4 Chapter EXPERIMENTAL PROGRAM

4.0 GENERAL

We have two different designs of the volute casing. One based on “Free Vortex Method” i.e. “Constant angular momentum” and other one is based on “Constant velocity method”. In both the volute casings the axial width of casing remains same and it is twice of impeller width. The main object of experiment is to analyze the flow phenomenon and the loss mechanism in the volute casing, which is based on ‘Free vortex Design’ and ‘Constant mean velocity’. It aims at designing a new volute casing and analyzes the flow phenomenon and loss mechanism in it. The flow is analyzed at various angular positions and at different radial positions along the axial width of casings. The experiment also aims at analyzing mismatching of the impeller with casing and its experimental effect. To measure 3-dimensional flow within the volute casings we have used five hole probe. Probes are calibrated as per standard. On completion of the analysis, a comparative analysis for both the designs has been done with the help of the flow parameters like stagnation pressure, static pressure, velocity, Pitch angle variation, Pressure recovery co-efficient and loss coefficient. It has been verified whether the volute geometry affects the flow from impeller or not.

Further, after getting the optimized results, volute casing was designed on evaluated method and experimental analysis was done. To get the accurate and stabilized reading of the experiment, instruments used for the measurement should be calibrated. The instruments should have minimum error with repeatability. Experimental program is performed in four steps such as 1) Fabrication of casing 2) Experiment setup 3) Instrumentation and 4) Operation of experiment.

4.1 FABRICATION OF VOLUTE CASING

Fabrication of volute casing is of acrylic sheet of 8mm thickness walls of both the side of Blower. The outer radial wall is made up of FRP. It is designed as per “Free Vortex Method” of which dimensions and line diagram as shown in figure: 4.1. Similarly, another volute casing is designed as per “Constant Mean Velocity” with the same material and dimensions and line diagram as shown in figure: 4.2.

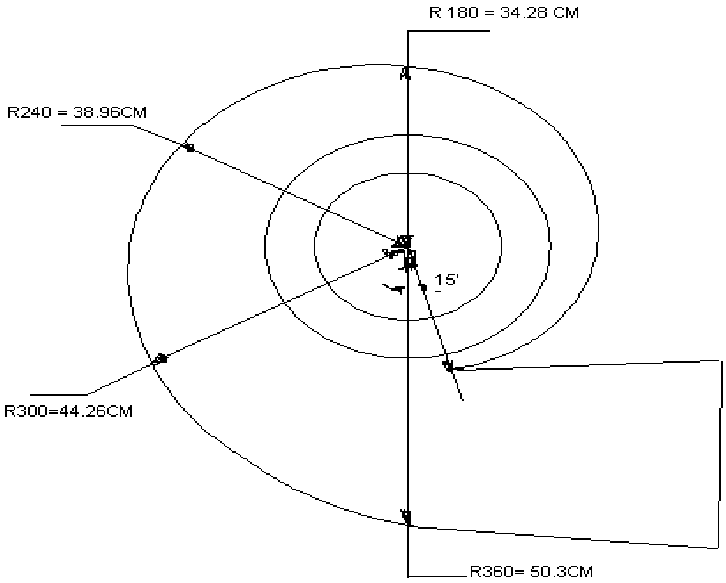

Figure: 4.1 Volute casing based on “ Free vortex design”

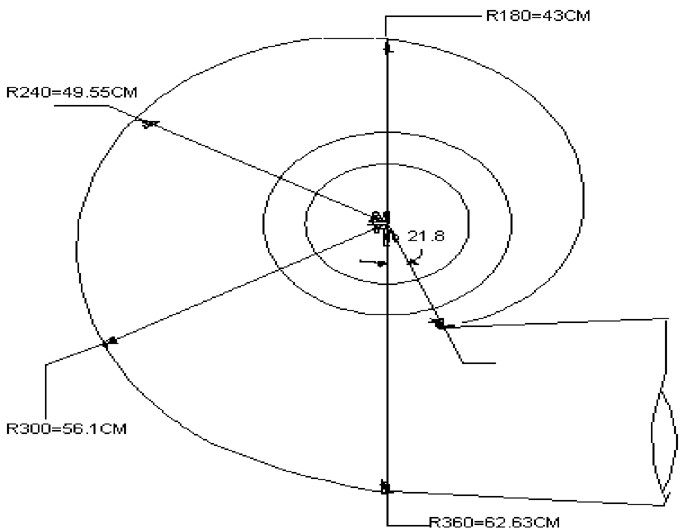

Figure: 4.2 Volute casing based on “Constant Velocity design”

Table:1 shows the cross sectional area at various angle of both volute. At the suction side of the volute, modification is made to give the strength and minimize the losses as shown in figure: 4.3. Taper portion is made on the suction side of the casing.

Volute Casing based on	A_{180} cm^2	A_{240} cm^2	A_{300} cm^2	A_{360} cm^2
Free Vortex Method	283.66	405.34	543.14	700.18
Constant Velocity Method	549.64	680.68	851	1020.76

Table: 1

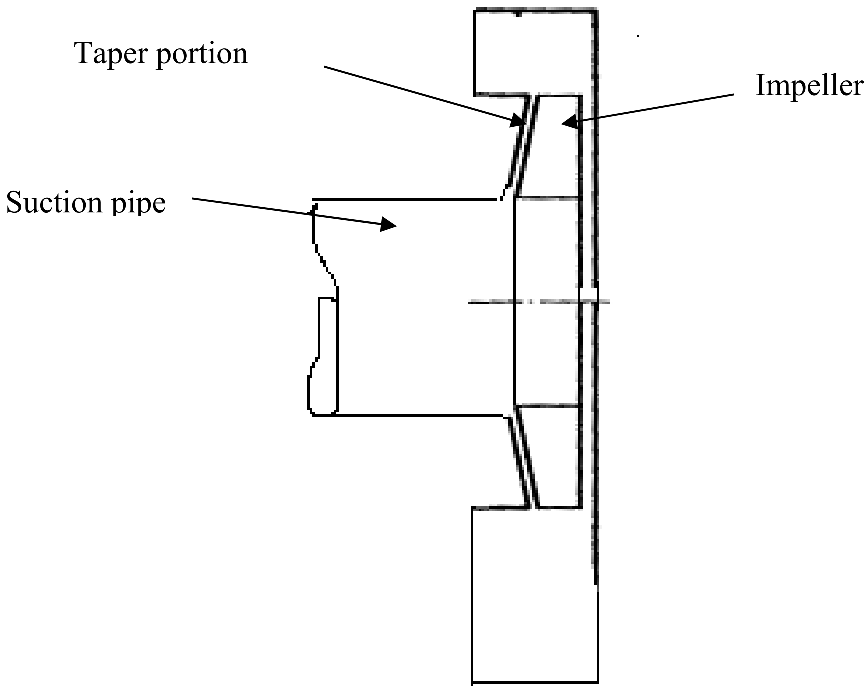

Figure: 4.3 Modified constant velocity casing.

After fabrication of volute casing is assembled on the motor as shown in figure: 4.4 and setup is made ready for measurement.

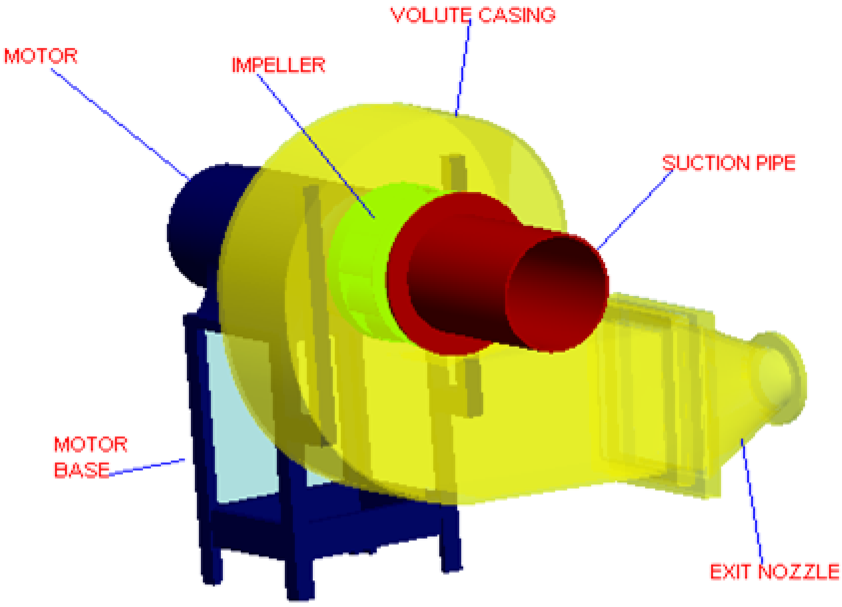

Figure: 4.4 setup unit

Further fabrication of volute casing based on optimized method as shown in figure: 4.5. It is fabricated from M.S sheet of 2mm thickness.

Figure: 4.5

For mismatching of casing and impeller for the experimental setup forward blade impeller is fabricated as shown in figure: 4.6. It is fabricated from 5mm ms sheet and balancing is done, to remove the whirling while rotation.

Figure: 4.6

4.2 EXPERIMENTAL SETUP

Experimental setup consists of blower unit, probe, probe holder, traversing mechanism and monometer. Blower unit consist of motor, casing and impeller as shown in figure: 4.4. This blower unit is fixed on the foundation. For the measurement of flow probe is used with the probe holder accompanying the circular disc on which angle is measured. To traverse the probe in volute casing from tongue to exit traversing mechanism is fabricated. This whole assembly is shown in figure: 4.7. Multi-tube Manometer is used to measure static and total pressure of the probe. It is kept inclined to magnify the readability and sensitivity.

1- Motor
2- Casing
3- Traversing Mechanism
4- Probe holder
5- Manometer

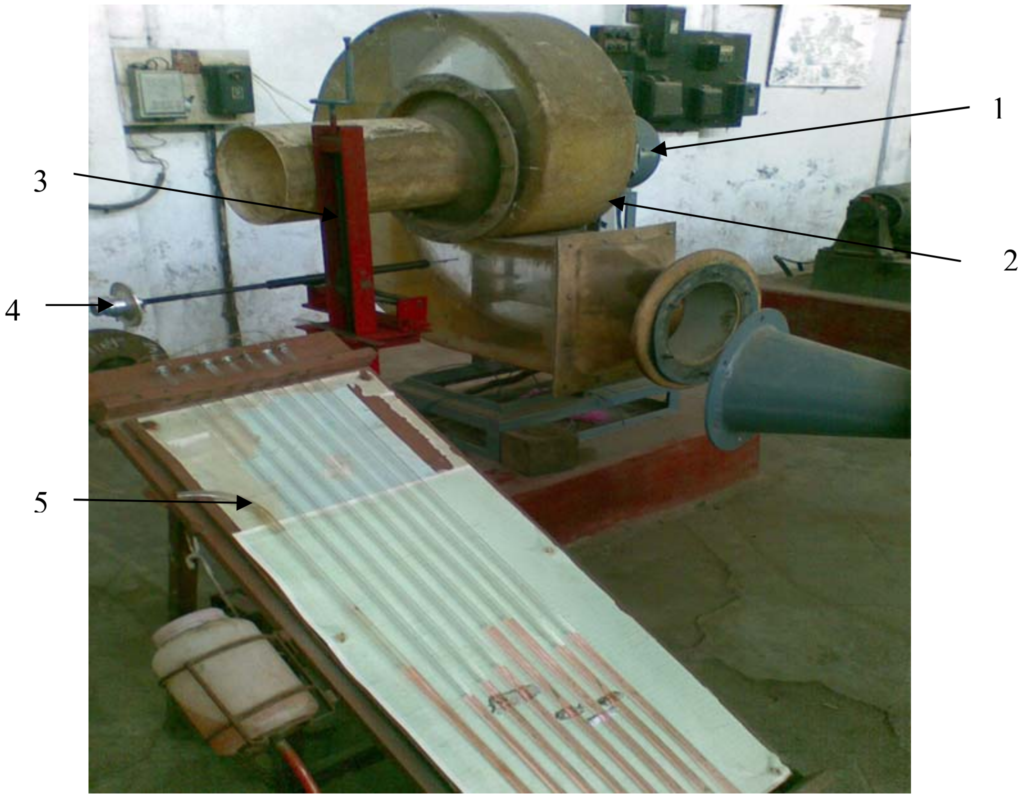

Figure: 4.7 Experimental setup

4.3 INSTRUMENTATION

During the experiment, the following flow parameters were measured in the flow through passage, i.e. velocity, stagnation pressure, static pressure, flow angle. The instruments used for measuring were the pitot-tube, pressure probe and manometer. A multi-limb inclined tube manometer used with experimental apparatus investigating air flow. Notice that the angle of inclination can be varied. This allows adjustment of the range and sensitivity to suit the pressure being measured. The accuracy of inclined tube manometers relies less on the skill of reader. They are more sensitive, but unless the inclined limb is relatively long they cannot be used over as wide a range of pressures. Inclined tube manometers are used where higher sensitivity than a U-tube manometer is required. The pressure (p) to be measured is to be compared with the height (h) of a liquid column. If the pressure exerted on the two surfaces of the so-called confined liquid is not the same, there is a deflection and consequently a difference in height. In accordance with the laws of physics, the effect of the liquid column on the pressure in the liquid is, in essence, only dependent on height (h) of the liquid column and on density of the liquid. Further influences are relatively low and known. For highly precise measurements, correction calculations can be made. Recalibration is not necessary. To get the repeatability and stability in the readings cleaning of water tubes and airtight connections of manometers are required. Details of manometer specification are shown in table:2. Changes in flow direction in volute casing are directly related to the work interchange. An accurate knowledge of the flow direction is therefore very important. Pressure probes that are sensitive to flow direction are used for this purpose. The probes are usually calibrated to determine the effect of their orientation to the flow on the measurement. To determine the effects of pitch and yaw, the test probe is rotated about its axes. The most common of the pressure sensitive direction probes are the cobra, the wedge, the five-hole and cylindrical probes. In all of these designs one or two pairs of symmetrically constructed pressure tapping are inclined with respect to the flow stream. When only one pair of pressure tapping is used, two-dimensional flow direction measurements are obtained; two pairs are used for three-dimensional measurements.

Manometer	Multi-tube with inclination
Range	1 - 500mm
Accuracy	± 1mm
Manometric fluid	water
Wetted part	Glass tube
Mounting	Wooden stand

Table: 2 Manometer Specifications

4.3.1 CONSTRUCTION OF FIVE HOLE PROBE

5-hole probe is used when we want to measure 3-D flow in casing. A more common five-hole probe is shown in figure: 4.8. In this, tube 2 & 4 and 1 & 2 gives static pressure and the middle tube give stagnation pressure. At the same time yaw angle obtained from the orientation and static pressure is average of other four tubes. The pitch angle, dynamic pressure and kinetic head obtained from equation.

As we assume 3-D flow in blower casing, we used five-hole probe. Probe made of S.S. material tube having diameter of 1 mm. Stem of probe having outer diameter of 6.5mm, thickness of 1 mm & length of 90cm. The flow direction can be found either by calibrating the body to find the variation of the pressure difference co-efficient with yaw angle or by rotating the body until the pressure difference is zero. The later one i.e. null displacement method is more accurate, although it is still wise to make a preliminary test in a stream of known direction to allow for any slight difference in hole position between the two sides.

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Figure: 4.8 Five Hole Probe.

The main disadvantage of null displacement method is that of the probe must be adjusted, which is particularly difficult if the probe is also to be traversed linearly across the flow or if both yaw angle and incidence angle are to be measured. The five-hole probe was calibrated in a suction subsonic wind tunnel having working section of 50cm X 60cm. It was calibrated for Zero setting and for dynamic pressure and pitch angle.

4.3.2 METHOD OF PROBE CALIBRATION

The ability to measure total and static pressure (hence velocity magnitude) and flow direction with a five-hole probe is well established. To remove the errors in manufacturing of probe and to quantify uncertainty of probe measurements results with repeatability in the reading calibration of probe is required.

Zero Setting Adjustment

The probe may not be perfectly symmetrical about the axis of the central tube due to unavoidable errors in fabrication. Therefore it must be adjusted so that when the probe is aligned with the yaw direction as indicated by the equalization of the pressure in the side tubes 2&4 as per figure: 4.8 the pointer reads zero on the circular scale. This was carried out in wind tunnel axis. The probe stem was rotated till pressure readings of the two tubes were equal. A circular probe stem disc having the hole, which matches with the pin provided in the recess of the probe holder was then rotated and soldered with the probe stem.

Calibration for Dynamic Pressure and Pitch Angle

The probe was calibrated against a standard pitot static tube for dynamic pressure and pitch angle. Pressure signals from the pitot static tube and all five tubes of the probe were read on an inclined multi-tube manometer. Tunnel flow velocity was varied in steps and for each velocity readings of true dynamic pressure from standard pitot tube and the pressure of each tube of the probe after null position of side tube were recorded. These were repeated for pitch angle which was varied from +25deg to –25deg in step of 5deg. The total pressure is then read directly from the center tube when the pressures of side tubes are equal.

Let,

P_o = Stagnation pressure of Pitot tube

P = Static pressure of Pitot tube

P_5 = Stagnation pressure measured by probe

P_{1-4}= Average static pressure of probe

$= (P_1 + P_2 + P_3 + P_4)/4$

q = Dynamic Head = $\frac{1}{2} \rho V^2$

α = Pitch angle

Then,

$q = \frac{1}{2} \rho V^2 = P_o - P = K (P_5 - P_{1-4})$ ……………(4.1)

$Po = P5 + f (\alpha) q$ ……………………………(4.2)

$\alpha = \{C (P3 - P4)/ (P5 - P1\text{-}4)\}$ ……………………(4.3)

From the above equation the constant K, C and f (α) were obtained which is used for the probe. The velocity is varying in the range 0 to 20 m/s. To hold the probe and measure the various angle in the flow inside the casing, mechanism is made.

4.3.3 CALIBRATION OF FIVE HOLE PROBE

The five-hole probe is calibrated in a suction subsonic wind tunnel having working section of 50cm X 60cm. It is calibrated for Zero setting and for dynamic pressure and pitch angle by adopting the following procedure.

The probe is calibrated against a standard pitot static tube for dynamic pressure and pitch angle. Pressure signals from the pitot static tube and all five tubes of the probe were read on an inclined multi-tube manometer. Tunnel flow velocity was varied in steps and for each velocity readings of true dynamic pressure from standard pitot tube and the pressure of each tube of the probe after null position of side tube were recorded. These were repeated for pitch angle which was varied from +25deg to –25deg. in step of 5deg. The total pressure is measured directly from the center tube, when the pressures of side tubes (tube 2 & 4) are equal. From the above equation the constant K, C and f (α) were obtained which is used for the probe. The velocity is varying in the range 0 to 20 m/s.

Calibration graph is shown in figure: 4.9 represent the graph of probe for dynamic head constant, for different pitch angle from –25 to +25 deg. The different values of True dynamic head and probe head were plotted. After plotting all the values, average trend line is derived, which give the value of Dynamic head constant K = 2.2029. The graph for Pitch angle constant represented in the figure: 4.10. In which at different pitch angle the value of $(P_2-P_4)/(P_5-P_{1-4})$ plotted and got the average value of pitch angle constant, which comes C = 10.423. The values of Total pressure constant derived from the graph represented in figure: 6.5. In which for different pitch angle the value of (Po- P5)/q plotted and got the parabolic type curve. By this graph we can see that there is no variation occurring in the value of actual total pressure and measured total pressure upto pitch angle 0 to –15 and 0 to +15. For pitch angle greater than 15 and less than –15, it is observed that variation in actual total pressure and measured total pressure is occurring. We get the average value of Total pressure constant f (α) = 0.12 if α>15 or α<-15 otherwise f (α) = 0.

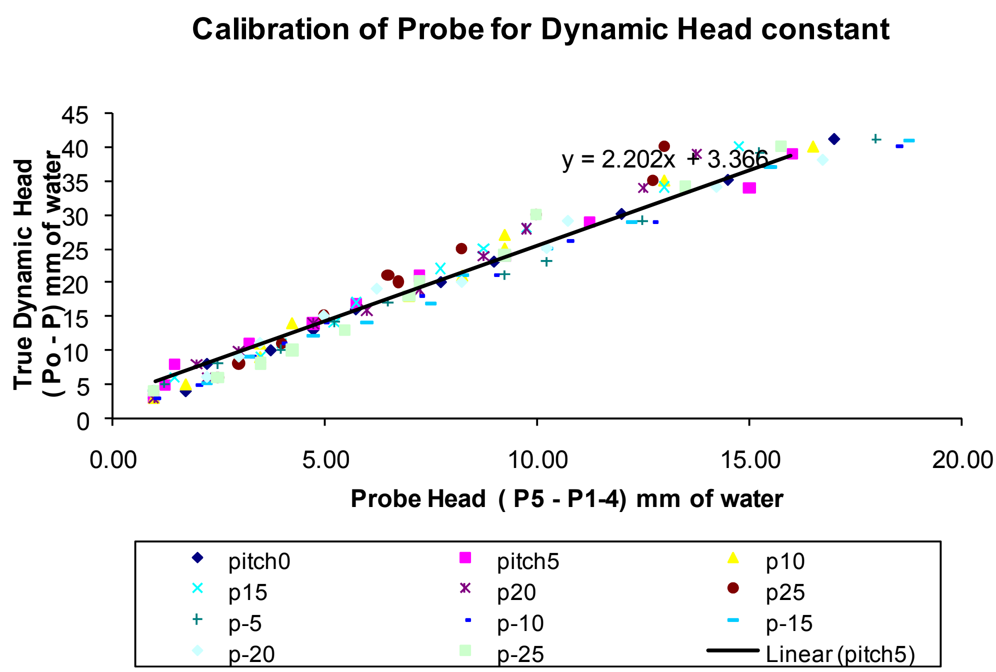


Figure: 4.9 Calibration of probe for Dynamic Head constant

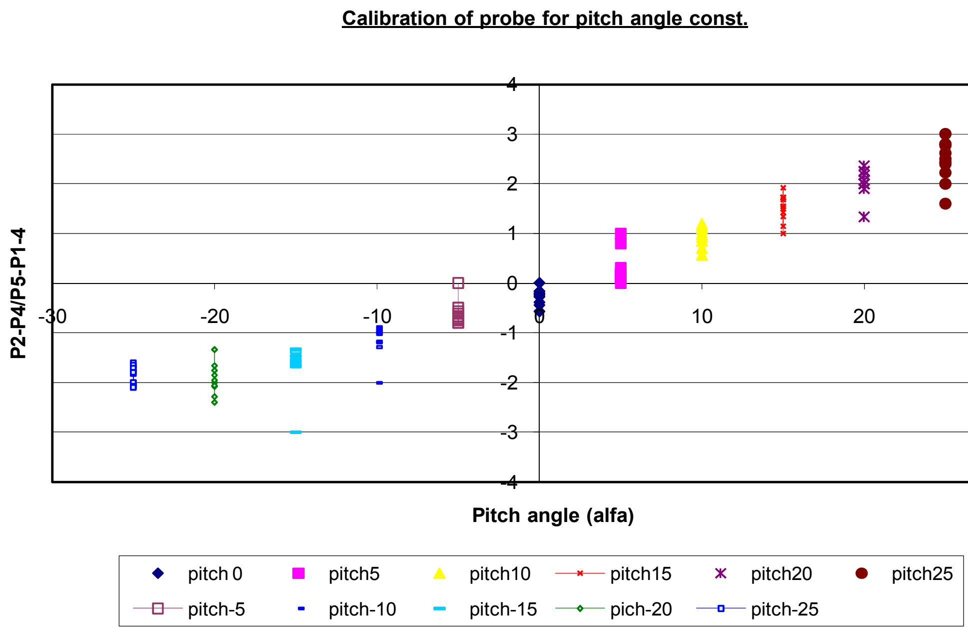


Figure: 4.10 Calibration of probe for Pitch angle constant

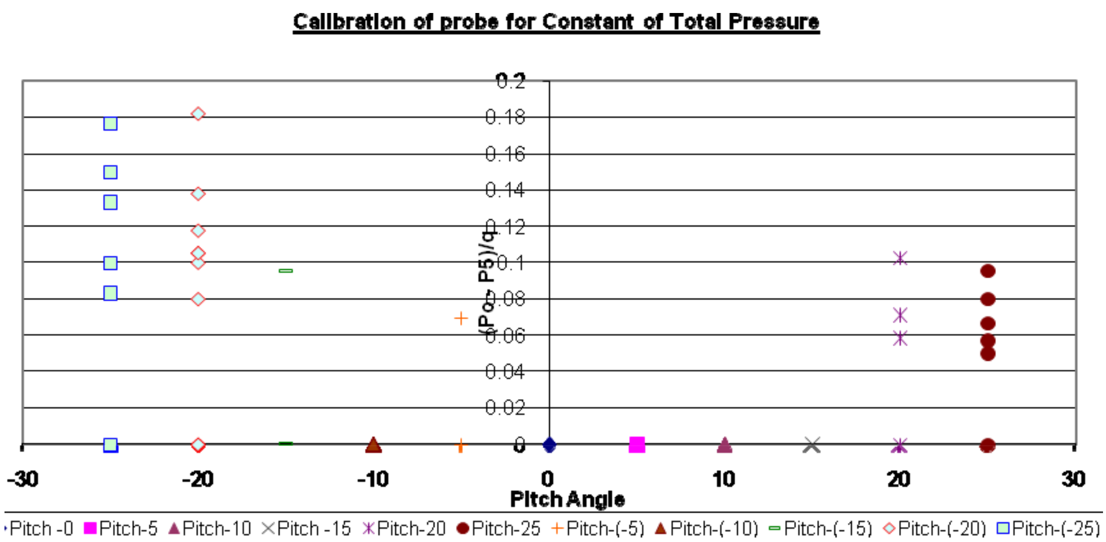


Figure:4.11 Calibration of probe for constant of total pressure

The experiment is carried out to know the flow condition within the volute based on Free Vortex design, Constant Mean Velocity, Modification in volute casing based on constant mean velocity, Mismatching of impeller in volute casing and optimized design of casing. Using a calibrated probe, observations were taken at different planes in the casing and observed flow parameters.

4.3.4 PROBE TRAVERSING MECHANISM

For survey in flow conditions probe should traverse in axial, vertical and horizontal direction along with a simultaneous Yaw movement in the flow passage. Therefore, probe was provided with three traversing mechanisms.

i) axial and Yaw movement.

ii) Horizontal movement.

iii) Vertical movement.

The probe holder shown in figure:4.12. The hollow lead screw with 14.5mm outer diameter, 7.0mm inner diameter and 65cm long made up of M.S. with matching nut. The lead screw accommodates 6.5mm diameter probe stem. The complete assembly is than passed through hollow cylinder of inner diameter 15mm. The matching nut of lead screw fixed on this cylinder in such a way that by rotation of the nut provides axial motion of the lead screw holding the probe. A longitudinal slot of 6mmX280mm was cut on the surface of hollow cylinder which provides the guidance for linear movement of probe.

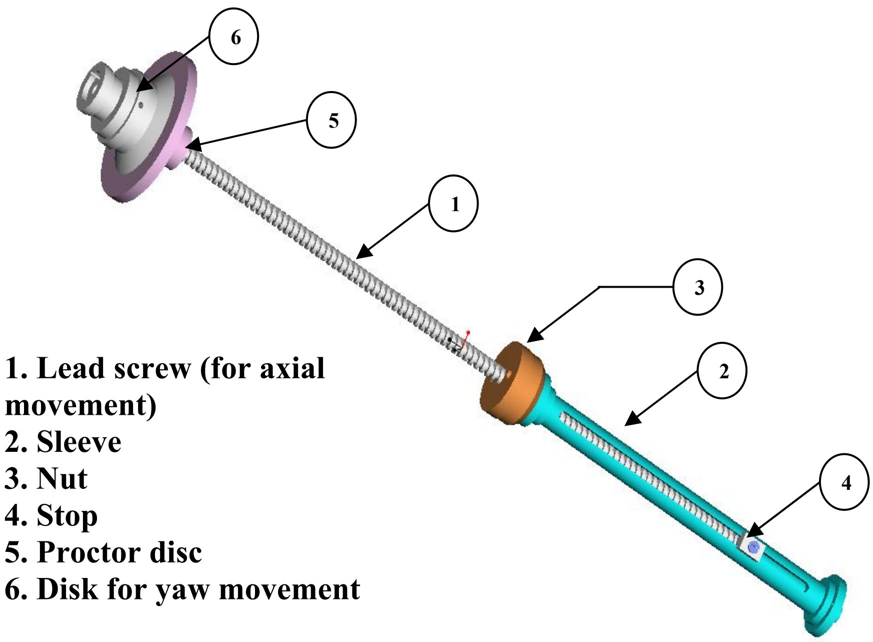


Figure: 4.12 Probe holder

The bore of the lead screw was made equal to the probe diameter. A disc carrying protector of 0° to 360° attached to one end of lead screw. The disc carrying protector had a cylindrical projected portion on upper end. This portion had a circular grove into which probe holding unit was screwed. Angular movement for the yawing was provided by probe holding unit by loosening the screw. The probe holding unit in its upper recess carried a locking pin which matched with the hole on the disc soldered on the probe stem adjusting zero position. A scale was fixed on the cylindrical header which measures the axial traverse with an accuracy of 1mm. the accuracy of the protector scale was 1°.

It consists of a ‘C’ channel section of 100mmX50mm, having the length of 139cm as shown in figure: 4.13. A vertical lead screw with matching nut and a guiding rod assembly was used for the vertical traversing of the whole probe holding assembly. The platform for the probe holding assembly was made of angle section of 50mm. The supporting palate (platform) carries the mechanism of the horizontal movement as shown in figure: 4.14, with the help of another lead screw. The up-down and horizontal position of the mechanism thus controlled the position of the probe radially and circumferentially.

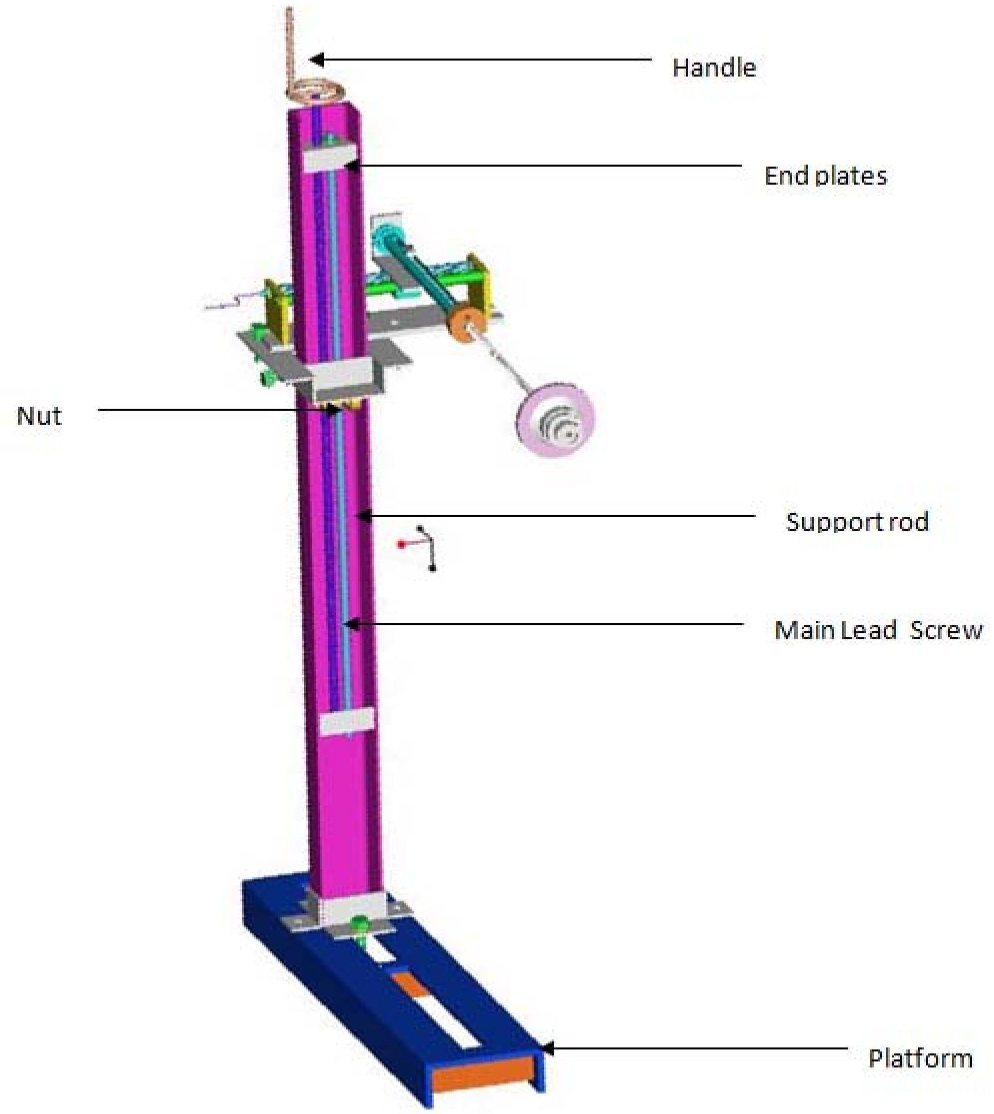


Figure: 4.13 Probe holder traversing mechanism

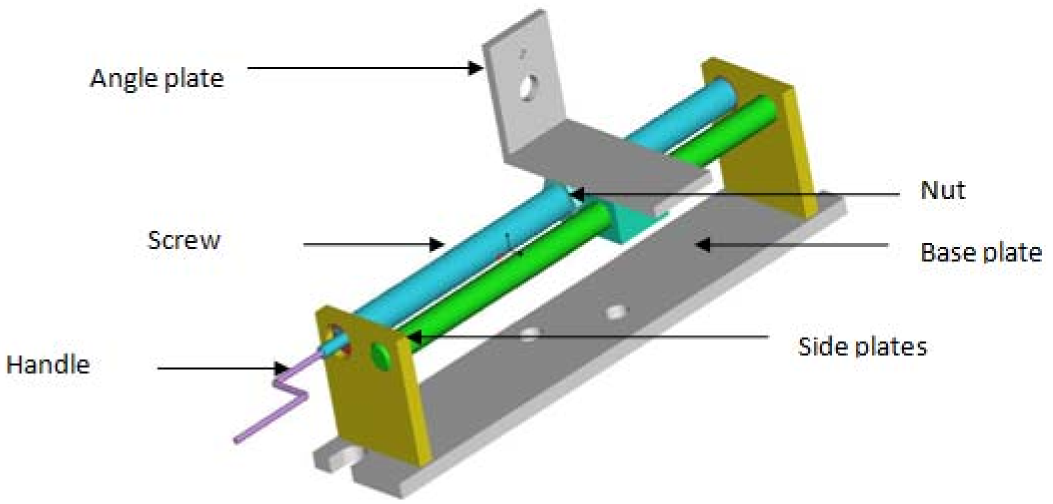
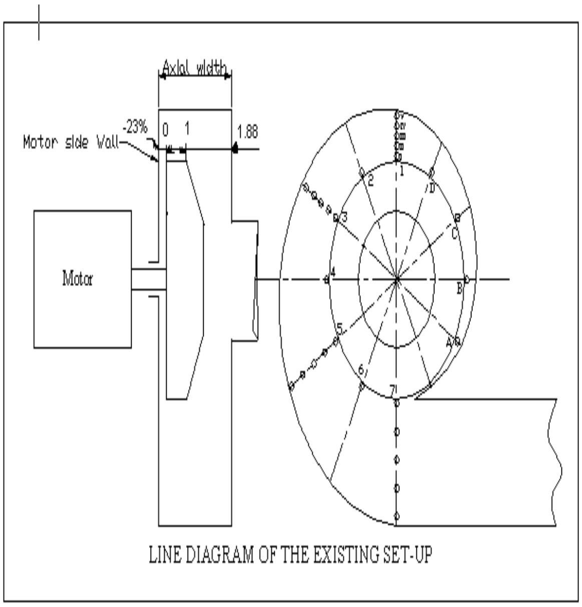


Figure: 4.14 Platform for probe holding

As the instrumentation is complete with various standards and as per the various mechanisms to hold and move the probe in the various locations inside the volute casing. Finally, setup is ready for the measurement of the flow inside the casing. This setup is able to measure the flow at any locations inside the casing.

4.4 PROCEDURE FOR MEASUREMENT OF FLOW

The flow analysis was carried out first for volute casing based on “Free Vortex Method” at four different radial- planes i.e. at 180deg., 240deg., 300deg. and 360deg. throughout the radial distance and from suction to exit of volute casing i.e. a - 7 as shown in figure:4.15(a) holes near the impeller. All these radial planes and also the planes A, B, C and D are 30° apart from each other. The readings were taken at five different radial positions from near to impeller to outer wall of volute casing; i.e. I, II, III, IV, V. They are equally placed in the radial direction. For each hole; i.e., for ‘0’, 33 readings are taken axially; each at 5mm distance from both the walls for first few readings and in between at a distance of 10mm, starting from motor side wall. Thus readings taken at total 27 holes of volute casing as per experimental setup shown in figure: 4.15(b). Same way the flow analysis was carried out for volute casing based on “Constant Velocity Method” as shown in figure: 4.16(a) & 4.16(b). Total 1900 readings were taken for analysis of the flow in the volute casings. During the experiment atmospheric temperature and pressure was recorded at each half an hour interval for calculation of the density of air. Same method is applied for mismatching of impeller in volute casing and optimized design based volute casing as shown in figure: 4.17(a) & (b). At starting of any new readings probe has to clean and connections are to be checked, so that there is no leakage. Manometer water is to be change as per requirement. Zero setting of manometer is to check at each sets of reading, as this will lead to error in reading.



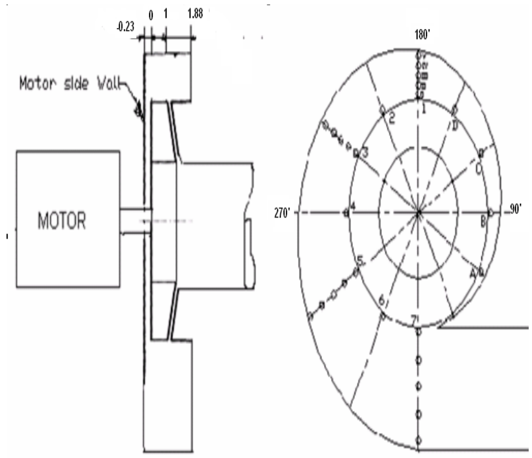


Figure:4.15(a)

Figure:4.16(a)

Figure:4.15(b)

Figure:4.16(b)

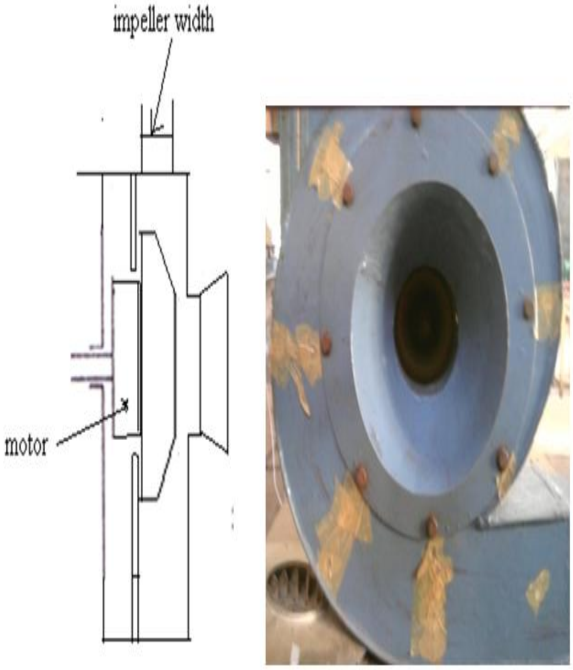


Figure:4.17(a)

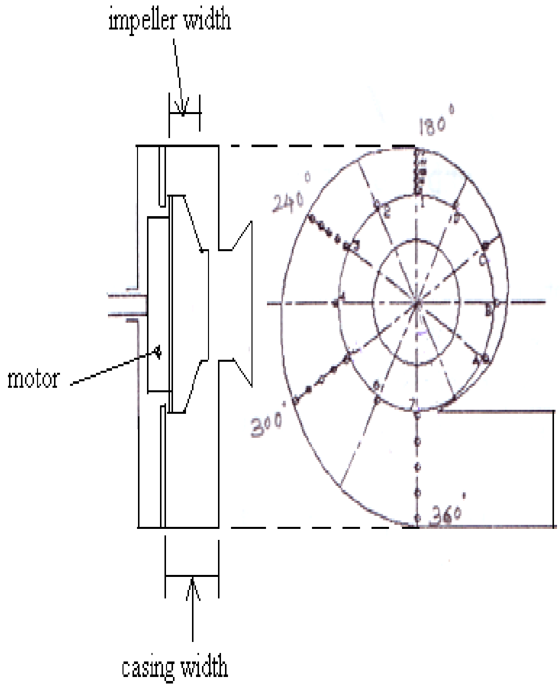


Figure: 4.17(b)

4.5 EXPERIMENTAL DILEMMA

- Problem: Motor shaft of experimental rig was shifted during the experiment, due to that the impeller fouled to the suction pipe of volute casing.
  Reason: The tightening nuts of motor base became loose at its base.
  The above problem was rectified by doing proper alignment of motor shaft and tightening the nuts of motor base.
- Problem: Probe had got slightly bend.
  Reason: Vibration in the experimental set-up.
  The solution to this was made by provided sufficient strength and guide for sliding in the hole.
- Problem: Probe reading value was not changing.
  Reason: Tube is clog with dust.
  The solution was done for every new reading, probe is to be clean.

- Problem: probe was vibrating.
  Reason: Due to vibration of motor.
  The solution was done by providing packing to the motor and support of the casing was separated from the motor base. So that vibration was not transfer.

Following Precautionary measure were taken:

- All instruments including blower aligned properly.
- Probe was calibrated separately for each setup.
- Vibration level of the experimental set-up was broke down by firmly tightening the bolts of motor base.
- Leakage of air from the volute casing was prevented by tightening the bolts of casing.
- Joints of the probe tube and manometer tube were checked frequently. so that leakage is not there.

4.6 Summary

Experimental setup for various volute casing based on design of constant mean velocity and free vortex method is fabricated in FRP material and optimized method is fabricated in ms sheet. For measurement of flow five hole probe is used and traversing mechanism is fabricated for maintaining the stability of the readings. Probe is calibrated to get the correction factors for pressure and flow angle. Manometer is used with more accuracy and sensitivity to get readable values of the readings. Complete experimental setup was prepared considering various aspects of the readings. Further, to validate it with theoretically analysis CFD is required. In which we can get the clear view of various region in volute casing. As experimental works take much time in maintaining the accuracy and taking the number of readings at various locations in the casing. It is economical and time saving tool for investigation of flow in volute casing of blower.