

Analysis Of Fluid Flow In Contracting Transition Duct Using Ansys Software Package

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Abstract—Equal Lengths of three transition ducts with similar inlet diameter but different outlet diameters were analyzed. All three ducts were subjected to different temperature and velocity conditions. The first duct has inlet and outlet diameters of 11.28mm and 3.57mm respectively. Its initial flow conditions are at 12cm/s and 15°C. The second and third ducts have outlet diameters of 6.67mm and 8.67mm respectively. Both the second and third ducts have inlet velocities of 24cm/s and 48cm/s and temperatures of 25°C and 40°C respectively. After carrying out Computational Fluid Dynamics (CFD) analysis on the three ducts using Ansys Software package, the outlet velocity obtained from the software corresponded with manually calculated values for the three ducts. Also, Reynolds Numbers were calculated to determine the type of flow from the inlet to the outlet for the three ducts. It was observed that while the flow in the first duct transitioned from Laminar to Transient, the flow in the second duct changed from Transient to Turbulent flow and the third one was Turbulent throughout the duct. The different types of flow obtained are in agreement with user point graphs obtained from the Ansys Software.

Keywords—Ansys; Computational Fluid Dynamics (CFD); Reynolds Number; Transition duct; Turbulent flow; Transient flow; Laminar flow; Flow in pipe.

I. Introduction

A careful inspection of flow in a pipe shows that fluid flow is streamlined when the velocity is low but turns chaotic as the velocity increases above particular critical value. When the flow is streamlined, it is called laminar and characterized by highly ordered movement [1]. The flow is turbulent if it is characterized by velocity fluctuations and highly disordered motion [2]. The transition from laminar to turbulent flow occurs over some region in which the flow fluctuates between laminar and turbulent prior to becoming fully turbulent [3]. This transition depends

on the geometry, surface roughness, flow velocity, surface temperature and type of fluid among others [4]. This was discovered by Osborne Reynolds in 1880s when he stated that the flow regime depends mainly on the ratio of inertial forces to viscous forces in fluid and called this ratio Reynolds Number [5]. Hence with given Reynolds Number, one can deduce the flow type of a particular fluid.

This paper aims to validate the continuity equation of fluid flow by comparing values obtained from Ansys software and manual calculations. To accomplish this aim, three different states of the fluid flow along the transition ducts were verified.

II. Methodology

The method applied in the design and analysis of the transition ducts is as explained follows:

A. Meshing Options And Input Parameters

Three Transition ducts of equal inlet diameter with different outlet diameters were analyzed. The input and output parameters are presented in Table (1). The angle (α) shows gradual contraction in size of the ducts while the input temperatures (T) and Velocity (u_1) are the temperature and velocity respectively of the fluid at the entrance region. The input diameter (d_1) is constant while the output diameter (d_2), varies. The transition ducts were drawn in Solidworks Software according to the dimensions given in Table (1) and imported into Ansys environment in which meshing is done and CFD used to analyze the flow of the fluid in the different ducts. The meshing option is as shown in Fig (1). Using the computational fluid program from the Ansys Software toolbar, the material is set to water, normal speed at 12cm/s and static temperature at 15° for the first duct as required by Table (1). The whole process is set to adiabatic indicating that there is no heat transfer to or from the wall. After running the solution for the first duct, the speed and static temperature are then changed for other ducts.

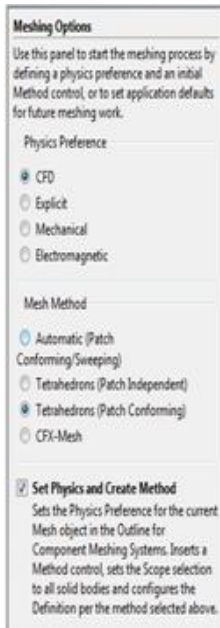


Fig.1. Meshing options for all transition ducts

Table I. Input parameters of ducts and fluid

Duct	u_1 (m/s)	α^0	T(°C)	d_1 (m)	d_2 (m)
1	0.12	20	15	0.1128	0.00357
2	0.24	45	25	0.1128	0.00667
3	0.48	60	40	0.1128	0.00867

B. Contuinity And Navier Stoke (Ns) Equation

The continuity equation which is also called conservation of mass equation depicts that since mass can neither be created nor destroyed, the amount of fluid entering a region equals the amount that leaves that region.

Fig (2). shows illustration of conservation of mass in fluid flow. The momentum equation (or Navier Stoke equation) tells about the balance of the momentum during the flow [7]; and both were married together to study fluid flow in transition ducts .

$$\begin{aligned} \dot{m}_1 &= \dot{m}_2 & (1) \\ \frac{dm_1}{dt} &= \frac{dm_2}{dt} \\ \rho A_1 u_1 &= \rho A_2 u_2 \end{aligned}$$

$$A_1 u_1 = A_2 u_2 \quad (2)$$

where A and u represent area and speed respectively.

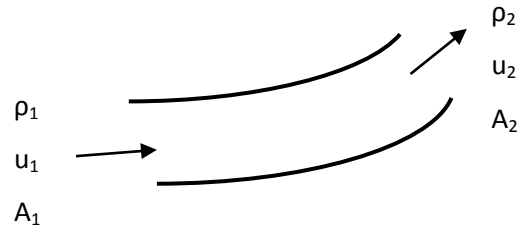


Fig 2. Illustration of Continuity Equation

III. Comparison Of Simulated And Manually Calculated Results

A. Simulated Results

An important graph is the User Point Graph which is shown in Fig (3). The User Points Graph shows values of the average velocity at the inlet and outlet regions. From the graph, the velocity profile for the duct with smallest outlet diameter (3.57mm) is fully grown and remained constant throughout the length of the duct. This is a characteristic of laminar flow. However, the entrance length of Fig (3) is longer than that of Figs (4) and (5). This might mean that as the flow changes from laminar to turbulent flow, the entrance length becomes smaller and smaller while the uniform velocity profile changes towards non-uniformity.

In addition, the flow attained maximum velocity towards the center of the duct.

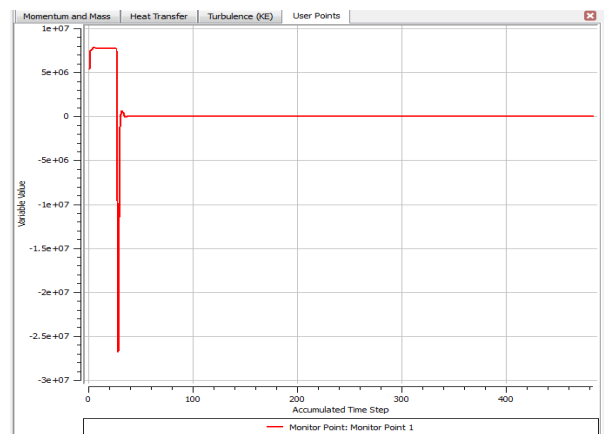


Fig.3. User point plot for duct of outlet diameter 3.57mm

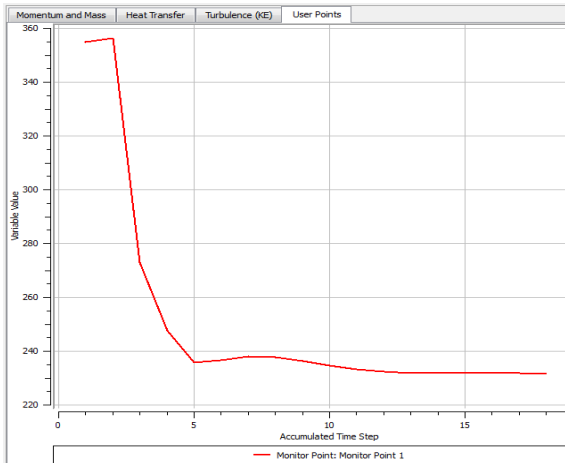


Fig 4. User point plot for duct of outlet diameter 6.67mm

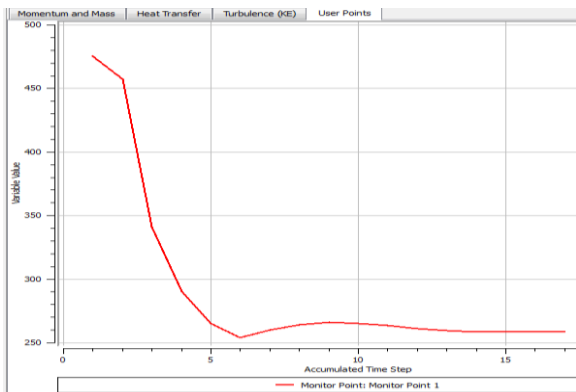


Fig 5. User point plot for duct of outlet diameter 8.67mm

Also, at the wall, where the fluid makes contact with the duct, there is zero velocity or insignificant amount of velocity as indicated in Figs (6), (7) and (8). This is due to friction between layers of the fluid molecules and the wall of the transition duct.

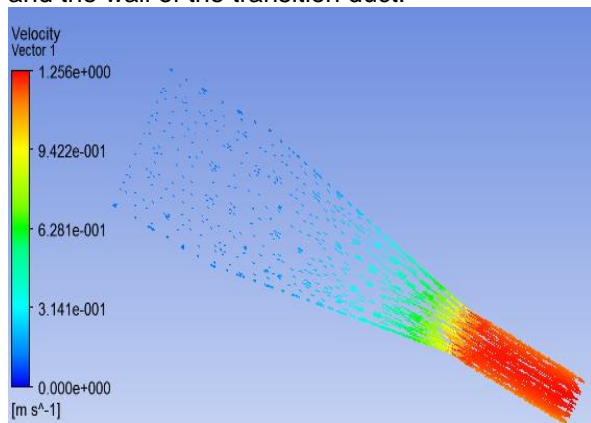


Fig. 6. Velocity Vector Plot for duct of 3.57mm outlet diameter

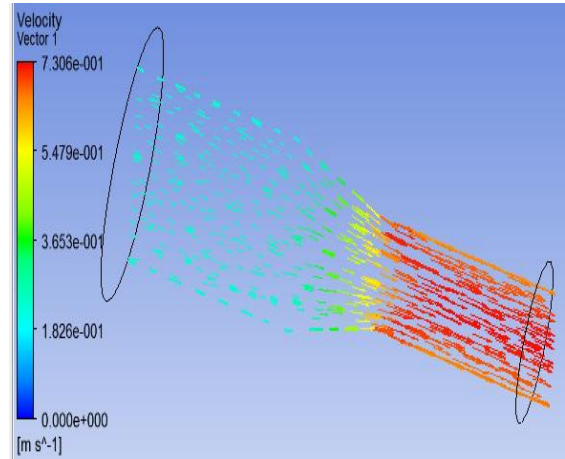


Fig. 7. Velocity vector plot for duct of 5.67mm outlet diameter

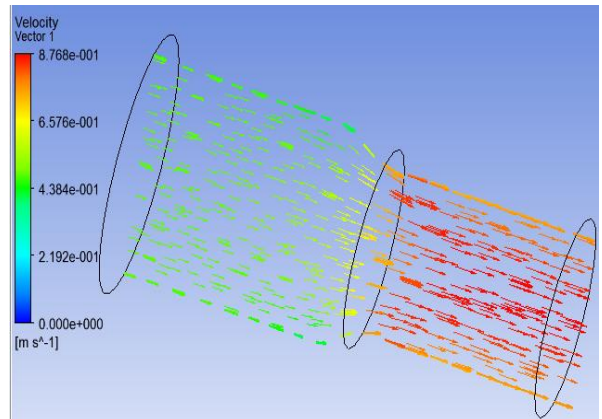


Fig 8. Velocity vector plot for duct of 8.67mm outlet diameter

B. Mathematical Analysis

From Equation 1;

$$A_1 u_1 = A_2 u_2$$

$$\therefore u_2 = \frac{u_1}{\left(\frac{A_2}{A_1}\right)} \quad (3)$$

Using values indicated in Table (1), maximum velocity for the different ducts can be obtained as shown in Table (2), [6].

Table 2. Maximum velocity table

Duct	u_1 (m/s)	d_1 (m)	d_2 (m)	$u_2 = \frac{u_1}{\left(\frac{A_2}{A_1}\right)}$ (m/s)
1	0.12	0.1128	0.00357	1.20
2	0.24	0.1128	0.00667	0.70
3	0.48	0.1128	0.00867	0.81

The maximum values of the outlet velocity obtained manually correspond with the software values which are shown in Figs (6), (7) and (8) for the three transition ducts.

C. Types of flow in the ducts

Figs (3), (4) and (5) clearly show that the flow types in the different ducts are different. Each of these flows behave differently and have different characteristics that predict their behaviors. It was Osbourne Reynolds (1842-1912), who studied the

conditions under which different types of flow occur. Reynolds assigned different numbers (called Reynolds Number) to the flow types [5]. Hence to determine the type of flow in this analysis, Reynolds Numbers have to be calculated using equation 4.

$$\text{Reynold's Number (Re)} = \frac{\rho Du}{\mu} \quad (4)$$

Where ;

ρ = Density;

D = Diameter;

u = Velocity;

μ = Dynamic Viscosity;

The dynamic and kinetic viscosity the fluid (water) at different temperatures are tabulated in Table (3). The flow is

- Laminar if $Re < 2300$
- Transient if $2300 < Re < 4000$
- Turbulent if $4000 < Re$

For the First Transition Duct with Inlet Diameter of 11.28mm,

$$Re = \frac{1000 \times 11.28 \times 0.12 \times 1000}{1000 \times [(1.307 + 1.002) / 2]} = 1172$$

Hence the flow in the Entrance Region is Laminar because Reynolds Number in this region is less than 2300. Reynolds number for other ducts are also calculated in like manner with values from Tables (2) and (3).

Table 3. Dynamic and Kinematic Viscosity of water at different temperatures.

Temperature -t- (°C)	Dynamic Viscosity - μ - (Ns/m ²) X 10 ⁻³	Kinematic Viscosity - ν - (m ² /s) X 10 ⁻⁶
0	1.787	1.787
5	1.519	1.519
10	1.307	1.307
20	1.002	1.004
40	0.653	0.658

The Reynolds Number and types of flow for other regions of the other ducts are presented in Table (4). It is obvious that as the temperature of the fluid increases and the outlet diameter decreases, the type of flow changes from laminar through transient to turbulent flow as the designed outlet diameter varies considerably.

Table 4. Reynolds Number with types of Flow in different Regions of the Transition Ducts

Duct	Inlet Diam (mm)	Outlet Diam (mm)	Reynolds No. for Inlet Region	Reynolds No. for Outlet Region	Types of Flow in Inlet Region	Types of Flow in Outlet Region
1	11.28	3.57	1172	3710	Laminar	Transient
2	11.28	6.67	2762	4764	Transient	Turbulent
3	11.28	8.67	8292	10, 755	Turbulent	Turbulent

5.0. Conclusion

In conclusion, different types of flow have been analyzed both mathematically and using software. Ansys Software values and manual calculations have been computed and compared. Differences from both results are insignificant as they are approximately equal. In fluid flow, velocity reduces as area increases and vice versa. This has been observed from the analysis and manual calculations.

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