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Modeling Study of Interaction between Fluid Flow and Pipe Wall Formed in Piping Erosion Phenomenon with SPH Method

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ABSTRACT

This study observes the interaction between fluid flow and the solid particles using Smoothed Particle Hydrodynamics (SPH) as a numerical approach with the DualSPHysics platform and the flow assumed as a laminar flow with Re of 25, 50, and 100. As an approach study of internal piping erosion phenomenon, there are two types of pipes simulated, pipe with smooth wall and rough wall with different geometry and height of roughness. The geometry of roughness simulated are semi–circular ribs, triangular ribs, and rectangular ribs. The evaluated output of this research is the friction coefficient and velocity distribution occurring. In the case of flow through smooth wall, it is found that the increase of Reynolds number causes the decrease of friction coefficient. The next case of flow through rough walls shows that the height and shape of roughness affect the friction coefficient and velocity contour of the flow.

Keywords: piping erosion; friction coefficients; poiseuille number; SPH method; fluid-solid interaction.

INTRODUCTION

Internal piping erosion is one of the failures that frequently happened in earth fill dam structures. Piping erosion happens when soil particles of the earth dam eroded continuously and it creates a hollow space in a form of a pipe. About 47% of failures in earth fill dams that occur are caused by the phenomenon of internal piping erosion. Therefore, this phenomenon is important to study in order to plan dam structures that are more resilient and safer from failure.

Internal piping erosion phenomenon consists of interaction between solid particles eroded and fluid flow. The interaction between water and solid particles involving large deformation that needs a more adaptive numerical approach, and this problem can be solved by using SPH (Smoothed Particle Hydrodynamics) numeric method. The advantage of using this numerical method is the more adaptive property compared to grid base method. Because this method is meshfree or gridles.

Previous study shows that DualSPHysics can simulate the interaction between water flow and solid particles with several errors. These errors can be overcome by extending the simulation time to ensure that the flow formed is in stable condition, and by increasing the volume control to reduce the wall effect and so that the flow conditions are more similar with the original conditions. Another limitation of the DualSPHysics platform is the inability to observe turbulent flow due to the low resolution. Therefore, this study only observed the early stage of the piping erosion phenomenon when the flow was still laminar.

It is known that the pipe wall formed in the piping erosion phenomenon is shaped like a pipe with a certain roughness. Different roughness results in different pressures, flow velocity, resistance factor, and critical Reynolds number. Therefore, this research is to be carried out in pipe wall with different roughness.

This study aims to know the effect of varied Reynolds Number to the flow velocity and pressure distribution in the case of laminar flow through a smooth wall. This research also observed the effect of varied roughness shape and roughness height to the flow velocity, pressure distribution, and Darcy friction factor in the case of laminar flow through rough pipe wall.

RESEARCH METHOD

SPH Method

Partial differential equations can be solved by arithmetic calculation or numerical procedures by Smoothed Particle Hydrodynamic (SPH) method in interpolated integral equations that estimate the value and derivative of an entity using particles as discrete forms. This SPH method uses particles, each of which represents a material with its own properties and mass (Monaghan, 1992). These particles can move in space, carry information necessary for computation, and can form a computational framework for solving partial differential equations that describe the conservation laws of the dynamic fluid continuum.

The SPH Formulation needed in this study is defined below this passage.

$$f(x) = \sum_{j=1}^{N} \frac{m_j}{\rho_j} f(x_j) W(x - x_j, h) \qquad (1)$$

$$< \nabla . f(x) >= - \int_{\Omega} f(x') . \nabla W(x - x', h) dx' \qquad (2)$$

This formulation is implemented for general dynamic fluid flows by applying it to the equation of momentum conservation in Lagrangian form.

$$\frac{dv}{dt} = -\frac{1}{\rho} \nabla P + g + \Gamma \qquad (3)$$

$$\nabla P(x) = \sum_{j=1}^{N} \frac{m_j}{\rho_j} P(x_j) \nabla W(x - x_j, h) \qquad (4)$$

$$\frac{dv}{dt} = -\sum_{j=1}^{N} \frac{m_j}{\rho_j} \left(\frac{P_i}{\rho_i^2} + \frac{P_j}{\rho_j^2} \right) \nabla W(x - x_j, h) + g + \Gamma \qquad (5)$$

$$\frac{dv_i}{dt} = -\sum_j m_j \left(\frac{P_i + P_j}{\rho_i . \rho_j} \right) \nabla W(x - x_j, h) + g + \Gamma \qquad (6)$$

Where Γ is dissipative terms, g represents gravity acceleration, P is pressure, and ρ density.

There are two types of viscosity treatment that could be used in DualSPHysics, those are artificial viscosity proposed by (Monaghan, 1992) and laminar viscosity and sub-particle scale. Previous research shows that laminar viscosity and sub-particle scale viscosity treatment is more stable compared to artificial viscosity. The viscosity treatment used in this study is laminar viscosity and sub-particle scale.

$$(\upsilon o \nabla^2 \mathrm{v}) = \sum_{j=1}^{N} m_j \left(\frac{4\upsilon_0 r_{ij.} \nabla W(xi - xj, h)}{(\rho_i + \rho_j)(r_{ij}^2 + \eta^2)} \right) v_{ij} \qquad (7)$$

Where υ_0 is kinematic viscosity. Hence, equation of momentum conservation can be rewritten in SPH method formulation as follows.

$$\frac{dv_i}{dt} = -\sum_j m_j \left(\frac{P_i + P_j}{\rho_i . \rho_j} \right) \nabla W(x - x_j, h) + g + \sum_{j=1}^{N} m_j \left(\frac{4\upsilon_0 r_{ij.} \nabla W(xi - xj, h)}{(\rho_i + \rho_j)(r_{ij}^2 + \eta^2)} \right) v_{ij} \qquad (8)$$

Poiseuille Flow Theory

Poiseuille flow is the closest approximation of physical flow that happens in a pipe with small Reynolds Number. To use Poiseuille Flow Equation, the water flow should follow these followings conditions that are low Reynolds Number, laminar, Incompressible Newtonian Fluid, steady, constant, and uniform viscosity.

These fluid assumptions should be followed to solve the navier stokes in analytical way as follows.

$$\rho\left(\frac{du}{dt}+\upsilon_r\frac{du}{dr}+\frac{\upsilon_\theta}{r}\frac{du}{d\theta}+u\frac{du}{dx}\right)$$
$$= -\frac{dp}{dx}+\gamma\sin\theta+\mu\left(\frac{d^2u}{dr^2}+\frac{1}{r}\frac{du}{dr}+\frac{1}{r^2}\frac{d^2u}{d\theta^2}+\frac{d^2u}{dx}\right) \qquad (9)$$

No acceleration (the left-hand side is zero) of the fluid particles as they move in the pipe, equation 9 can be simplified as follows.

$$\frac{1}{\mu}\frac{d}{dx}(p+\gamma h)=\frac{1}{r}\frac{d}{dr}\left(r\frac{du}{dr}\right) \qquad (10)$$

Integrate r independently and we got equation 11.

$$u(r)=\frac{\lambda}{4}r^2+A\ln r+B \qquad (11)$$

Velocity must remain finite at r = 0, hence A=0. Also, at r=r0, u=0.

$$u(r)=\frac{\lambda}{4}(r^2\text{-}r_0^2)=\frac{1}{4\mu}\frac{d}{dx}(p+\gamma h)(r^2\text{-}r_0^2) \qquad (12)$$

RESULTS AND DISCUSSION

Flow Through Smooth Wall (Poiseuille Flow)

This study is conducted by varying the Reynolds number to see its influence toward flow with smooth wall. Table 1 shows the variation of Reynolds Number used in this study.

Table 1. Variation of Reynolds Number in Poiseuille Flow Case

Case	Reynolds Number (Re)	Fluid Viscosity (υ)
1.1.	25	0.04
1.2.	50	0.02
1.3.	100	0.01

Figure 1 shows the volume control of flow through smooth wall pipe, that is H = 1, with dp = H/40. To ensure the flow evaluated is already in a stable state or has fully developed the two pressure measurement points are selected in the center of the length or the area after the entrance length (Le) (Kays, 2004). The length of the wall is calculated based on the formulation below..

$$L = Le + 5H = 0.05 \times Re \times H + 5H \qquad (13)$$

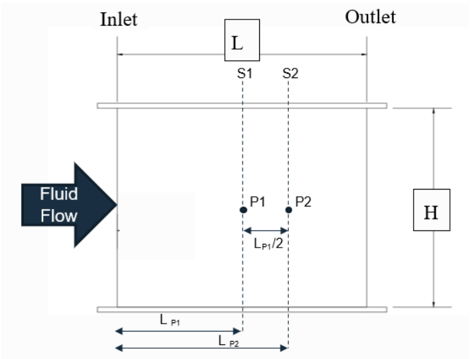


Figure 1. Smooth Wall Control Volume

Validation of this study is evaluated by comparing the Darcy friction coefficient, Poiseuille number, and velocity distribution obtained by using Smoothed Particle Hydrodynamics Method with its analytical solution. Friction Factor (f_D), is the theoretical equation used to predict the friction energy loss in a pipe based on the fluid velocity and friction resistance. Darcy Friction Factor of this simulation can be calculated from the following equation.

$$f_D = \frac{\Delta p.2H}{\Delta x.\rho {U_\infty}^2} \qquad (14)$$

Poiseuille Number is a non-dimensional number that describe the characteristic feature of a flow. Poiseuille Number (Po) can be calculated by this equation.

$$\mathrm{P_o} = \mathrm{f_D}.\mathrm{Re} \qquad (15)$$

The result of Poiseuille flow case is shown in Table 2 below.

Table 2. Results of the Poiseuille Flow Case

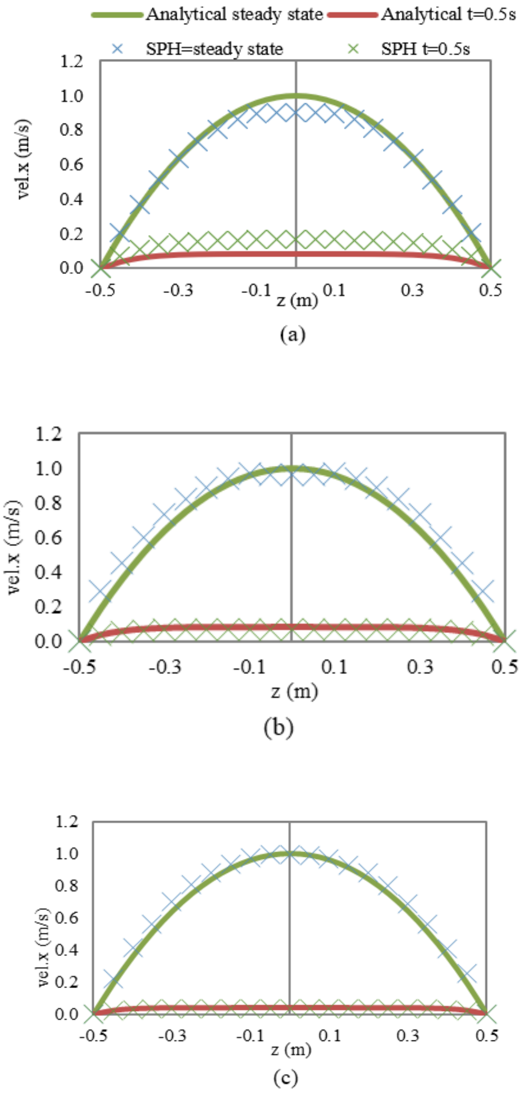
Re = 25	Analytic	Dual SPHysics Result	
		Value	Error Percentage (%)
Δp	-300	-293.05	2.32%
f_D	1	1.04	8.24%
Re	0.96	25	0.00%
P_o	25	25.98	8.24%
CPU Time		2	hours
Re = 50	Analytic	DualSPHysics Result	
		Value	Error Percentage (%)
Δp	-300	-308.50	2.83%
f_D	0.48	0.55	13.94%
Re	50	50	0.00%
P_o	24	27.35	13.94%
CPU Time		5	hours
Re = 100	Analytic	DualSPHysics Result	
		Value	Error Percentage (%)
Δp	-300	-293.44	2.19%
f_D	0.24	0.24	1.00%
Re	100	100	0.20%
P_o	24	23.95	0.00%
CPU Time		15	hours

Poiseuille flow case in smooth wall for Re= 25 is performed along a conduct length of 6.25H. The error percentages of DUALSPHYSICS method results compared to the analytical solution for pressure, friction coefficient and the Poiseuille number respectively 2%, 8% and 8%. The deviation is still less than 15%, this is considered acceptable for a quantitative result.

Poiseuille flow case in smooth wall for Re= 50 is performed along a conduct length of 7.5H. The error percentages of DUALSPHYSICS method results compared to the analytical solution for pressure, friction coefficient and the Poiseuille number respectively 2%, 14% and 14%. The deviation is still less than 15%, this is considered acceptable for a quantitative result.

Poiseuille flow case in smooth wall for Re= 100 is performed along a conduct length of 10H. The error percentages of DUALSPHYSICS method results compared to the analytical solution for pressure, friction coefficient and the Poiseuille number respectively 2%, 1% and 1%. The deviation is still less than 15%, this is considered acceptable for a quantitative result.

Respectively, the whole Poiseuille flow case has also shown velocity distribution value that is similar compared to the analytical calculation as shown in figure 2 below.



(a)

(b)

(c)

Figure 2. Velocity Distribution of Poiseuille Flow Case for: (a) Re=25, (b) Re =50, and (c) Re = 100

Velocity profile of the simulation is also generated to visualize the velocity distribution occurring in the Poiseuille case (Figure 3).

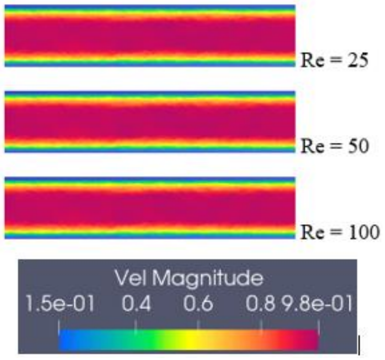


Figure 3. Velocity Profile of Poiseuille Flow Case

Through this simulation, it is found that the bigger the Reynolds Number occurring in a flow, the smaller the friction coefficient is. This is in line with the equation of Poiseuille number, where Reynolds number and friction coefficient are supposed to be inversely proportional.

Flow Through Rough Wall

Flow through rough wall case is conducted by varying the shape of roughness and the height of roughness (ε) to see its influence toward flow. There are three types of ribs shape simulated in this study, they are semi – circular ribs, triangular ribs, and rectangular ribs.

In the Previous study (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010) shows that when the friction coefficient is calculated by using the original diameter, the existence of roughness elements affected and gives off a friction coefficient higher than that obtained for smooth walls.

In the previous experimental study by (Kandikar, 2005) and (Nikuradse, 1950), observed flow through rough walls with different kind degrees of relative roughness. This study shows that the roughness of the wall does not affect the friction coefficient in flow with small Reynolds number (laminar condition). The calculation of the friction coefficient and other dimensionless parameters is examined by taking the constriction height of the pipe wall H_{cf} and not the original diameter H.

$$H_{cf} = H - 2\varepsilon \tag{16}$$

$$K_{cf} = \frac{\varepsilon}{H_{cf}} \tag{17}$$

$$Re_{cf} = \frac{v_{average} \cdot H_{cf}}{\nu} \tag{18}$$

$$f_{D-cf} = -\frac{\Delta p.2H_{cf}}{\Delta x.\rho U_{\infty}{}^{2}} \tag{19}$$

In this current study both equation of friction coefficient is calculated.

Flow Through Semi-circular Ribs

In this case, the number of roughness height is varied to to 0.05H, 0.1H, and 0.2H. The influence of spacing(w) is not evaluated. Spacing is made constant of 4ε.

Figure 4 shows the volume control of flow through semi-circular ribs case, that is H = 2, with dp = ε / 6.25.

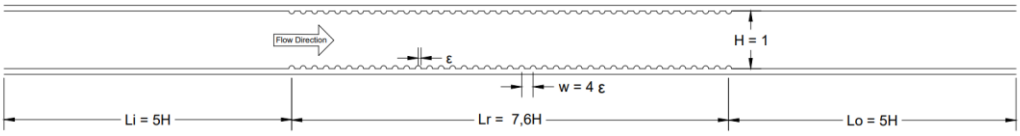


Figure 4. Flow through Semi-circular Ribs Volume Control

The result of the second case flow through semicircular ribs is shown in table 3 below.

Table 3. Results of the Friction Coefficient in Flow Through Semi - Circular Ribs Case

Re = 100, ε = 0.05 H	Analytic	DualSPHysics Constriction Height Equation		DualSPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall
Δp	-333.33	-332.01	0.4%	-332.01	1.23 times
f_D	0.24	0.26	10.36%	0.29	
Re	100	100	0.00%	100	
P_o	24	26.49	10.36%	29.43	
CPU Time		15	hours		
Re = 100, ε = 0.1 H	Analytic	DualSPHysics Constriction Height Equation		DualSPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall
Δp	-375	-377.1	0.56%	-377.1	1.26 times
f_D	0.24	0.241	0.56%	0.301	
Re	100	100	0.00%	100	
P_o	24	24.134	0.56%	30.17	
CPU Time		15	hours		
Re = 100, ε = 0.2 H	Analytic	Dual SPHysics Constriction Height Equation		Dual SPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall
Δp	-500	-491.87	1.63%	-491.87	1.64 times
f_D	0.24	0.23	1.63%	0.39	
Re	100	100	0.00%	100	
P_o	24	23.61	1.63%	39.35	
CPU Time		15	hours		

Flow through semicircular ribs for ε = 0.05 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 10% compared to the analytical solution. The deviation is still less than 15%, this is considered acceptable for a quantitative result. Without changing the height in friction coefficient equation, it is found that its ratio compared to smooth wall 1.25 times bigger, which confirms previous study by (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Flow through semicircular ribs for ε = 0.1 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 5% compared to the analytical solution. The deviation is still less than 0.6%, this is considered acceptable for a quantitative result. Without changing the height in friction coefficient equation, it is found that its ratio compared to smooth wall 1.26 times bigger, which confirms the previous study by (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Flow through semicircular ribs for ε = 0.2 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 4% compared to the analytical solution. The deviation is still less than 15%, this is considered acceptable for a quantitative result. Without changing the friction coefficient equation, it is found that its ratio compared to smooth wall 1.64 times bigger, which confirms the previous study by (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Velocity profile of the simulation is also generated to visualize the velocity distribution occurring in the flow through semicircular ribs case (Figure 5).

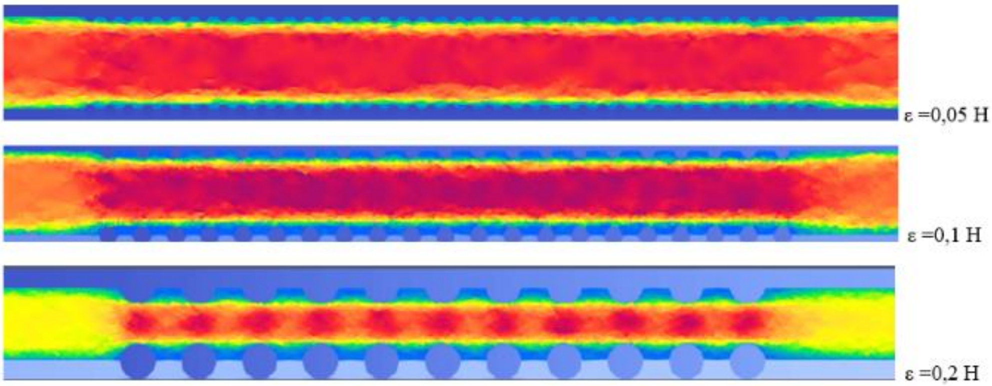


Figure 5. Velocity Profile of Flow Through Semi - Circular Ribs Case

Flow Through Triangular Ribs

In this case, the number of roughness height is varied to 0.05H, 0.1H, and 0.2H. The influence of spacing(w) is not evaluated. Spacing is made constant of 4ε.

Figure 6 shows the volume control of flow through triangular ribs case, that is H = 2, with dp = ε / 6.25.

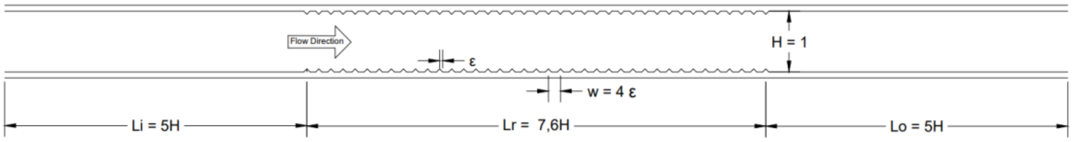


Figure 6. Flow through Triangular Ribs Volume Control

The result of the third case flow through triangular ribs is shown in table 4 below.

Table 4. Results of the Friction Coefficient in Flow Through Triangular Ribs Case

Re = 100, ε = 0.05 H	Analytic	DualSPHysics Constriction Height Equation		DualSPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall

Δp	-333.33	-313.25	6.03%	-313.25	1.16 times
f_D	0.24	0.25	4.13%	0.28	
Re	100	100	0.00%	100	
P_o	24	24.99	4.13%	27.77	
CPU Time		15	hours		
Re = 100, ε = 0.1 H	Analytic	DualSPHysics Constriction Height Equation		DualSPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall
Δp	-375	-373.29	0.46%	-373.29	1.24 times
f_D	0.24	0.24	0.46%	0.30	
Re	100	100	0.00%	100	
P_o	24	23.89	0.46%	29.86	
CPU Time		15	hours		
Re = 100, ε = 0.2 H	Analytic	Dual SPHysics Constriction Height Equation		Dual SPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall
Δp	-500	-447.96	4.41%	-447.96	1.59 times
f_D	0.24	0.23	4.41%	0.38	
Re	100	100	0.00%	100	
P_o	24	22.94	4.41%	38.24	
CPU Time		15	hours		

Flow through triangular ribs for ε = 0.05 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 4% with the analytical solution. The deviation is still less than 15%, this is considered acceptable for a quantitative result. Without changing the friction coefficient equation, it is found that its ratio compared to smooth wall 1.16 times bigger, which confirms the previous study by (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Flow through triangular ribs for ε = 0.1 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 0.5% with the analytical solution. The deviation is still less than 15%, this is considered acceptable for a quantitative result. Without changing the friction coefficient equation, it is found that its ratio compared to smooth wall 1.24 times bigger, which confirms the previous study by (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Flow through triangular ribs for ε = 0.2 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 5% with the analytical solution. The deviation is still less than 15%, this is considered acceptable for a quantitative result. Without changing the friction coefficient equation, it is found that its ratio compared to smooth wall 1.59 times bigger, which confirms the work of (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Velocity profile of the simulation is also generated to visualize the velocity distribution occurring in the flow through semicircular ribs case (Figure 7).

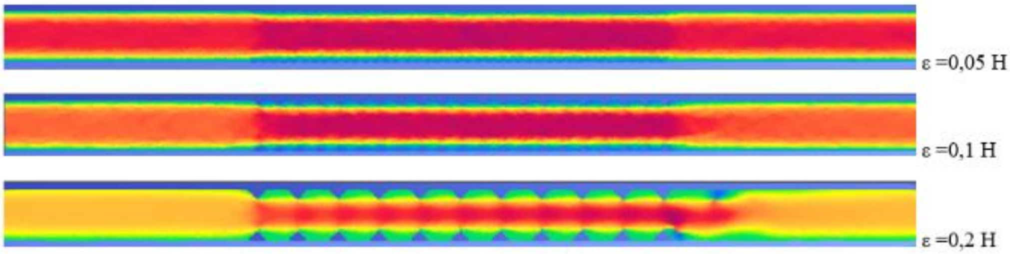


Figure 7. Velocity Profile of Flow Through Triangular Ribs Case

Flow Through Rectangular Ribs

In this case, the number of roughness height is varied to 0.05H, 0.1H, and 0.2H. The influence of spacing(w) is not evaluated. Spacing is made constant of 4ε.

Figure 8 shows the volume control of flow through rectangular ribs case, that is H = 2, with dp = ε / 6.25.

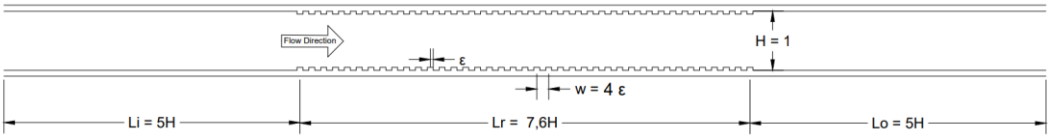


Figure 8. Flow through Rectangular Ribs Volume Control

The result of this case flow through rectangular ribs is shown in table 5 below.

Table 5. Results of the Friction Coefficient in Flow Through Rectangular Ribs Case

Re = 100, ε = 0.05 H	Analytic	DualSPHysics Constriction Height Equation		DualSPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall
Δp	-333.33	-336.64	4.80%	-336.64	1.24 times
f_D	0.24	0.25	5.48%	0.30	
Re	100	100	0.00%	100	
P_o	24	25.32	5.48%	29.84	
CPU Time		15	hours		
Re = 100, ε = 0.1 H	Analytic	DualSPHysics Constriction Height Equation		DualSPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall
Δp	-375	-377.12	0.57%	-377.12	1.26 times
f_D	0.24	0.24	0.57%	0.30	
Re	100	100	0.00%	100	
P_o	24	24.14	0.57%	30.17	

CPU Time		15	hours		

Re = 100, ε = 0.2 H	Analytic	Dual SPHysics Constriction Height Equation		Dual SPHysics Original Height Equation	
		Value	Error Percentage (%)	Value	Ratio compared to smooth wall
Δp	-500	-506.48	1.30%	-506.48	
f_D	0.24	0.24	1.30%	0.40	1.69 times
Re	100	100	0.00%	100	
P_o	24	24.31	1.30%	40.52	
CPU Time		15	hours		

Flow through rectangular ribs for ε = 0.05 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 5.5% with the analytical solution. The deviation is still less than 15%, this is considered acceptable for a quantitative result. Without changing the friction coefficient equation, it is found that its ratio compared to smooth wall 1,17 times bigger, which confirms the previous study by (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Flow through rectangular ribs for ε = 0.1 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 0.6% with the analytical solution. The deviation is still less than 15%, this is considered acceptable for a quantitative result. Without changing the friction coefficient equation, it is found that its ratio compared to smooth wall 1,26 times bigger, which confirms the previous study by (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Flow through rectangular ribs for ε = 0.2 H is performed and the friction coefficient obtained from DualSPHysics method using constriction height equation give a deviation of 1,3% with the analytical solution. The deviation is still less than 15%, this is considered acceptable for a quantitative result. Without changing the friction coefficient equation, it is found that its ratio compared to smooth wall 1,69 times bigger, which confirms the previous study by (Wang et al, 2013), (Mahrous, A. F., S. Mahmoud, R. K. Al-dadah, & A. M. El-syaed, 2011), and (Zhang et al, 2010).

Velocity contour of the simulation is also generated to visualize the velocity distribution occurring in the flow through semicircular ribs case (Figure 9).

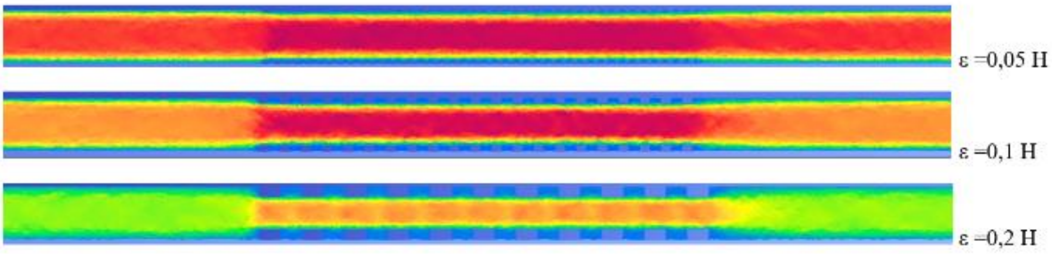


Figure 9. Velocity Profile of Flow Through Rectangular Ribs Case

CONCLUSION

From the smooth wall case, it is found that the Reynolds number occurring in a flow, is inversely proportional to the friction coefficient, this confirms the equation of Poiseuille number, where Reynolds number and friction coefficient are supposed to be inversely proportional. The deviation of the pressure difference, friction coefficient and the Poiseuille number obtained from DUAL SPHYSICS method compared to the analytical calculation give a small difference below 15%. The deviation is still less than 15%, this is considered acceptable for a quantitative result. This also confirms that Dual SPHysics is able to simulate the Poiseuille Case. The behavior of the velocity in the x-axis direction in the middle of the span in scenario 1 (flow through a smooth wall) shows parabolic results. A value of 0 at the point where the wall coincides and a maximum value in the middle point. The velocity results for all variations every value of Reynolds number in smooth wall case, has also shown velocity distribution value that is similar compared to the analytical calculation. The study case of laminar flows through different shape of rough walls also evaluated. The influence of the surface roughness of the pipe wall on velocity shows that the velocity behavior is no longer linear along the x-axis in the center of the volume control, in contrast to a smooth wall which shows velocity that is linear along the x-axis. From this study, it is found that by performing the calculations based on the constriction height (H_{cf}), the result gives a small deviation below 15% to the analytical solution. However, by calculating the friction coefficient based on its original height (H), it gives off different ratio for each shape and height of roughness. Triangular ribs case generates the smallest friction coefficient ratio compared to other shapes, and rectangular ribs generates the biggest friction coefficient ratio compared to other shapes. It is also found that the ratio of friction factor compared to the smooth case is directly proportional to the value of height of roughness. This is due to the ribs on the surface interrupt the flow and in turn, increases the pressure drop and friction factor.

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