PROCEEDINGS

ISBN : 978-602-1178-11-9

Padang, November 9-11, 2017

4th International Conference on Technical and Vocational Education and Training (TVET)

Theme :

Technical and Vocational Education and Training for Sustainable Societies

PENERBITAN & PERCETAKAN UNP PRESS
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Proceedings of 4th UNP International Conference on Technical and Vocation Education and Training November 09-11, 2017, Padang, Indonesia

RELATIONDRAG FORCE REDUCTION ON CIRCULAR CYLINDER USING CIRCULARDISTURBANCE BODY WITH TURBULENCE INTENSITY

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ABSTRACT: This experiment will be conducted experimentally on a wind tunnel that has a narrow section with square cross section 125 mm x 125 mm and 26.4% and 36.4% blockage ratio. The specimens used are circular cylinder with diameter 25mm (d / D = 0.16) and 37.5mm (d/D = 0.107) and circular cylinder rod with diameter 4 mm. The cylinder disturbance body (CBD) are placed on the upper and lower sides with the position of $\alpha=20^0$, 30^0, 40^0, 50^0, $60^0$and distance (δ = 0.4 mm) against the main circular cylinder. Reynolds number based on hydraulic diameter 11.6 x 10^4 and 15.6 x10^4. The results shown that the use of disturbance body was able to reduce the pressure drop value on the narrow channel with square section. For D = 25mm (d / D = 0, 16) the reduction of the pressure drop value occurs in the disturbance body position $\alpha = 20^0$, $\alpha = 30^0$, while for D = 37.5mm (d / D = 107) occurs in the stalking rod position $\alpha=20^0$, $\alpha=40^0$, $\alpha=30^0$. The increase of turbulence intensity value can reduce the value of drag pressure coefficient (C_{dp}) for circular cylinder for D = 25mm (d / D = 0.16) for Reynolds number 11, 6 × 10^4 and 15.6 × 10^4 happened disturbance body position $\alpha = 30^0$ and $\alpha = 20^0$. In the circular cylinder D = 37.5mm (d / D = 0.107) the reduction of drag pressure coefficient (C_{dp}) at Reynolds number 11.6 x 10^4 and 15.6 x10^4 occurs at the disturbance body position $\alpha=30^0$, $\alpha=40^0$ and $\alpha=20^0$.

Keywords: turbulence Intensity, disturbance body, circular cylinder

INTRODUCTION

Research on fluid flow across a single circular cylinder was performed [1]. This study mainly process secondary data obtained from previous studies by discussing the interaction between fluid flows with circular cylinder. It is concluded that the fluid flow will transition from laminar flow to turbulent until the flow separation phenomenon occurs. This phenomenon is strongly influenced by several factors, namely by the speed of free-stream and flow profile, free-stream turbulence, objects (geometry and orientation toward the flow direction), and the roughness of the surface of the object.

This study was conducted [2]. The configuration used is a circular cylinder tested on Reynolds number 4x10^4 to 3x10^5, that the value of the C_d will decrease as the turbulence intensity increases on the same Reynolds number. From the above conditions we can conclude the correlation between the turbulence intensity to the C_d value, which the C_d value will decrease along with the increase of turbulence intensity on the same Reynolds number.

Reference [3] conducted a study with Digital Particle Image Velocimetry (DPIV) method, he used a circular cylinder test object with a diameter of 20 mm. This research was conducted in close loop free surface water channel with width = 1000 mm, length = 8000 mm and height = 750 mm. Reynolds number based on circular cylinder diameter used 550 ≤ Re ≤ 3400 and turbulence intensity is 0.2%, when using circular cylinder, it is found that turbulent energy content at certain frequency fluctuates. The largest turbulent energy content at 1.8 Hz frequency is worth 50, it can be seen that the use of circular cylinder can cause an increase in turbulence intensity value this can be seen on the value of turbulent energy content.

Reference [4] they also see the influence of Reynolds Numbers value to the decrease of drag force. It appears that the effect of Reynolds number significantly on the drag force drop and the optimum conditions obtained for the reduction of drag coefficient and total drag coefficient by using a disturbing rod with diameter ratio d / D = 0.25, the ratio of L / D distance = 2.0 to Re <41000 and the ratio distance L / D 1.75 to Re> 41000. Decrease in CD and CDT values was 73% and 63%.

Reference [5] conducted a study to reduce the drag force on a single cylinder by using a bulb rod on the upper side with the direction of clockwise and counter-clockwise movement for the lower side of the main cylinder circle with smaller dimensions. The movement angle of the interference rods starts from ($\alpha = 20^0$) to ($\alpha = 60^0$)

with constant gap = 0.4mm between the cylinder rod with the main cylinder circle. Variations of annoying rods using different diameters (d) (4mm, 5mm and 6mm). While the main circular cylinder diameter D = 49mm. From experiment of drag coefficient value on circular cylinder of constant tendency to the gap treatment between cylinder rod with main circular cylinder for d / D_ <0.15, then for further research

Reference [5] conducted experiments at 0.4mm slit. The influence of the stalking (α) position on the drag coefficient (C_d) in the case of a disturbing rod with a diameter of 4mm, 5mm, and 6 mm.The study was conducted on a large rectangular wind tunnel with dimensions (p x l x t) 250 cm x 30 cm x 120 cm at Reynolds number 5.5 x 10^4. The purpose of this study was to determine the optimal position of the intruder rod in reducing the drag force on the main circular cylinder.

From experiment of drag coefficient value on circular cylinder of constant tendency to the gap treatment between cylinder rod with main circular cylinder for d / D <0.15, then for further research Reference [5] conducted experiments at 0.4mm slit. The influence of the stalking (α) position on the drag coefficient (C_d) in the case of a disturbing rod with a diameter of 4mm, 5mm, and 6 mm, the value of drag coefficient (C_d) by using a disturbing rod at position $\alpha = 30^0$, value C_d decreased by 67%. This occurs because the wake that is detached from the disturbing rod does not undergo reattachment on the surface of the main circular cylinder causing disturbance in the main cylinder border layer. With the disruption of making the flow more turbulent so as to counter the adverse pressure gradient and delayed separation point that is about $\theta = 110^0$ for the position of the disturbing rod $\alpha = 30^0$ and $\alpha = 40^0$distribution of the pressure coefficient (Cp) along the main cylinder. At $\alpha = 45^0$ and $\alpha = 60^0$ the drag coefficient value (C_d) rises higher than the coefficient value of drag (C_d) of this circular cylinder due to a separate boundary layer of the main circular cylinder forced to disrupt the outer stem of the cylinder (b) The distribution of the pressure coefficient (Cp) shows the separation point occurring at $\theta = \alpha = 46^0$ indicating the value of drag coefficient (C_d) is greater because wake the resulting greater.

Fluid flow certainly requires the media as a channel for the process of flowing. With the existence of this channel, the fluid is easier to be directed to the flow rate although channel usage also has an effect on the fluid characteristics. One of them is the coefficient of fluid resistance which becomes higher than without the channel.

By not forgetting the dimensions of the object to be tested (bluff body) in the aisle of the wind that influences the flow of fluid [6] has examined the effect of the ratio of bluff body dimension to channel width to fluid velocity and the coefficient of resistance. This influence is known as blockage effect. This blockage effect makes the free stream speed faster (at the point where the maximum blockage ratio) than its real velocity due to the narrowing of the fluid able area. From [7] research, they also show the results of Allen and Vincenti research that corrected the speed obtained. Allen and Vincenti's formulation of the free stream speed correction along with correction of the fluid resistance coefficient was obtained from Weidman's (1968) study and the barrier coefficient correction graph was obtained from [7]

The experiments performed by [8] produced a graph of the 2.16 pressure drop shown in the figure below. From the graph, we can see that the influence of the magnitude of the distance s / D (the distance of the two cylinders), the diameter of the cylinder, the cylinder shape and the Reynolds number to the pressure drop. Seen in the same Reynolds number condition, the lowest pressure drop is in use of distance s / D = 2.5 by using 25mm diameter cylinder. This pressure drop value is lower than single cylinder (s / D = 0).

From the above studies came the thought to conduct research on the effort to reduce pressure drop on the narrow channel with square section by adding circular cylindrical disrupting rods arranged in the upper and lower circular cylinders main and relation to the intensity of turbulence produced.

2. METHODOLOGY

Here is a scheme of research to be done. Figure 1 shows the location of the test specimen and the distorting bar in the form of a cylindrical, plain surface mounted on the upper side and lower side of the main circular cylinder and carried out in a narrow channel with a square section. The disrupting rod will be placed at $\alpha = 20^0, 30^0, 40^0, 50^0, 60^0$ to the upstream of the main circular cylinder at a constant gap distance (δ = 0.4mm), with the direction of clockwise shift for upper side and counter-clockwise for the lower side of the main circular cylinder. This experiment was carried out using a wind tunnel with an open circuit type subsonic wind tunnel. The dimensions of the channels used are square-shaped with dimensions of 125mm x 125mm x 2000mm. Also placed pressure tap on the four sides of the channel. The placement of pressure tap 1 located 600 mm from the beginning of the wind aisle. While pressure tap 2 is located at 600mm behind pressure tap 1. 600mm distance between pressure tap 1 and 2 is the test section area which becomes the pressure measurement area in this experiment.

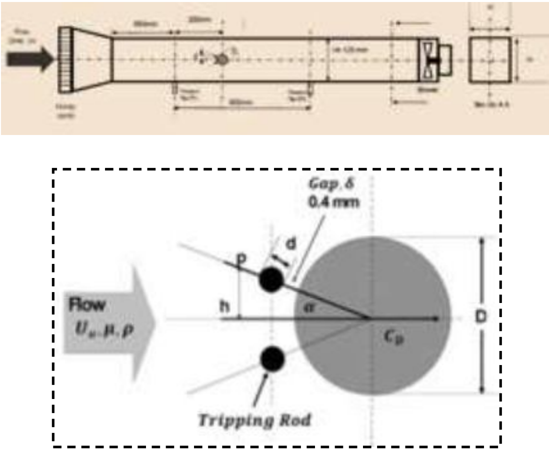


Figure 1. Wind tunnel scheme with the main cylinder circular configuration as well as the position of the disturbing rod

The specimens used in this experiment are circular cylinders with diameter D = 25mm and 37.5mm. As well as disturbing cylinder disturbing diameter d = 4mm with plain surface. The main cylinder is made of a pvc pipe while for the bully cylinder is made of brass rod. The resulting blockage ratio is 26.4% and 36.4%.This experiment uses the same Reynolds number as experiment, $11.6x10^4$ and $15.6x10^4$. Determination of Reynolds number is based on wind tunnel hydraulic diameter.

The pressure on the wind tunnel is measured at a pressure tap connected with an Omega PX655 pressure transducer. This pressure tap gives a current reading in the range of 4mA-20mA, data from pressure transducer is read with DAQPRO-5300 Omega acquisition data. Pressure data from the pressure readout results are calibrated to produce accurate data.

3. RESULT AND DISCUSSION

The pressure drop values generated by a single circular cylinder contained in a channel with D = 25mm and 37.5mm diameters placed in the test section are a 125mmx125mmx600mm square-shaped cross section. It can be seen that with the addition of a circular cylinder in the channel contributes to the increase in pressure drop.

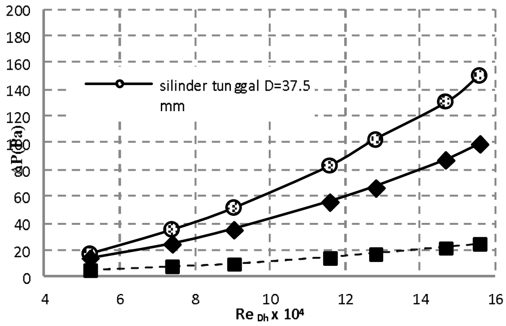


Figure 2. Pressure drop value Single cylinder and empty channel

The analysis that can be done from Figure 2 is the value of pressure drop function of Reynolds Numbers. As the Reynolds value increases, the pressure drop values increase both on empty channels and on channels with a single circular cylinder. This increase in pressure drop rate is contributed by the speed components contained in the Reynolds number. This means that any increase in Reynolds value will increase the pressure drop and will produce a pressure drop graph similar to the parabolic graph (quadratic equation).

Drag Pressure Coefficient Analysis (Cdp)

Further analysis that can be explained to clarify the phenomenon in the fluid flow contained cylinder configuration is the analysis of drag pressure coefficient (Cdp) obtained by integrating the value of pressure coefficient distribution (Cp) using numerical method of Simpson rule 1/3 double segment.

At D = 25mm (d / D = 0.16) with Reynolds number 11.6 × $10^4$and 15.6 × 10^4. Experimental results can be seen in table 1 with each configuration.

Table 1. Drag Pressure Coefficient (Cdp)

Configuration	Re_{Dh}=11.6×10^4 D= 25 mm	Re_{Dh}=15.6×10^4 D= 25 mm
Single Cylinder	1.17	1.25
α=20^0	0.80	0.89
α=30^0	0.70	0.80
α=40^0	1.53	1.60
α=50^0	1.82	1.93
α= 60^0	2.04	2.18

From table 1 we can see how the ability of the use of rods in reducing drag force on the main circular cylinder by looking at the value of drag pressure coefficient (Cdp)for more details we can see in Figure 3 the best position graph for the reduction of drag force

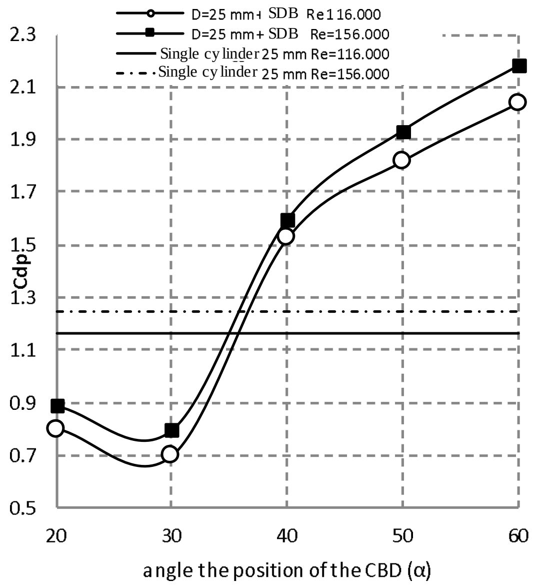


Figure 3. Comparison of drag pressure coefficient (Cdp) in each configuration D = 25mm (d / D = 0.16) with variation of cylinder disturbance body (CDB)

The first analysis we can do is the value of drag pressure coefficient (Cdp) on Reynolds variation 11.6 × 10^4lower when compared with Reynolds number 15.6 × 10^4. In the condition here there is an interesting thing that is with the increase of Reynolds number then the value of drag pressure coefficient (Cdp) is also increased, this condition is slightly different if the fluid flow across a cylinder is generally with increasing Reynolds number then the drag force on the circular cylinder will decrease if This phenomenon occurs in channels that have small blockage ratios. These different conditions were influenced by the value of blockage ratio. The blockage ratio that is owned by this configuration is 26.4% so that with the rise of the Reynolds number makes the fluid flow more quickly distorted due to the interaction of the main circular cylinder with the channel wall.

This condition is inseparable from the influence of wall shear layer is released so that it affects the separation point of the circular cylinder. However, with the use of annoying rods still able to reduce the drag force on the circular cylinder. From the experimental result, it is found that the most effective position to reduce drag force on circular cylinder at Reynolds number 11.6 × 10^4 with disturbance bar position α = 30^0 equal to 40,17% and at α = 200 equal to 31.62% while in Reynolds number 15.6 × $10^4$with disturbed stem position α = 30^0 of 36% and at α = 20^0 of 28.8%. For the stalking positions α = 40^0, α = 50^0 and α = 60^0 the use of annoying rods is no longer effective in reducing the drag force in circular cylinders, it proves by increasing the value of drag pressure coefficient (Cdp) for both variations of Reynolds number of stroke use.

At D = 37.5mm (d / D = 0.107) on Reynolds number 11.6 × 10^4 and 15.6 × 10^4. The results of the experiment can be seen in table 2 with each configuration.

Table 2 Drag Pressure Coefficient (Cdp)

Configuration	Re_{Dh}=11.6×10^4 D= 37.5 mm	Re_{Dh}=15.6×10^4 D= 37.5 mm
Single cylinder	**1.62**	**1.73**
α=20^0	1.08	1.16
α=30^0	0.88	0.96
α=40^0	1.04	1.13
α=50^0	2.04	2.13
α= 60^0	2.51	2.65

The results from table 2 will be digrafikan to make it easier to see the best position of the disturbing rod in reducing the drag force on the circular cylinder, this will be shown in Figure 4.

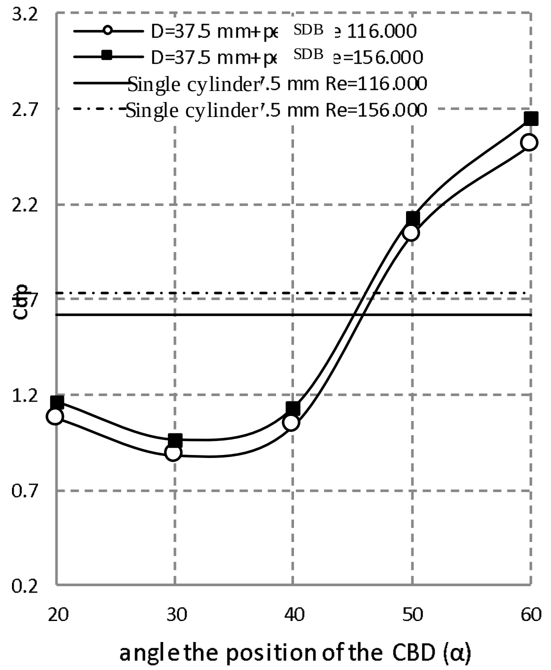


Figure 4 Comparison of drag pressure coefficient (Cdp) in each configuration D = 37.5mm (d / D = 0.107) with variation of cylinder disturbance body (CDB)

The phenomenon that occurs almost the same as the previous circular cylinder drag pressure coefficient (Cdp) on Reynolds variation 11.6 × 10^4tends to be lower when compared to Reynolds number 15.6 × 10^4. Different things that happen here is a slightly different condition that this configuration has a blockage ratio of 36.4%. This in turn greatly affects the ability of the rods in reducing the drag force on the circular cylinder. By looking at the value of drag pressure coefficient

(Cdp) the annoying rod is still the ability to reduce the drag force on the circular cylinder to the disturbing stem position α = 40⁰on both variations of the Reynolds number. The best inhibition position (Cdp) in Reynolds 11.6 × 10^4variation occurs in the position of α = 30⁰of 45,68% position of α = 40⁰equal to 35,80% and at position of α = 20⁰equal to 33,33%. Similarly, the Reynolds 15.6 × 10^4variation occurs. The best reduction occurs at the position of α = 30⁰of 44.51% and then the position of α = 40⁰of 34.68% and at the position of α = 20⁰of 32.95%.

Turbulence Intensity Analysis

The turbulence intensity data in this study was taken on Reynolds variation of 11.6 × 10^4 4 and 15.6 × 10^4. Turbulence intensity value in this study is obtained from the comparison between fluctuations in velocity and mean velocity on the flow behind the specimen. Placement of a disturbed rod on the upper and lower circular cylinders is expected to accelerate the flow of transition from laminar to turbulent.

Turbulence intensity value obtained by processing the value of fluctuations in speed behind the circular cylinder. The value of velocity fluctuation is obtained by converting the dynamic pressure value behind the circular cylinder from the Pitot static tube measurement. Pitot static tube is placed 2D behind the test specimen or circular cylinder and parallel to the outer diameter of the circular cylinder. This position was chosen based on the results of research by Tsutsui and Igarashi (2002) that in that position there is no back flow and quite fluctuating speed.

Table 3 Tabulation of Turbulence Intensity Data Collection

Cylindrical Diameter (m)	velocity (m/s)	Reynold number	St number	f (Hz)	T (s)	s=amount of data (/s)
0.025	14.48	11.6×10^4	0.2	115.84	0.0086	2896
	19.47	15.6×10^4	0.2	155.76	0.0064	3896
0.0375	14.48	11.6×10^4	0.2	77.223	0.0129	1931
	19.47	15.6×10^4	0.2	103.84	0.0096	2596

Based on the above calculation because the ability of data acquisition in the data retrieval above 2500 per second closest to the number 2500 per second is 4000 data per second. So the author to capture data as much as 4000 data every second.

On a single cylinder

Fluctuations in the flow velocity behind the circular cylinder for variations D = 25mm (d / D = 0.16) and D = 37.5mm (d / D = 0.107) at Reynolds number 11.6 × 10^4 and 15.6 × 10^4. The fluctuations shown by this figure indicate that the presence of circular cylinders and the rise of the Reynolds number can increase the intensity of turbulence behind the cylinder. From this velocity fluctuation obtained standard deviation and average speed at one point which can then be processed into turbulence intensity.

The experimental results of the turbulence intensity value on the confounding stem rod position configuration against the main circular len

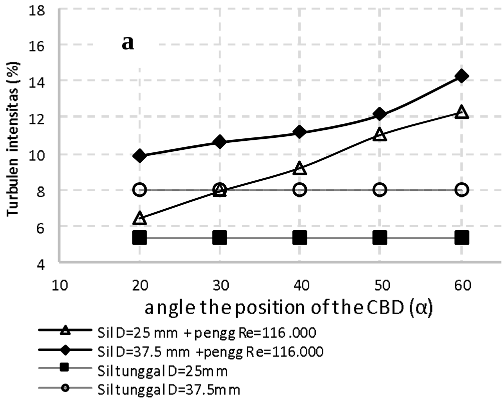
Table 4. Comparison of Turbulence Intensity Value in Circular Cylinder D = 25mm (d / D = 0.16) with cylinder disturbance body (CDB)

Configuration	D=25mm (d/D=0,16)	
	Re_{Dh}=11,6×10^4	Re_{Dh}=15,6×10^4
	IT (%)	IT (%)
Single Cylinder	5,40	6,72
α=20⁰	6,48	7,20
α=30⁰	7,95	9,25
α=40⁰	9,24	10,94
α=50⁰	11,05	12,00
α= 60⁰	12,28	13,75

Table 5 Comparison of Turbulence Intensity Value in Circular Cylinder D = 37.5mm (d / D = 0.107) with cylinder disturbance body (CDB)

Configuration	D=37,5mm (d/D=0,107)	
	Re_{Dh}=11,6×10^4	Re_{Dh}=15,6×10^4
	IT (%)	IT (%)
Single Cylinder	7,95	9,81
α=20⁰	9,87	10,59
α=30⁰	10,63	11,22
α=40⁰	11,13	12,61
α=50⁰	12,13	14,01
α= 60⁰	14,22	15,97

In table 5 for a single circular cylinder at D = 25mm with Reynolds number 11.6 × 10^4 yields a turbulence intensity value of 5.4% and at D = 25mm with Reynolds number 15.6 × 10^4turbulence intensity value of 6.72% done is with the increase of Reynolds number then the intensity value will also increase. In table 5 for D = 37,5mm with Reynolds number 11.6 × 10^4 yields turbulence intensity 7,95% and Reynolds number 15.6 × 10^4produces turbulence intensity 9,81% here turbulence intensity value increases with increasing number of Reynolds. In addition, the analysis that can be done is that the turbulence intensity value is blockage ratio where in the variation D = 25mm with the blockage ratio of 26.4% turbulence intensity is lower compared to D = 37.5 mm with the blockage ratio of 36.4% this is influenced by the speed of fluctuation resulting from the narrowing of the cross.



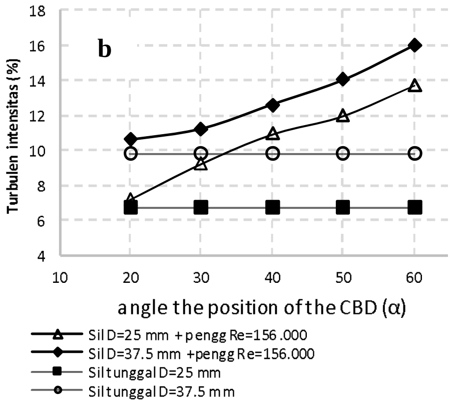


Figure 5Comparison of turbulence intensity graphs (a) on Reynolds number 11.6 × 10^4 and (b) Reynolds number 15.6 × 10^4

The turbulence intensity value is increased. This condition is influenced by several things: the first is the position of the disturbing stem (α), the turbulent value of intensity will also increase due to the wake interaction that is detached from the disturbing rod. The second increase of turbulence intensity is influenced by the increase of Reynolds number, the higher the Reynolds number, the intensity value will also increase.

This condition occurs at the position of the disturbing stem of variation D = 25mm (d / D = 0.16) at α = 20^0 and α = 30^0 and at variation D = 37.5mm (d / D = 0.107) at α = 20^0 α = 30^0 and α = 40^0 if we correlate the increase of turbulence intensity value contribute in reducing the coefficient value of drag pressure (Cdp). Enhance the variation D = 25mm (d / D = 0.16) at α = 40^0 α = 50^0 and α = 60^0 and variation at D = 37.5mm (d / D = 0.107) at α = 50^0 and α = 60^0 if connected with the value of drag pressure coefficient (Cdp) generated then the increase of turbulence intensity value experienced an inverse state that is with the increase of turbulence intensity value also resulted in the increase of drag pressure coefficient (Cdp).

4. CONCLUSION

the use of a distorting rod to reduce the drag force on a circular cylinder is highly effective at position α = $20^0$and α = 30^0 for circular cylinders of 25 mm diameter and position α = 20^0α = $30^0$and α = $40^0$for circular cylinders 37.5 mm in diameter, while an increase in turbulence intensity value is only effective in the above mentioned positions. While at α = 30^0α = 40^0α = $50^0$and α = 60^0circular cylinder with 25 mm diameter not effective, and also at position α = $50^0$and α = 60^0 for circular cylinder diameter 37.5 mm also not effective.

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