International Journal of Research and Publication
Issue 5:Vol. 2 (May, 2023)

Design and Implementation of vortecis for student Laboratory experiement in China.

Jin Qi

Institute of Mechanics, Hohai University, China.

Abstract

This design, construction and Test on Vortex apparatus was to demonstrate obtained both free and forced vortices for Student Laboratory experiment. The apparatus was designed and constructed using transparent Perspex approximately 380mm diameter by 180mm deep. Perforated cylinder constructed from transparent Perspex, approximately 286mm diameter by 180mm deep. Motor with low voltage for safety) and equipped with a long connection cable, normally 3 meters. Roller to rubber bushing rotating axially on an electric motor spindle rubbing counter clockwise was used on the extended edge of the cylindrical Perspex. 2 lengths of mild steel square metal of 1 9ft/1 x 1 inch thickness were used for construction of the tables. 4 lengths of 750mm were cut and joined across by welding it with 2 lengths of 650mm and 550mm respectively. The setting up was done carefully using a square – meter for the Vortex construction to be completed.

Keywords: Apparatus, Cylinder, Vortex, Motor, Technology, Construction

Introduction

The Vortex apparatus is laboratory equipment used for teaching specifically in the area of fluid mechanics (dynamics). Like all laboratory equipment, its primary objective is to enable students compare the physical characteristics of real fluid with the mathematical models and assumptions made in theory. In order words, it enables practical testing and demonstration of theoretical works.

Fluid Flow Features

When the vessel is rotated about its vertical axis 0 – 0, It will be noticed that the liquid surface, in the vessel, no longer remains level. But it has depressed down at the axis of its rotation and has risen up near the wall of the vessel on all sides.

If the vessel is revolved with an increased angular velocity, it will be noticed that the liquid has depressed down to a greater extent at its axis of rotation, and at the same time, it has also risen up to a greater height near the wall of the vessel.

If we go on increasing the velocity of rotation, a stage will come when the liquid starts spilling out of the vessel. If we still go on increasing the velocity the depression of liquid at its axis of rotation, will also go on increasing, till the axial depth of the liquid is zero.

Free Vortex

It is a type of flow, in which the liquid particles described circular paths, about a fixed vertical axis, without any external force acting on the particles. The common example of a free vortex occurs when the water escapes through the hole in the bottom of a wash basin.

A Transparent cylindrical vessel is rotated about its vertical axis by a low voltage, variable speed motor. Speed is varied by an electrical control unit which is mounted externally from the main apparatus and on a bench. When a fixed amount of water is contained in the rotating vessel, it will rotate as if it were a solid body and a forced vortex is formed.

A free vortex may be produced by passing a continuous flow of water through the apparatus. For this a transparent perforated cylinder is placed inside the main vessel to form annulus into which an external water supply is directed. During rotation, this water passes through the large number of short tube perforations and spirals slowly, inwards to a small hole in the centre of the base of the vessel. The surface falls rapidly towards the centre and an air core is produced.

Design of the Vortex

Determination Of The Power Of The Pump

Pump as we all know is a machine driven mechanically to work on the fluid system and thereby transform mechanical energy into fluid energy. From various considerations, the power of the pump that will transfer water from the reservoir to the transparent cylindrical vessel is to be calculated.

Hence the average speed of the motor is

W = 2nN/60…………………. (3.1)

W = 2n(700) / 60

= 733 rad/sec.

From the various considerations of the speed of the motor that will not throw or splash water was selected to be Therefore, to calculate power required by the pump, we have:

T = 238.67xlO3xnxSxd2 / 2.38

T = 283.67x103x5x103x625x106 / 2.83

T = 2.78 / 2.83

T = O.98KN or

T = 984.07N

Methodology

Construction Procedures:

In the construction of a vortex apparatus, we tried to bring about a new design that would rotate the Perspex cylindrical vessel without much wobbling or vibration. We were considering something less bulky as the pulley and belt mechanism.

It has been known that roller to roller mechanism gives less room for wobbling and vibration because of its close contact. We now thought of roller to rubber bushing rotating axially on an electric motor spindle rubbing counter clockwise on the extended edge of the cylindrical Perspex. This give minimum friction considering the speed and the size of area of contact.

a) **Fabrication**

Step 1

We started the fabrication from the Perspex cylinder. From the drawing, dimensions of the total area of Perspex sheet required was calculated and marked out carefully. The cutting was done using a saw and a specialized cutting knife. The marked out was done easily of the brown paper wrapping t comes with. Now a sheet of metal of length 760mm and width 360mm ad a second sheet was 572mm in length with 360mm in width. The second sheet is perforated with a manual drill diagonally spaced and folded, later was welded. The first sheet metal was folded in cylindrical form to form a cylinder of 380mm x 180mm. And the outer cylinder which was folded is 286mm x 180mm. The Perspex sheet was later folded under heat to form the cylindrical vessel. Both cylinders were then held down concentrically of the first plate with special glue. Before this, holes for bolts pass through were drilled eccentrically 12mm to the edge and equidistance to each other on the plates. Also, a whole of 1 2.5mm was made to pass the centre of both plates. This was done using a special long arm saw. On the second plate, it was drilled 3 holes that would aid the attachment of a sitting moon on the next stage.

Step 2

A sitting moon was welded centrally to a Boll bearing of diameter and a pipe of 200mm mild steel was welded to the inner ring of the pipe. The sitting moon already has three holes for attachment of bolts. This would form the rotor spindle for the vortex cylinders.

Step 3

2 lengths of mild steel square metal of 1 9ft/1 x 1 inch thickness were required for construction of the tables 4 lengths of 750mm were cut and joined across by welding it with 2 lengths of 650mm and 550mm respectively. The setting up was done carefully using a square - meter. Finally a mild steel sheet of gauge 1 8 as placed on the stand and welded to form a table tope.

The center upon which the rotor/sitting moon would be inserted was marked-out. Also the position where the bracket/holders of an electric motor carrying a rubber bushen out top as its spindle was marked out. Two slots for its bolts to pass were made also

Step 4

The bracket for the motor was made from a thick mild steel sheet of gauge 16. A rectangle was cut and formed into a u-channel. Another strip was welded across, holding the two ends of the u-shape internally. At the top outer end, a slot was made for attaching the motor with bolt. While at the bottom 2 holes were drilled to attach holder to the table with bolts.

Step 5

On completion of the bracket, a rectangular plate of 1 00mm x 1 50mm was cut and rectangular openings were made on it with chisel and hammer to take a switch and a motor regulator. This will serve as the control panel.

Step 6

On the base of the stand a plate was welded across as a support for the reservoir just at the cross members, a square metal was welded across the half the rectangular area and another are at left. One section of the divided area forming a 'T'. Also plates were cut and welded round the square metal around the edges. This was welded at the outer edge of the base at the same height and supported by at an angle by a square metal. This was welded from the outer edge to the wall of the legs of the stand. This would serve as the pump stand/base.

The reservoir consists a very deep u-shaped plastic container. A hole at the base was made to insert a pipe socket. The pipe from this would connect to the pump. Another pipe would go vertically upwards to the top of the Vortex cylinder for supply of liquid. These pipes were forced in and glued with PVC glue.

Step 7

The measuring stand was made by cutting 2 equal lengths of angle iron of 420mm and another 520 x 1/2 H thickness. They are welded to form a u-shape. It was welded exactly above the rotor making its height give enough room for the vortex cylinder. Calibration was made on a strip of paper with Autocard and laminated and pasted at the top and left hands side of the vertical meaning stand. The pointer hat measures the radius of the vortex is made by brazing a bicycle spoke onto a metal peg.

Step 8

Finishing torches were carried out on the apparatus like filings with grinding machine. Cleaning and smoothening with putty sealants and sand papering. Finally painting was done with a spraying machine before installation commences.

Material Selection

The task of selecting a material in engineering involves the detailed and careful consideration of all the available materials and limitation they imposed on the design. The number of engineering materials has made selection a formidable affair; however, the range of properties from which to choose has made possible entirely new form of design operating under more severe conditions.

In our design, we have at the back of our mind that cost is a priority since we can achieve our desired goal and an optimum design. The materials selected in our design were based on mostly on availability of materials an cost. Optimum materials like copper and alloy of aluminum are very expensive and may prove hard to be worked on, for instance, it is not easily welded.

With all these, we chose carbon steel as the basic metal both for the sheets and the square pipe. And the plastic glass (Perspex) for the construction of the cylindrical vessel. These are the run down.

Cylindrical Vessel -

Perspex

Rotor - Carbon Steel

Sitting Moon - Alloy steel

Bench - Carbon Steel (gauge 1 6)

Bracket - Carbon Steel

Reservoir - PVC (plastic)

Plastic Pipes and Socket PVC

Motor - Mild Steel (with some cast iron components)

Bearing - Alloy Steel

Material Properties

Every material has properties on which the designer depends on his selection. The properties are like

1) Strength under tensile, compressive load and dynamic load.

2) Stiffness against deformation under static loads

3) Behavior under dynamic loads - vibration

4) Sliding properties in the case of bearing

5) Ability to moulded in case of perspex.

Properties of Alloy Steel

Alloy steels are those steels whose properties are greatly modified by the presence of alloying elements in amounts substantially greater than are found in plain carbon steels. It's advantages are greater resistance to wear, fatigue, creep and corrosion, greater toughness, greater strength with little sacrifice in ductility.

Effects of Alloying Element on the Bearing

Elements	Effects

Chromium (Cr)	Increases hardenability (0.5 - 2%)
	Increases resistance abrasion and wear (4 - 8%)
Nickel (Ni)	Increases toughness and impact strength (2 - 5%)
	Improves corrosion resistance (12-20%)
Titanium (Ti)	Reduces martenstic hardness in chromium steel.

Increases strength while retaining ductility (0.15%)

Properties of Carbon Steel

The particular type of carbon steel chosen for our design is medium carbon steel because it provides necessary strength and hardness. The carbon content is (0.01 - 0.10%). May be heat treated to provide a wide range of properties. They can be used for forging. Readily weldable but require more care than low carbon steel.

Mechanical Properties of Carbon Steel (pp. 6 - 20 of Mark's Standard Handbook for Mechanical Engineers)

ASTM Designation - ASTM A 2 & 3 Grade A

Thickness (mm) - All Thickness

Yield Point (Mpa) - 165

Tensile strength (Mpa) - 310

Elongation in - 28

<200mm) mm

Suitable for Welding? - Yes

Properties of the Perspex Glass

The selection of Perspex glass was because it has the ability to being molded, it is transparence, weightless; it is also excellent corrosion resistance and also resistance to ultraviolet exposure.

Mechanical Properties of a Perspex Glass (pp. 6 203 of Mark's Standard Handbook for Mechanical Engineers)

Fibre diameter (,um) - 8- 14

Fibre density (g/cm3) - 2.54

Tensile Strength (Gpa) - 3.43

Tensile Modules (Gpa) - 72.4

Factors That Influence Selection Of Material

In selection of materials for design, many factors like quantity required, environmental factors, nature of loading In analysis

1. Quantity Required

Quite often, the quantity required of a component will affect the selection of the material to use. This is because the quantity required will influence the method and cost of production. Example, in the construction of a vortex apparatus, it is seen that in selection alloy steel like stainless, the quantity required will be reduced due to cost of material and the method of production will be effected.

2. Environmental Factors

The environment in which the components operates determines the material from which it will be made.

Environment could involve temperature effects or chemical effects. Temperature effect is quite often considered under creep and oxidation. Chemical effects are due to atmosphere in the component it is operating. Such effects are considered under corrosion.

3. Nature of Loading

In engineering practice, loading varies with time, and in some cases the variation may not be uniform, under such conditions. The component may fail under fatique, incremental collapse, or low stress brittle fracture. For such conditions, the material required must be of acceptable toughness.

Other factors include, ability to resist wear, the type of heat treatment and reliability of product.

Result

From the data obtained from the standard equipment of Vortex apparatus, it is seen that the data obtained from designed equipment is favorable, but slight variations: Those variations are as a results of non-availability of necessary materials that are needed for the construction, and finally unable to select a specified speed for the motor and other parameters.

From the plotted graphs, the graphs given in the Tech Equipment Journal, it is seen that the graph plotted from the standard equipment is also favorable to the plotted graph from the design equipment only that the graphs are more slope than the standard equipment, it varies a result of variation in the speed of the motor. In summary, this paper concludes that the principles of vortex apparatus were achieved.

Conclusion

The operation of the vortex apparatus, as well as the principle guiding it were made easy, even to the extent that a lay man can operate and appreciate it. The connection of the variable motor switch was made tight to ensure that electrocution is eliminated, or rather reduced. The pump is connected in parallel to the motor, so that the apparatus/set up will have one power source, but separate switches. For the maintenance of the apparatus, provisions were made so that the apparatus can undergo maintenance whenever need. Some of these provisions made are as follows:

- The use of nuts and bolts in fastening the electric water p urn p.

Recommendation

It is recommended more research that will result to discoveries of some new projects should be carried out.

This study also recommends that fully equipped laboratory and workshops should be assured for technocrats and institutions of Technology by government, so that they can have easy assess to some of the machines which are needed for the construction. This will limit the cost of construction and transportation.

Technologist should be recruited into workshops.

The school authority should try as much as possible to issue out or approve student's project at the first week of the beginning final year, this will help the students to have enough time for the project and also standardize their project.

Finally, federal and state government should try and fund student's project so that more design could be achieved.