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Reynolds Horizontal and Vertical Test Bench from an Educational Point of View

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ABSTRACT

The Reynolds Number Test Bench is a self-contained device that uses water to allow students to study laminar, turbulent flow regimes, and transition conditions. The vertical test bench does not allow a large number of students to see the experiment clearly, it only takes two people in front of the device to block the view of the rest of the students and this causes a problem. The idea of this work is to build a horizontal test bed that allows students to see the experience clearly and easily. The results obtained from our horizontal device are the same as that of the vertical bench.

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1. INTRODUCTION

The patience and the desire to build prototypes of the different systems can be found in research laboratories and as well as in the laboratories of amateurs. This construction does not stop progressing sometimes by necessity and other times by improvement (Golnabi & Asadpour, 2007; Li et al., 2019; Khechekhouché et al., 2019). The history of the Reynolds number is written in an annual of fluid mechanics (Rott, 1990). A study has shown that fluid particles travel in parallel layers in laminar flow in pipes without interfering with each other. The distribution of the speed of the fluid in the pipe is not homogeneous. The fluid is broken by the pressure of the pipe in the peripheral field and flows more slowly than the axis of the pipe. The decrease in pressure is proportional to the average speed of the fluid. The multiple layers of fluid bubble and exchange energy with each other is in a turbulent flow. Non-stationary movements characterize the type of flow produced. In addition, but only in the peripheral region of the pipe, a laminar boundary layer remains. The speed distribution is almost constant over a large part of the pipe section. The pressure drop is equal to that of laminar flow (Fontane, 2005; Brunetière, 2010). When the Reynolds number is greater than 3000, the flow regime in the pipe is turbulent flow; the friction factor depends on the Reynolds number but also on the relative roughness and of course other factors. Our manuscript shows that the Reynolds vertical test bench (H 215) does not allow a large number of students to see the experience correctly and this causes a real problem in educational laboratories, on the other hand, the horizontal test bench designed in the laboratory, allows the same number of students to see all stages of the experiment clearly.

2. METHODS

2.1. Reynolds number device

In this experiment a blue dye injected into a laminar flow will form a simple and well defined line. Due to molecular diffusion, it cannot mix with water. When the flow in the pipe is turbulent, the dye can easily mix with water. Between laminar and turbulent flow, there is also a transition stage in which the flow of dye wanders and displays occasional bursts of mixing, followed by a more laminar stage. We measure the Reynolds Re number in the pipes crossed by a flow from the inside diameter of the pipe D , the average fluid V speed, and the viscosity kinematics ν (see equation 1).

$$Re = \frac{V.D}{\nu} \quad (1)$$

The distinction between laminar flow and turbulent flow can be determined using the Reynolds Re number. The Reynolds number is a dimensionless number. When the Reynolds number is less than 2300, it is called laminar flow. From a Reynolds number equal to 2300, we speak of turbulent flow. Flows with the same Reynolds number have similar behaviour.

2.2. Construction of horizontal Reynolds device

Figure 1 shows the vertical test bench H-125 (VDR) which is located at the educational laboratory at the University of El Oued-Algeria. **Figure 2** shows the horizontal test bench (HRD) designed in the same laboratory. Both tests include a vertical head tank which provides a constant head of water, ie a constant head. Small filling balls are distributed evenly inside the tank to calm the flow of water entering the tube. The flow through this tube is controlled by a regulating valve. The flow velocity can therefore be determined to calculate the Reynolds

number. A blue dye reservoir is mounted on the head reservoir, from which the dye can be launched into the water to allow observation of flow conditions.

2.3. Comparison between VRD and HRD

Figure 3 shows the use of the apparatus by a teacher and a group of students. From the figure we note that only one student can clearly see the experiment, the other students cannot even see the test bench (VRD). **Figure 4** shows the use of the apparatus by a teacher and a group of students. We note that all the students can clearly see the progress of the experiment and that they can also easily adjust the water flow through the control valve. This gives (HRD) a big advantage over (VRD).



Figure 1. Vertical Reynolds Device H215 (VRD). Figure was adopted from [Rott \(1990\)](#).

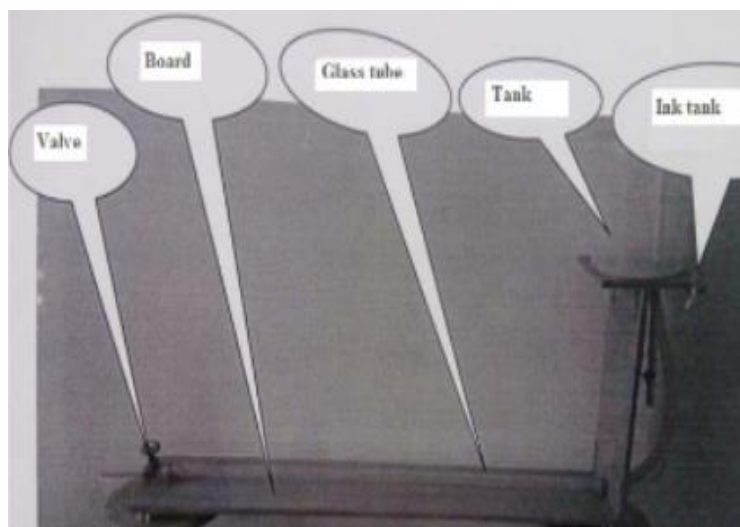


Figure 2. Horizontal Reynolds Device (HRD)

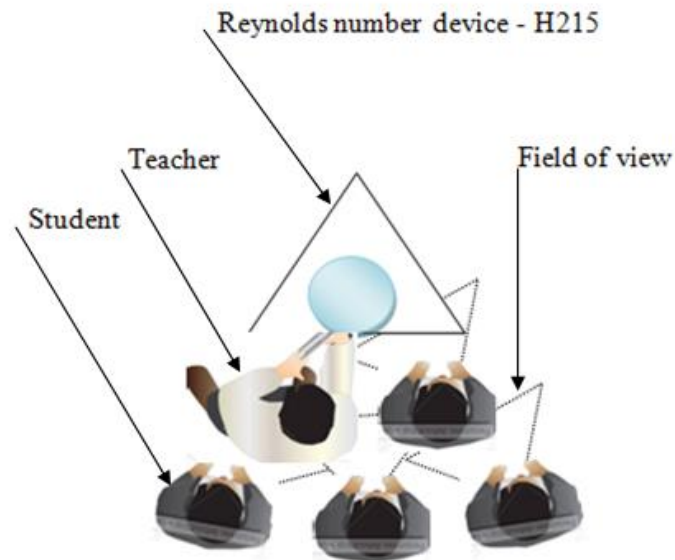


Figure 3. Vision field of students with VRD

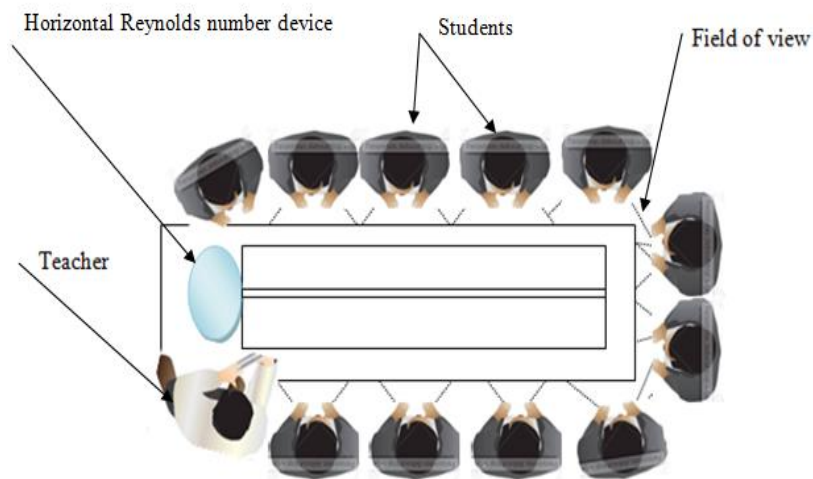


Figure 4. Vision field of students with HRD

3. RESULTS AND DISCUSSION

3.1. Flow Regimes

Figure 5 shows the results obtained by VRD and we see that the device gives very acceptable results. In general, the experiment determines the critical Reynolds number for different flows in a tube at which the laminar flow ($Re < 2000$) becomes transitional ($2000 < Re < 2300$) and the transient flow becomes turbulent ($Re > 2300$). The advantage of using a critical Reynolds number, instead of a critical velocity, is that the results of the experiments are applicable to all Newtonian fluid flows in pipes of the circular cross section.

3.2. CFD Simulation

Figure 6(a) represents the distribution of the pressure in the tube. We notice the pressure is high at the beginning of the pipe and it gradually decreases at the end of the pipe. This pressure difference represents the pressure drop in the pipe. **Figure 6(b)** represents the

profile of the velocity in the pipe when the flow is laminar, i.e. the Reynolds number < 2000 . This result reinforces our experimental result and proves that our prototype works very well.

In the case where the flow is turbulent, that is to say the Reynolds number > 2300 . **Figure 7(a)** shows the distribution of the pressure in the tube and Figure 5b shows the profile of the speed in the same tube. We see that the profile gives us a clear idea of the turbulent regime in the tube and this proves that our prototype is in correspondence with the literature.

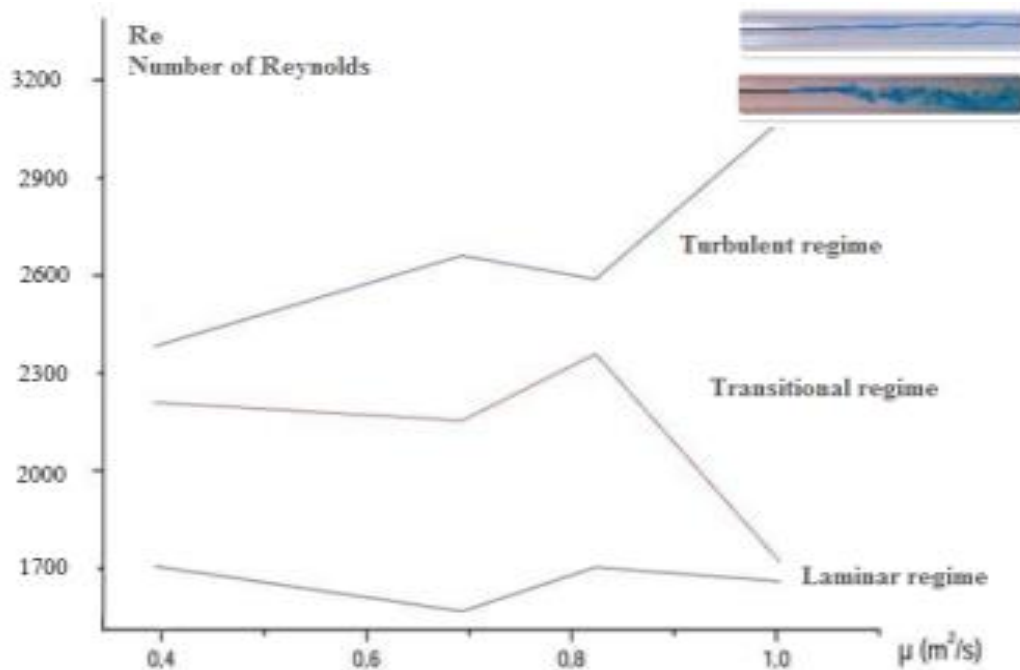


Figure 5. Flow regimes with HRD

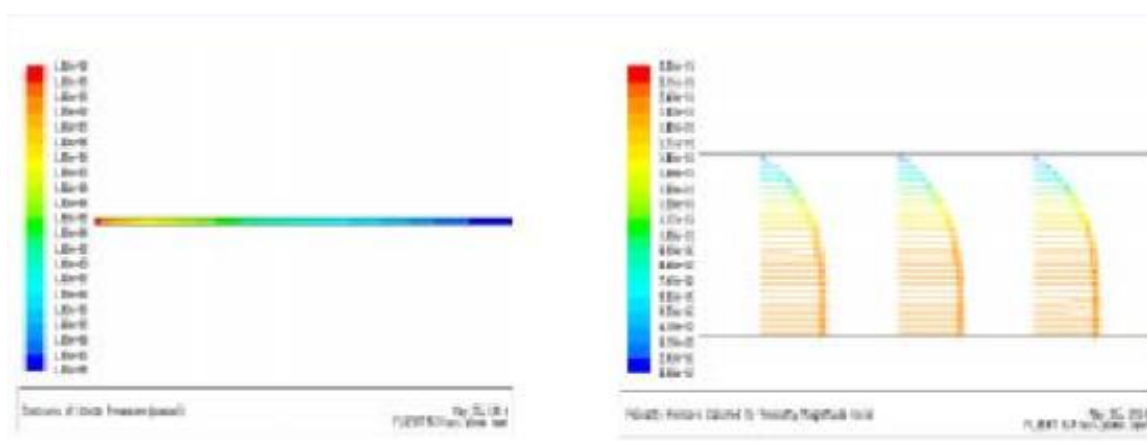


Figure 6. (a) Pressure along the tube- laminar regime, (b). Speed profile - laminar regime

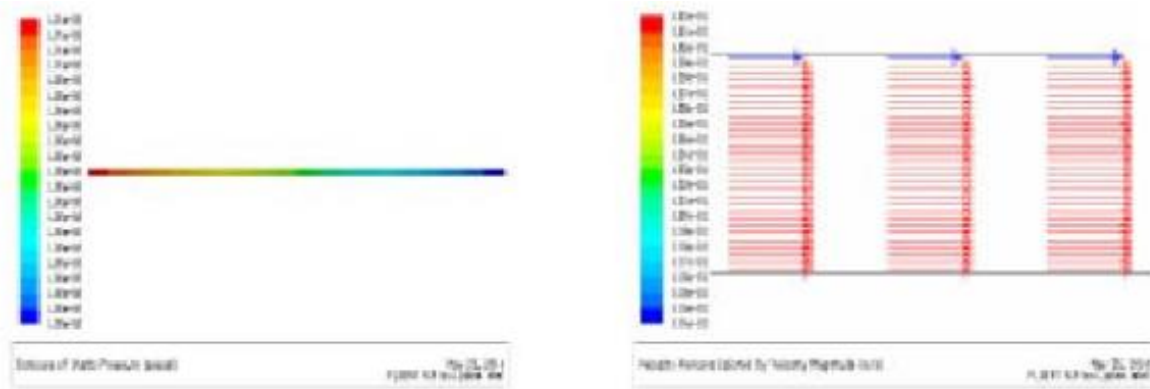


Figure 7. (a) Pressure along the tube- turbulent regime, (b) speed profile - turbulent regime

4. CONCLUSION

The Reynolds H215 vertical test bench has been dealt with in this article. In educational laboratories, the H215 poses a problem and only two individuals can see the experience clearly. Our horizontal prototype, on the other hand, provides a interesting number of students with the ability to see the experience clearly. We have shown that on the one hand, our prototype provided results compatible with the literature and on the other hand, compatible with the original prototype H215. Our experimental findings on our prototype have been improved by the simulation analysis, which demonstrates that our device can replace the H215 product with merit.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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