the time mean drag is caused by a drop of the base pressure as well as an increase in the pressure at the front part of the cylinders(near the gap), the increase in the repulsive lift force is mainly caused by the raising of the pressure at the front. Because of the re-establishment of the strong vortex shedding, large increases in the fluctuating pressures and forces are observed.

From both the present results and those by other researchers, it has been found that three different interference regimes can be specified for the side by side arrangement, which is shown in Figure 3. It was reported by a few researchers(2)(3) that in the second regime, where the normal vortex shedding process was disrupted, the flow through the gap between the cylinders becomes biased to one side. The biased gap flow was unstable and swung from one side to the other randomly. The swing frequency was very low. As a result, the two cylinders experience two Strouhal numbers due to the biased gap flow. The Strouhal number for the cylinder which has a narrower wake is about 0.3 and the other for the wider wake is about 0.1. The cylinders experience narrow and wide wakes alternatively in a random fashion. Hence, the results on the forces and pressures on the cylinders can be very scattered in this regime. The Reynolds numbers used by those researchers were of the order of 10^4. It is interesting to notice that, based on the force and pressure measurements in the present experiment where the Reynolds number is of the order of 10^5, those two frequencies can only be observed very occasionally and the corresponding energy is very small compared with the energy at low frequency. The fluctuating forces and pressures are maily caused by the swing of the gap flow.

3. Conclusions

Based on the above results, some conclusions can be drawn.
For the interference between two cylinders of side by side arrangement in smooth flow, three interference regimes can be divided as shown before. Severe interference occurs only for the third regime, where the cylinders are positioned closely. For the second regime, the swing of the wakes at low frequencies plays a major role in the interference and the corresponding vortex shedding is very weak, which is different from the results at lower Reynolds numbers obtained by others

3. References

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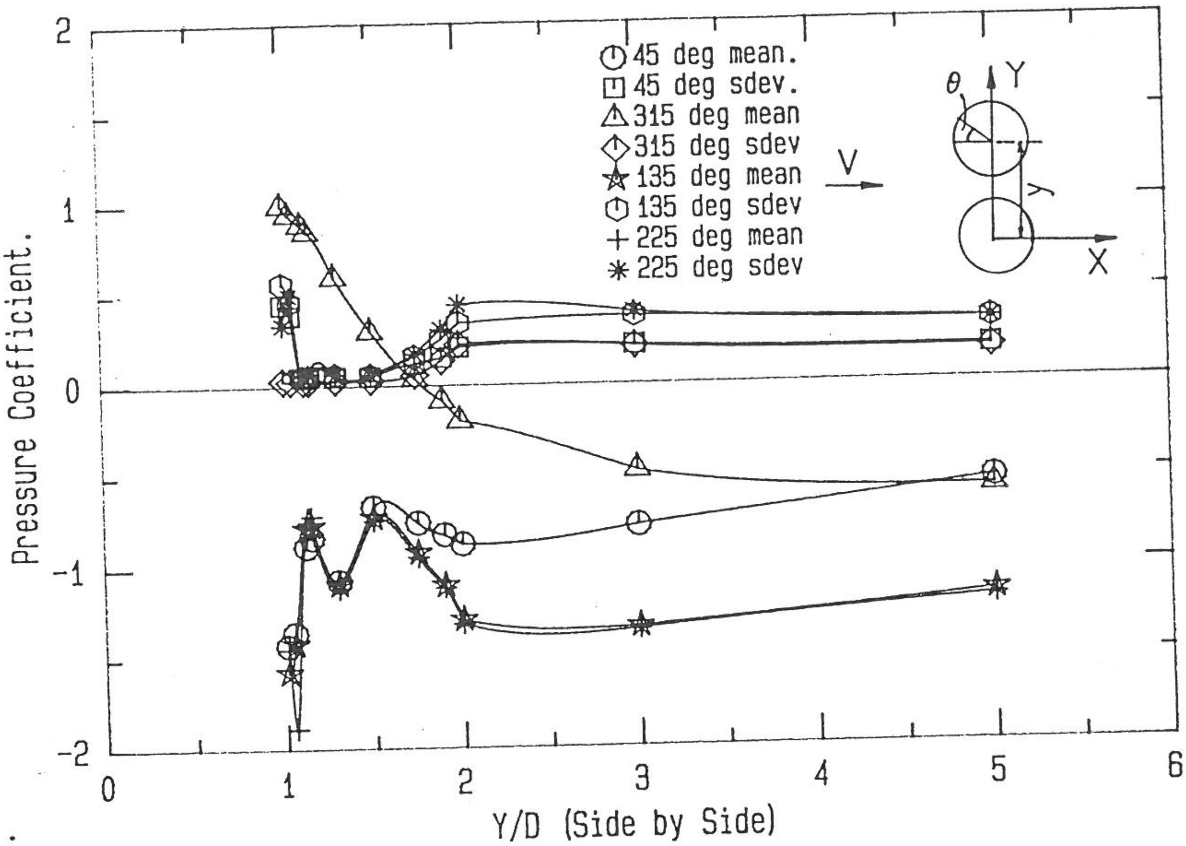


Fig.1 Pressure Coefficients for Different Cylinder Arrangements. (Re=1.1*E+5; Iu=0.4%; X=0)

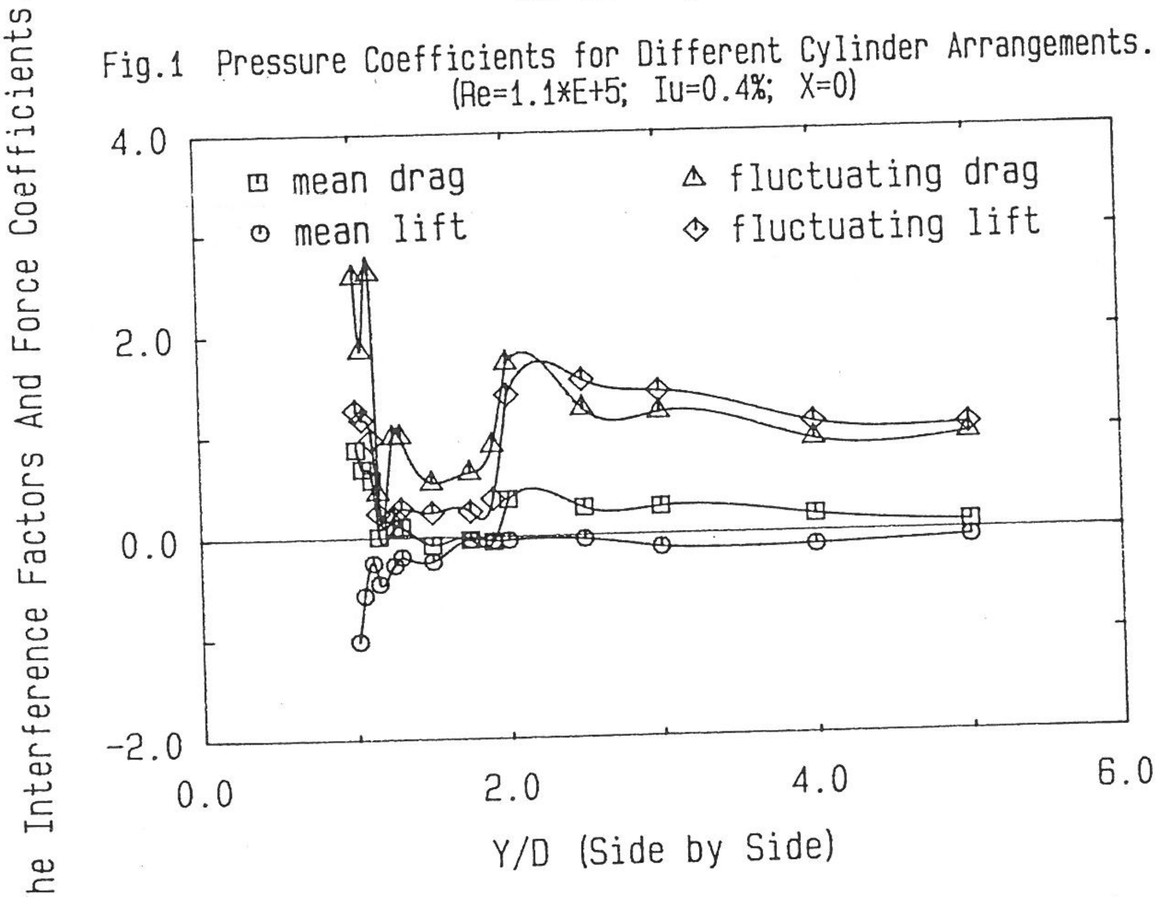
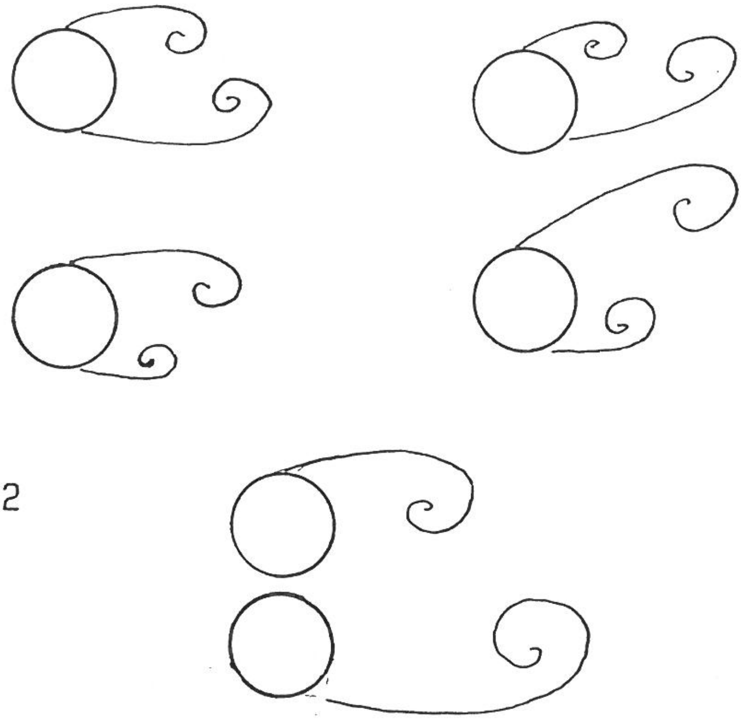


Fig.2 The Interference Factors And Force Coefficients for Different Cylinder Arrangements. (Re=1.1*E+5; Iu=0.4%; X=0)

Regime 1: Y/D > Y1;

Regime 2: Y2 <Y/D < Y1 ;

Regime 3: Y/D < Y2



2 < Y1 < 1.9 ;   1.12 < Y2 < 1.15

Fig.3 The Sketch of Different Interference Regimes for Side by Side Arrangement in Smooth Flow. (1*E+5 < Re < 2*E+5)

$Re = \frac{VD}{\nu}$

$10^5 = \frac{V \times 0.1}{10^{-5}}$