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Determination of Flow Characteristics and Performance Analysis of the Non-Rotating & Rotating Cylinder

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ABSTRACT: *The study of flow field over the bluff body has huge contributions in aerodynamic science. A closed looped wind tunnel was employed to determine the flow field around the cylinder. Flow characteristics and flow velocity over the cylinder was observed by taking five stations in the different regions around the rotating and non- rotating cylinder. Four stations were taken in the upstream and downstream and one was in origin. Two free stream velocities were taken for two different Reynolds numbers. Three tube yaw meter was used to calculate the total and local pressure. Flow velocity and its direction was calculated by using total pressure and static pressure with the help of Bernoulli's principle. Yaw meter was adjusted to the inclined manometer to determine the manometric height of the total and local pressure. By using manometric height velocity was evaluated. Same process was followed while the cylinder was in rotation. A dc power supply was used to rotate the dc motor. The motor was rotated using a certain voltage for which the rpm had a fixed value. A MATLAB code for analysis of the velocity vector field was employed to visualize flow characteristics around the cylinder.*

Keywords: Flow Characteristics, Finite Circular Cylinder, Velocity Profile, Velocity Vector, Rotating & Non-Rotating Cylinder, Streamline.

1. INTRODUCTION

Flow over a spinning and stationary cylinder has been a subject of several investigations. Interest in this flow arises not only from the point of view of understanding flow characteristics but also from its applications to flow control. The aerodynamics characteristics of three-dimensional bluff bodies and flow details around them have attracted much attention due to engineering requirements for the construction of high structures or tall buildings as well as speeding up of load vehicles or high speed transit railways. A finite circular cylinder is one of the most typical three-dimensional bluff bodies with the simplest geometry. Therefore, it is essential to clarify the aerodynamic characteristics of the finite circular cylinder from the point of view not only the engineering requirements but also of academic interests in fluid mechanics, because it could give us many informations about the essential flow characteristics and flow velocity. The flow details behind or around the circular cylinder at the high Reynolds number are great importance in an engineering point of view.

The characteristics of flow is investigated here by using rotating and non-rotating cylinder. In the experiment, five stations have been taken for determining flow characteristics and velocity profile of the flow. From the experiment velocity vs distance graph is evaluated by different tapping point of the station of cylinder which is in rotation and without rotation state. If the cylinder is in stationary condition, then flow velocity in the upper and lower surface of the cylinder remain same but at the origin of the cylinder in the upstream becomes zero. In the upstream where the origin of the cylinder situated

pressure is high but the upper and lower body of the cylinder pressure is low and velocity is high and symmetric. For rotating cylinder pressure is also high in the upstream of the cylinder at origin. In the upper and lower body of the rotating cylinder velocity profile and magnitude is not symmetric. In the upper body velocity magnitude is higher than the lower body in the rotating cylinder. But pressure is lower in the upper body than the lower body in the rotating cylinder. In the downstream pressure decreases and turns to negative pressure in the middle where cylinder actually situated. In the cylinder flow separation is higher than the cylinder and for this reason wake region is higher in cylinder. Velocity profile in the upstream away from the origin, upper and lower surface of the cylinder becomes symmetric. But in the surface of the test section velocity drops significantly because of boundary layer.

As cylinder is a bluff body, enough wake creates in the downstream region of the cylinder. That's why, velocity profile in the downstream becomes opposite to actual flow in the upstream. In the right side of the cylinder which is downstream, flow is symmetric in the upper and lower side of the cylinder but in the mid-section cylinder velocity direction and magnitude changes. Here in the mid-section flow velocity reduces significantly in and direction changes as opposite to the free stream velocity direction. As there is a large wake region creates for flow separation, flow velocity magnitude and direction alter.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1 Closed loop wind tunnel

In wind tunnel air blow is conducted in a controlled way through the large tube. The measurements of different parameters (pressure, velocity etc.) can be achieved both electrically and mechanically.

In the existing closed loop wind tunnel the test section was attached with a dc motor (rotating speed over 2000 rpm). To control the flow rate in a specific part of wind tunnel a regulator was installed. An internal blade is attached with the regulator inside the wind tunnel which controls the flow rate with variation in angle of rotation. Connection between two electric motors and the wind tunnel was established for providing high power continuous flow.



Figure01. Closed Loop Wind Tunnel

Here, in closed looped wind tunnel free stream flow velocity which is provided in upstream was 16.75 m/s. Mass flow rate is controlled by rotating the nob. Two free stream velocity used for this experiment. One velocity is taken 16 m/s when nob is in 90° position which means flow does not affect by the internal blade. Other velocity is taken 8 m/s when nob is in 45° position which means internal blade blocks 50% mass flow of its original mass flow.

2.2 Yaw meter

Yaw meter is a device to measure airflow pressure. Yaw meter consists of a forward facing pitot tube and two inclined or chamfered side tubes that can be used to determine wind speed in addition to flow direction. The central tube gives total pressure and static port gives static pressure. The difference between them gives flow velocity eventually. Yaw meter measures the value of total pressure over the test models as well as upstream and downstream pressure of the test model. Yaw meter was made using three conventional needles of syringe with 1.2 mm diameter. The needles were attached with a stainless steel rod of 6 mm diameter. Each needle is connected with a tube of 1.5 mm diameter which is passed through the rod and can be connected to the manometer. The middle of three tube measures the total pressure which is denoted by P_1 . Other two tube is denoted by P_2 and P_3 by which flow angle is determined.



Figure02. Yaw meter

A special facility was established to calibrate the yaw meter with the current facility. To calibrate the yaw meter, it is aligned horizontally with the direction of flow in the test section. Then the yaw meter is rotated with 5 degrees' increment both clockwise and anti-clockwise direction. This same procedure is done within 20 degrees.

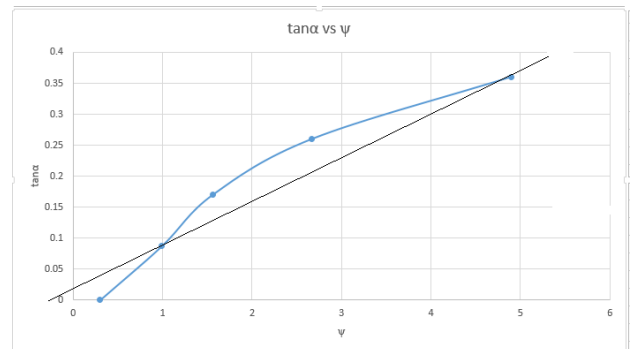


Figure03. Calibration of Yaw meter

Table 01. Yaw meter calibration table

α	$\tan \alpha$	P1	P2	P3	$\Psi = \tan$
0	0	14.2	9.1	27	0.31
5	0.088	6.4	14.5	26.5	1.1
10	0.1763	3.1	16.8	25.3	1.5
15	0.268	-0.25	19.8	18.5	2.78
20	0.364	-0.44	18	19	4.9

From the calibration, the equation what we get $\tan \alpha = 0.037\psi + 0.019$

That can be written as $\tan \alpha = \psi$

Here, $m = 0.037$ and $c = 0.019$ as it is compared to the equation of $\tan \alpha = m\psi + c$

2.3 Inclined manometer

For low levels of deflections, manometers are used to measure pressure of fluids. Traditional variants include single tube, multi tube, U-tube, vertical, inverted, inclined ones, etc. The most popular use for manometer is probably measuring static and total pressure of fluid. To conduct the experiment four U-tube manometers are required as yaw meter has three probes and for the static pressure value. So, four U-tube manometers were set up on a wooden box using glass tube, pipe fittings, measuring scales etc. Wooden blocks were used to

keep the manometers inclined at different angles.



Figure04. Incline manometer

2.4 DC power supply

A DC power supply is used to rotate the motor which actually rotates the cylinder. Power source gives the electrical power that is taken by the motor. Motor converts it to the mechanical energy. For rotation of the motor in a decent speed 4.5V is used.



Figure05. DC Power Supply

2.5 DC motor

A DC motor is used to rotate the cylinder. It transfers power supply's electrical energy to mechanical energy. Taco meter is used to determine motor r.p.m and it was 2100 per minute. Motor is attached to the cylinder shaft. Bearing is set to the test section so that cylinder can rotate easily and less effect of vibration.

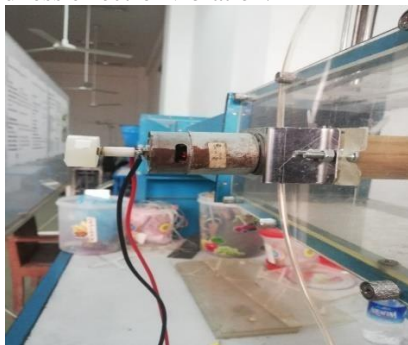


Figure06. DC motor

3. PROCEDURES AND MEASURING SYSTEMS

Cylinder is placed in the middle of the test section. Test section is square in size which width and height is 150 mm but length is 440 mm. As cylinder is placed at origin of the test section, its upper and lower length from the wall is 75 mm. Cylinder diameter is 40mm. Five station is taken for the measurement. Two station

is taken in the upstream and downstream. One station is taken in the origin. Two upstream stations are 115 mm and 105 mm left from the origin. Two downstream stations are 20 mm and 30 mm right from the origin. Yaw meter is connected with the manometer by the pipe. Four tube of yaw meter is connected with the manometer. When internal blade is in 90° condition mass rate is maximum. For maximum mass flow rate free stream velocity is 16 m/s. For free stream velocity 16 m/s, total pressure and local pressure is measured by the manometric height. For each station from bottom to top 17 points is taken to measure the total local pressure. By this flow velocity and direction is calculated. Flow velocity is measured by this equation:

$$v = 2.35\sqrt{h_k} \quad [1]$$

Then dc power supply is connected with the motor. DC power supply voltage is taken 4.5V. At 4.5V dc motor rotates by 2100 rpm. Local pressure and total pressure is measured by this condition. By the local pressure and total pressure height, flow velocity magnitude and direction is identified. Another free stream velocity taken when nob is in 45° position. When nob is in 45°, mass flow in wind tunnel reduces half to original mass flow rate. Mass flow rate reduces because the flow controller is in the 45° position. Free stream velocity becomes 8 m/s for this position of flow controller. Total and local pressure of fluid is measured in same condition as free stream velocity 16 m/s. Velocity is measured at the same way as previous. Then same process is done determining pressure and velocity when cylinder is in rotation.

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

Two Reynolds number is considered for two different free stream velocities. In a particular free stream velocity, flow characteristics is determined by rotating and without rotating cylinder. In the upstream velocity remains constant as flow is not obstructed by the object.

4.1.1 Upstream (16 m/s):

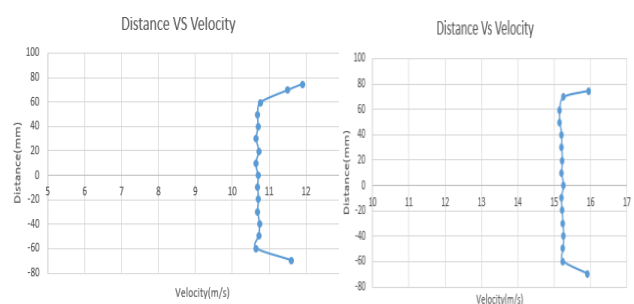


Figure07. 115 mm upstream non rotating(left) and

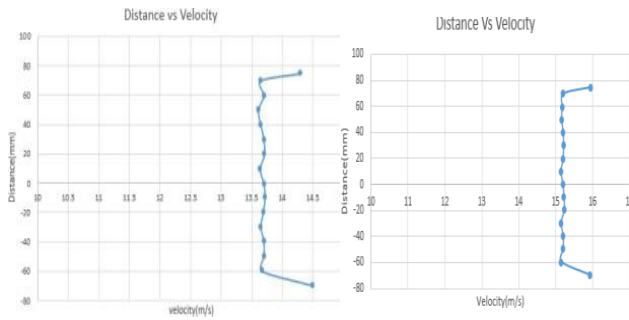


Figure08. 105 mm upstream non rotating(left) and rotating(right) cylinder

4.1.2 Upstream (8 m/s)

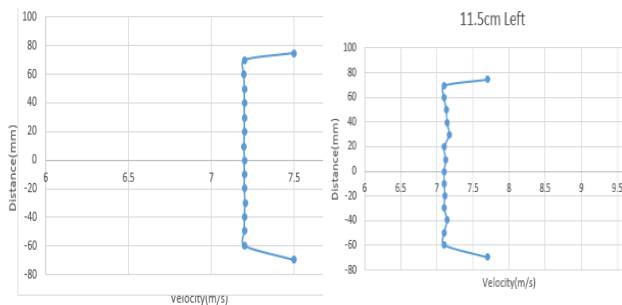


Figure09. 115 mm upstream non rotating(left) and rotating(right) cylinder

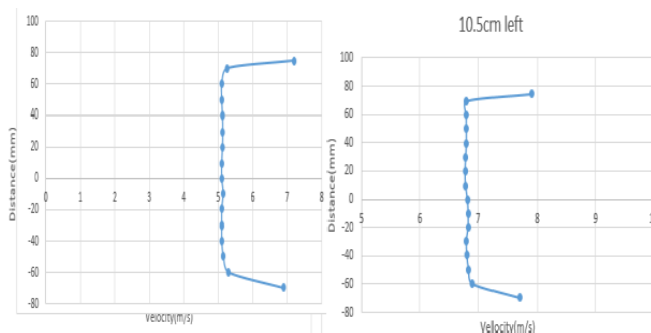


Figure10. 105 mm upstream non rotating(left) and rotating(right) cylinder

As the cylinder is rotating along the flow direction, the velocity of the upper portion of the cylinder increases but lower portion of the cylinder decreases. In lower portion of cylinder velocity decreases because cylinder motion direction is opposite to the flow direction.

4.2.1 Origin (16 m/s):

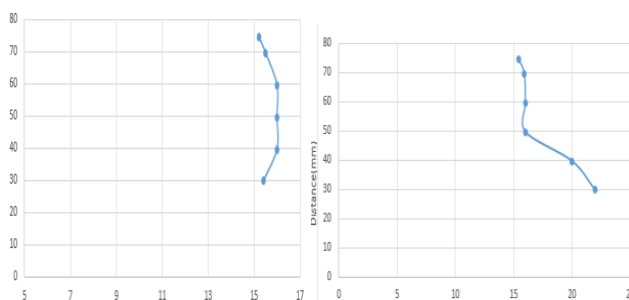


Figure11. Upper portion of cylinder with no

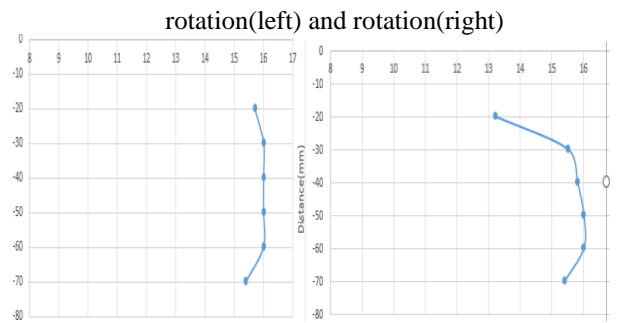


Figure12. Lower portion of cylinder with no rotation(left) and rotation(right)

4.2.2 Origin (8 m/s):

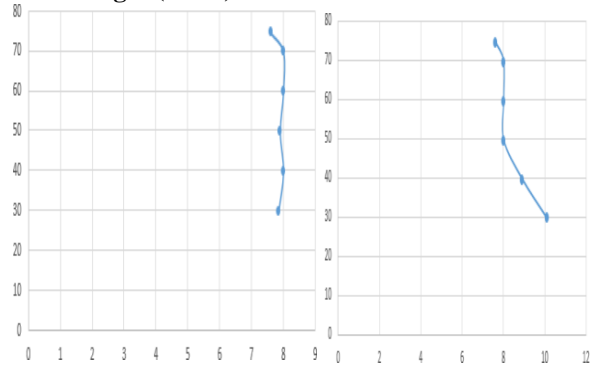


Figure13. Upper portion of cylinder with no rotation(left) and rotation(right)

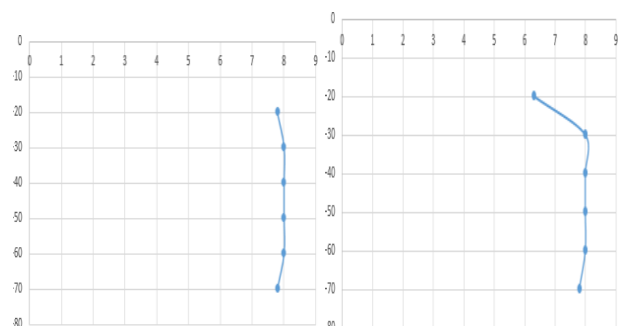


Figure14. Lower portion of cylinder with no rotation(left) and rotation(right)

In the downstream velocity direction changes frequently in a particular station. Direction of velocity changes for flow separation and wake region behind the cylinder. As cylinder is bluff body, wake region plays a significant role to influence the characteristics of flow. For energy transfer flow velocity changes in the station in a particular point.

4.3.1 Downstream (16 m/s):

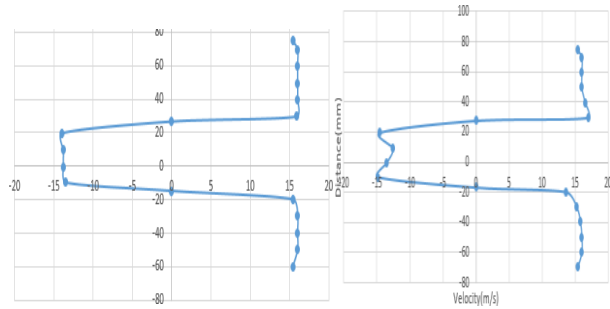


Figure15. 20 mm downstream non rotating(left) and rotating(right) cylinder

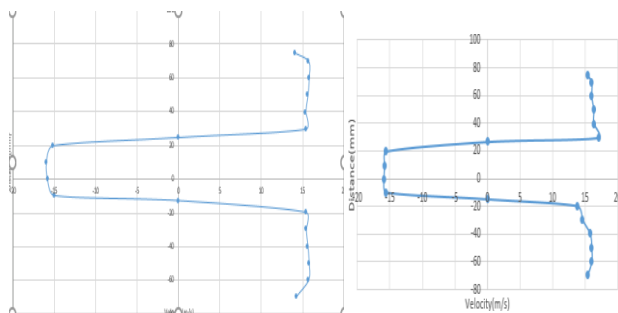


Figure16. 40 mm downstream non rotating(left) and rotating(right) cylinder

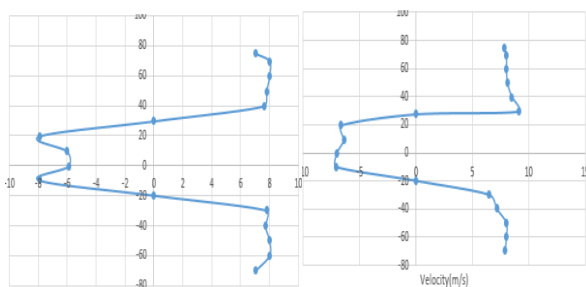


Figure17. 20 mm downstream non rotating(left) and rotating(right) cylinder

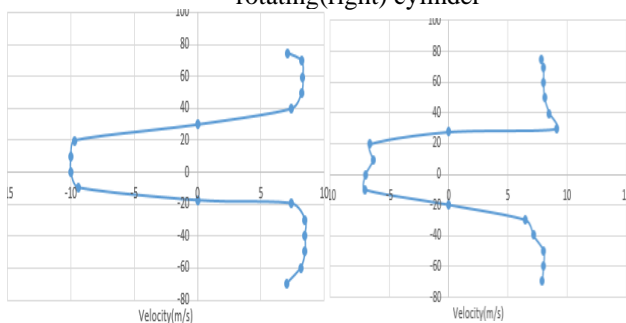


Figure18. 40 mm downstream non rotating(left) and rotating(right) cylinder

Flow Characteristics is determined by using total pressure and local pressure of yaw meter. Then MATLAB code is developed to visualize the flow characteristics.

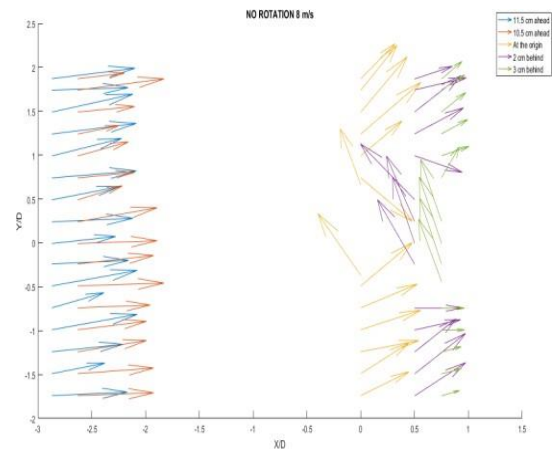


Figure19. 16 m/s no rotation

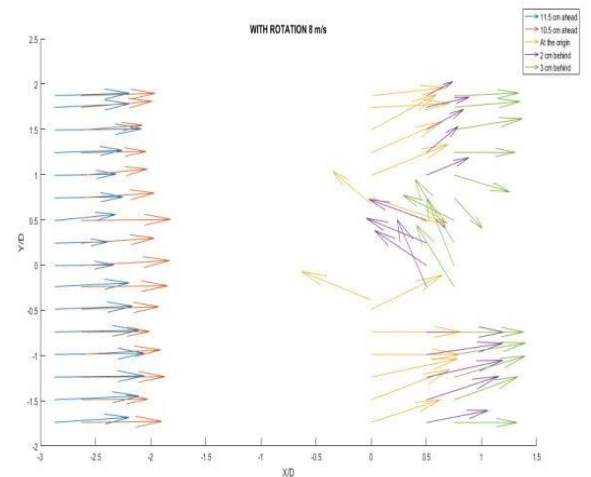


Figure20. 16 m/s with rotation

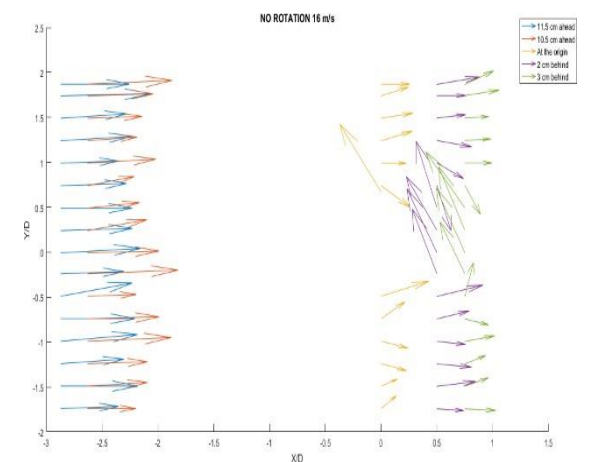


Figure21. 8 m/s no rotation

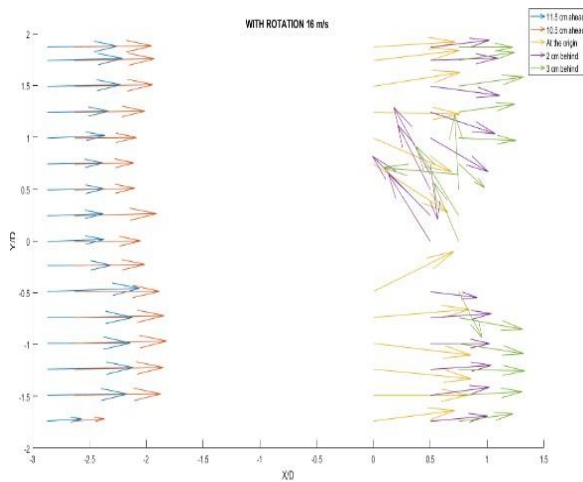


Figure22. 8 m/s with rotation

5. RECOMMENDATION

In the experiment, the static tube of the free stream should be kept attached to the wall while measuring local and total pressure. To control the vibration of the motor a well measured gear should be adjusted in the test section. DC power supply voltages should not drop while taking the measurements and the speed of the motor should not be less than 2000 rpm.

6. CONCLUSION

Flow characteristics and flow velocity is determined by using closed loop wind tunnel. How flow behaves through the bluff body is identified. In different stations flow velocity and angle is evaluated in two conditions for two Reynolds number. In first condition cylinder was in no-rotation and in second condition cylinder was in rotation. If cylinder is rotating towards the flow direction, then upper portion of cylinder velocity increases but lower portion decreases and vice versa. Flow characteristics is visualized by calculating the total and local pressures of the yaw meter.

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