Indian Journal of Engineering & Materials Sciences
Vol. 31, February 2024, pp. 76-83
DOI: 10.56042/ijems.v31i1.586

Prediction of pipe geometry influenced by various suction pressure

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Received: 14 April 2023; Accepted: 27 December 2023

There are two main types of fuel pipes, and each is categorized according to the maximum pressure it can withstand. The main purpose of low-pressure pipes is to transfer fuel from a storage tank to a service tank and then, *via* a feed pump, to injection pumps. Fuel from an injection pump has been delivered through high-pressure pipes to the engine's combustion chamber. The current work is concerned with low pressure pipes to determine the pressures at the inlet and outlet of diesel pipes of various cross sections used to transport diesel to the ships. Circular and rectangular cross-sectional pipes have been considered for the present study, and the influence of geometrical factors has been estimated on the inlet and outlet flow parameters of diesel fuel using Fusion 360/CFD software. The variations in the pressure, velocity of the fuel, and shear stress in fuel-carrying pipes in all planes have been presented. The rectangular-shaped pipe generated more shear stresses than the circular cross-sectional pipe. Further, different-shaped circular pipes have been designed and tested for temperature distribution in the pipes while carrying the diesel fuel. The present work has been used for the effective design of diesel-carrying pipes from the bottom to the top end from the perspective of suction pressure.

Keywords: Diesel pipes, Suction pressure, Geometrical parameters, Fusion 360 / CFD software

1 Introduction

Chetak Helicopters are two-ton helicopters. The Chetak helicopter has seven seats and is multifunctional, multi-role, multi-purpose, and capacious. The helicopter can be used for commuting, cargo or material transfer, casualty evacuation, search and rescue (SAR), aerial survey and patrol, emergency medical services, offshore operations, and under slung activities. The helicopter has a maximum operational altitude of 6,500 meters and a cruise speed of 185 kilometers per hour. It has a 500-kilometer range, a three-hour flight endurance, and a maximum fuel capacity of 575 liters. The diving support ships INS Nistar and INS Nipun (DSVs) The DSVs are 118.4 meters long, 22.8 meters wide at their widest point, and weigh 9,350 tonnes. The ships will be capable of continuous patrols, search and rescue operations, and helicopter operations from the high seas. The diesel oil from the INS Nistar and INS Nipun ships will be transmitted to the helicopter through diesel-carrying pipes. To gain a deeper understanding of the current issue, the following remarks are drawn from earlier literature.

The sound levels experienced by the crews of the Chetak and Pratap helicopters during the ground run and flight were well explored. A portable computerized Integrating Sound Level Meter with automatic data acquisition capability was used to collect data[1]. The injection pressure time history was quantitatively evaluated, as was the effect of the delivery return-flow restriction on the system performance of the diesel fuel injection system using experimental and simulation studies[2]. The biodiesel and blended diesel fuels' effects on the temperature of the fuel supply system were presented with the support of the experiments[3]. Physical-based simulation models can increase the number of variables explored while also providing a better understanding of localized events that affect the overall behaviour of the fuel supply system. In this line, an overview of diesel fuel injection system

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analysis, modeling, and diagnostics is provided[4]. An automobile diesel engine fuel injection system is investigated to explore the performance of two different delivery valve assemblies with a constant pressure valve and a reflex hole valve, respectively, using numerical and experimental techniques[5].The injection pressure simulation studies are performed to understand the injector needle lift, flow unsteadiness, and compressibility effect using simulation studies[2].

Based on the distance of delivery, different delivery systems are suggested for hydrogen, and it is concluded that pipeline delivery is ideal for dense areas with large hydrogen demand[6]. For steady and unsteady flow conditions, automotive turbocharger performance is estimated using the 1D approach[7]. Knowledge of the pressure and velocity of the diesel engine is required for its effective performance. In this line, many authors performed studies and raised the significance of the present topic. Using one-dimensional simulation software, the original engine model of the marine low-speed diesel engine and the high-pressure SCR system configuration model were created[8]. Metallic hydraulic pipes for aircraft commonly fail prematurely, and practically all pipes fail in a similar way. An in-flight pipe breakdown reduced hydraulic pressure, endangering the aircraft. A fractured pipe and a cracked hydraulic pipe underwent failure investigations. On the cracked surfaces, scanning electron microscopy revealed fatigue striations. As cracks began to form on the pipe's surface beneath the metallic sleeve, the fracture started at the constricted (inlet) end. Atthe ends of the pipes, metallic sleeves are crimped to aid in the connection of these to other parts of the hydraulic system[9]. It takes a lot of hydrogen to power a hydrogen fuel cell ship, which poses a safety risk due to the hydrogen's propensity for leaks and explosions. The major topic was a hydrogen fuel cell ship, and a corresponding geometric model was produced. The diffusion of hydrogen in various compartments was then simulated using ANSYS Fluent (a fluid computation programme), and the variation of the hydrogen concentration distribution with the leakage time was determined. In the case of a hydrogen explosion, hydrogen leakage was first calculated using the leakage model[10].

The frictional loss in a pipe is caused by shear stress generated in the pipe as a result of fluid viscosity. India's pipeline system is a large network, and reducing losses through these pipes can greatly benefit the nation. This essay analyses the movement of several fluids through a pipe. The ANSYS Fluent CFD 14.0 software was used to simulate the pressure drops between a pipe's inlet and output. Using the Darcy-Weisbach equation, the pressure difference and frictional coefficient were computed. Similar observations were made using experimental studies[11-14]. To check the pressure drops between a pipe's inlet and output, simulations were run using the ANSYS Fluent CFD 17.0 program. Using the Darcy-Weisbach equation, frictional coefficients and pressure differentials were computed. Three-dimensional fluids were created to flow through the model in ANSYS Fluent CFD 17.2 in order to conduct subsequent investigations. One of a six-cylinder diesel engine's typical faults is the rupture of high-pressure oil pipes. This study looks at the effects of applying a pipe clamp and the size of the oil pipe corner on vibration. ANSYS-based modeling is used to suggest an improved design. The outcome demonstrates that the enhancement clearly lowers the average and amplitude of vibrations while raising dependability and the anti-fatigue property[15].

The assurance of pipeline flow obtained by maintaining the lowest pressure losses is one of the most crucial aspects of the liquid transportation process, specifically the transportation of crude oil and oil products. A different pressure drop than the one intended under the single-phase flow assumption would result from the presence of two phases in the pipe. The study uses ANSYS- CFX software to simulate the solid-in-liquid behaviour of slurry horizontal pipe flow and presents the results. At different sand-in-Diesel 2D flow rates, the effect of sand particle diameter and concentration on pipeline pressure loss was investigated[16]. The benefits associated with nanotechnology have provided significant scope for enhancing mechanical material properties[17-20]. Moreover, the integration of artificial intelligence and machine learning, along with Internet of Things (IoT) approaches, has provided significant scope in the research domain of materials. These advancements have enabled researchers to address many real-time problems [21-28]. From the above-cited literature, it is found that the geometrical details of the pipes that carry diesel play a significant role in the output parameters of the pipe, i.e., pressure, velocity, and stresses generated in the fuel-carrying pipe under working conditions.

In this work, efforts are applied to estimate the diesel pipe performance while carrying fuel from the ship to the patrolling helicopter. The changes in the velocity, pressure, and stresses generated in the diesel-carrying pipe while performing its operation using Fusion 360 and CFD.

2 Materials and Methods

The patrolling Chetak helicopter needs to fill its diesel tank from the driving support vehicles. While lifting the fuel from the fuel tank to the helicopter, the diesel fuel supply pipes are used. These diesel fuel supply pipes have a generally circular cross section and a fixed flow rate. In this study, efforts are made to change the cross section of diesel carrying pipes to square, circular, pentagon, and hexagon by fixing the length of the pipes.

By varying the different cross sections of diesel carrying pipes while maintaining the same cross-sectional area, the effect of flow rate is estimated, and by varying the effect of flow rate, the output pressure of the pipe, velocity output, and shear stress generated in the pipe are estimated for considered pipes. To perform these studies, the following assumptions are made The pipe is assumed to be a straight vertical pipe, so any losses due to shape differences on the same pipe are ignored. The placement of the pump is at the top of the fuel pipe. There is no heat transfer involved between the diesel fuel and the pipe.

2.1 Geometrical details

The circular, square, pentagonal, and hexagonal cross-sectional pipes are used for the present work. In each case, the cross-sectional area is the same. The length of the diesel-carrying pipes is 5 meters. The cross-sectional details of the considered cross-sections are provided in Fig. 1.

The geometrical details of the two pipes considered for the analysis are presented in Table 1. Using the parameters in Table 1, above, the analysis is done in Fusion 360 and CFD software to predict the pressure, velocity, and shear stresses at the pipe's outlet. The geometrical details are presented in Fig. 2.

3 Results and Discussion

The patrolling aircraft fills up on fuel from the driving vehicle support system on a ship. Low-pressure straight fuel pipes are used to transfer fuel from the ship to the helicopter. In this work, different cross-sectional fluid pipes are analyzed in terms of velocity, pressure, and shear stresses, and variations of these magnitudes for circular, square pentagonal, and hexagonal cross- sectional diesel pipes are presented for different flow rates such as 3, 5, 7, and 9 m3/hour. Figure 3 shows the variation of velocity at a flow rate of 3 m^3/h. compared to all the sections, square pipe showed higher velocity at a flow rate of 3m3/hour.

The velocity of fluid flowing through a pipe depends on a variety of factors, including the diameter of the pipe, the roughness of the pipe wall, the fluid density, and the fluid viscosity. In this case, the roughness of the pipe wall, fluid density, and fluid

Table 1 — Geometrical parameters of the diesel pipes.

S. No	Type of cross section	Length (mm)	Diameter/ side length (mm)	Area (mm^2)	Volume (mm^3)
1	Circle	5000	30	706.8	3.53e6
2	Square	5000	26.58	706.8	3.53e6
3	Pentagon	5000	20.27	706.8	3.53e6
4	Hexagon	5000	16.49	706.8	3.53e6

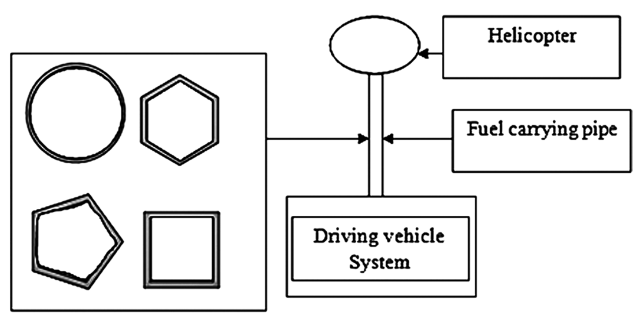

Fig. 1 — Representation of present problem.

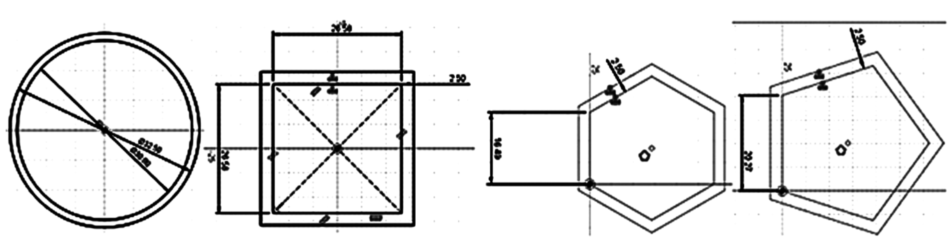

Fig. 2 — Cross sectional details of diesel carrying pipes.

viscosity are the same for the pipes. However, the shape of the pipe can also play a role in the fluid velocity. In this case, a square pipe with sharp corners can produce turbulence in the fluid, which can increase the fluid velocity. On the other hand, a pipe with rounded edges, such as a circular one, will have less turbulence and thus a lower velocity. Figures (4–6) show the outlet velocity of diesel-carrying pipes at different flow rates of 5, 7, and 9 m3/hour, respectively. Increasing the flow rate of diesel will generally result in an increase in theoutlet velocity of pipes with different cross-sectional shapes. The relationship between flow rate and velocity is governed by the principle of conservation of mass, which states that the mass flow rate must be constant throughout a system.

When the flow rate of diesel increases, the velocity of the fluid in the pipe must also increase in order to maintain the same mass flow rate. This means that for all pipes, regardless of their cross-sectional shape, an increase in flow rate will result in an increase in outlet velocity. At low volumetric flow rates such as 3 and 5m3/hour, there are clear changes in the velocity of the diesel carrying pipes; however, at higher flow rates (7 and 9m3/hour), the outlet velocity is nearly the same for every cross section considered for the study.

The observation that changes in velocity of diesel-carrying pipes are more pronounced at low flow rates and become less pronounced at higher flow rates is likely due to the effect ofturbulence on fluid flow. At low flow rates, the fluid in the pipe is less energetic and more susceptible to disturbances, such as changes in cross-sectional shape. This can result in significant changes in velocity as the fluid adjusts to the new conditions. However, as the flow rate increases, the fluid in the pipe becomes more energetic and less susceptible to disturbances. The increased turbulence in the fluid can help to average out differences in velocity caused by changes in cross-sectional shape. As a result, at high flow rates, the outlet velocity is more likely to be similar for pipes of different cross-sectional shapes.

At a lower volumetric flow rate, i.e., 3 m^3/h, a clear difference is observed in the outlet pressure of diesel pipes with different cross sections; however, increasing the flow rate to 5, 7, and 9 m3/hincreased the output pressure, and no significant changes have been observed with the different cross-sectional

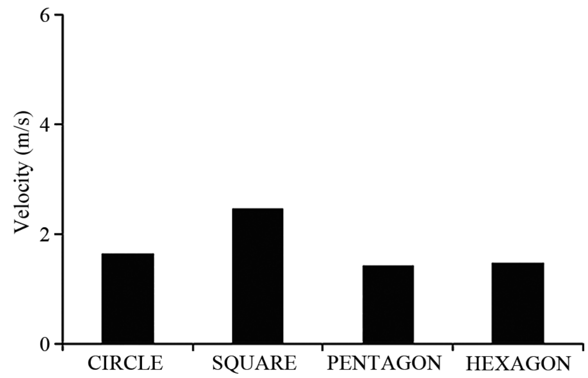

Fig. 3 — Velocity at a flow rate of 3 m^3/h.

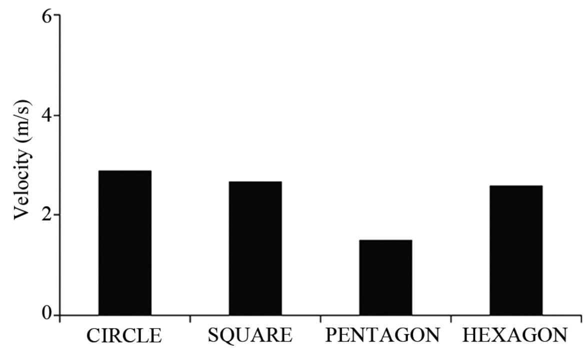

Fig. 4 — Velocity at a flow rate of 5 m^3/h.

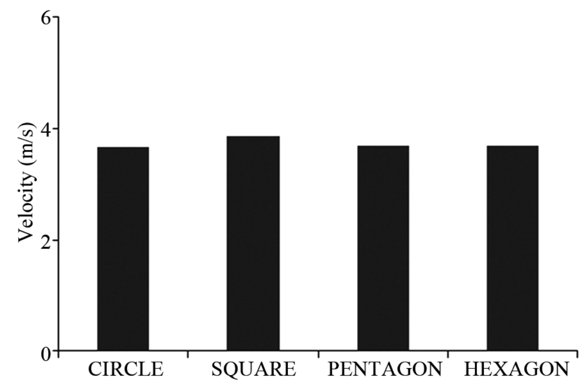

Fig. 5 — Velocity at a flow rate of 7 m^3/h.

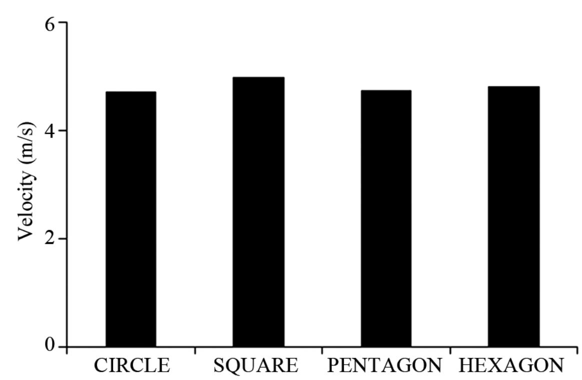

Fig. 6 —Velocity at a flow rate of 9 m^3/h.

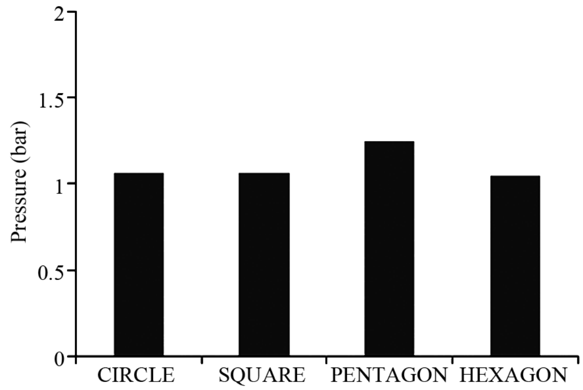

Fig. 7 — Pressure at a flow rate of $3m^3/h$.

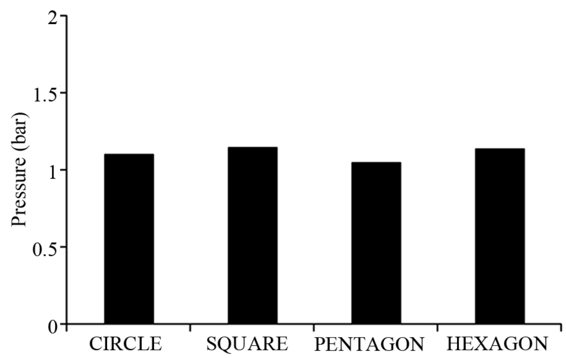

Fig. 8 — Pressure at a flow rate of $5m^3/h$.

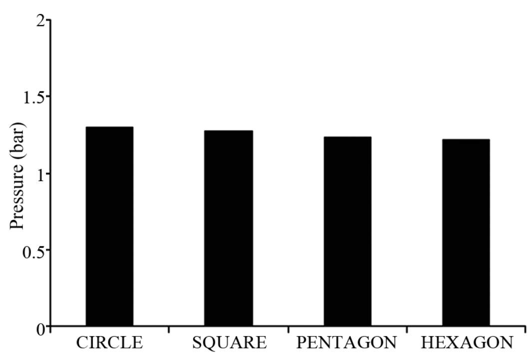

Fig. 9 — Pressure at a flow rate of $7m^3/h$.

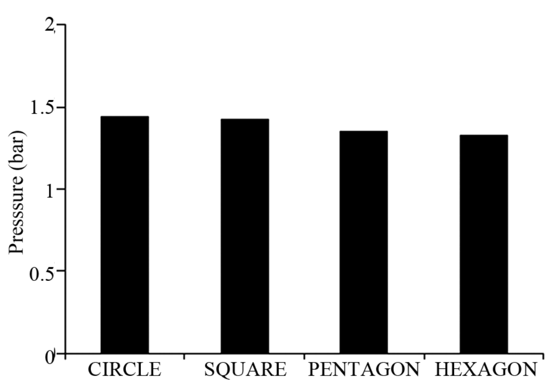

Fig. 10 — Pressure at a flow rate of $9m^3/h$.

pipes considered for the study. The observation described likely has to do with the relationship between flow rate, pressure, and cross-sectional area in fluid dynamics. The flow rate, or the volume of fluid that moves through a pipe in a given period, is related to the pressure difference between the inlet and outlet of the pipe. A lower flow rate means that there is less fluid moving through the pipe, which means that there is less pressure difference between the inlet and outlet.

When the flow rate is low, such as at 3 m^3/h, the pressure difference between the inlet and outlet is also low. As a result, the effect of the cross-sectional area on the outlet pressure is more pronounced, and a clear difference in outlet pressure can be observed between pipes with different cross-sectional areas. However, when the flow rate is increased to 5, 7, and 9 m^3/h, the pressure difference between the inlet and outlet also increases. This means that the velocity of the fluid must decrease to compensate for the changes in cross-sectional area. As a result, the effect of the cross-sectional area on the outlet pressure is less pronounced, and no significant changes are observed with different cross-sectional pipes [Figs (7-10)].

The variation of shear stresses at different flow rates for different cross-sectional diesel carrying pipes is presented in Figs (11–14) for different flow rates. The shear stresses generated in the diesel carrying pipe are low at the low flow rate considered for the present analysis, and the changes in the cross section are also insignificant at a lower flow rate. The shear stress in a fluid- carrying pipe is proportional to the product of the fluid velocity and the fluid density, and is related to the pressure difference between the inlet and outlet

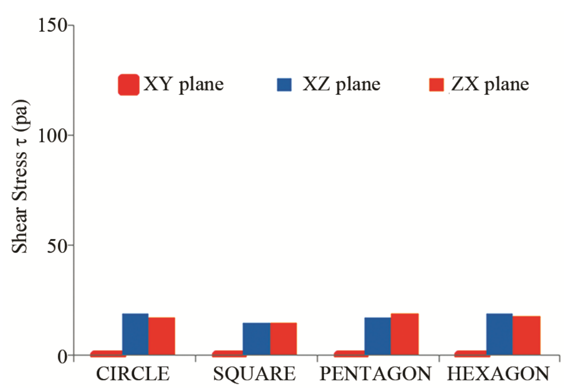

Fig. 11 — Shear stress at a flow rate of $3m^3/h$.

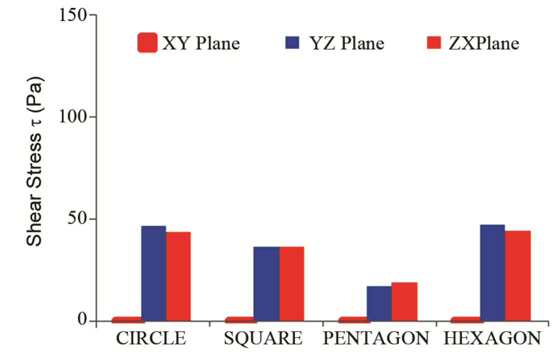

Fig. 12 — Shear stress at a flow rate of 5m^3/h.

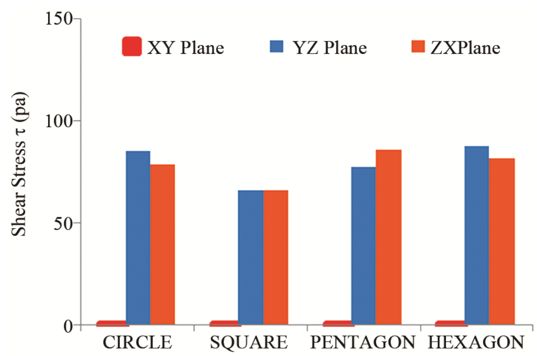

Fig. 13 — Shear stress at a flow rate of 7m^3/h .

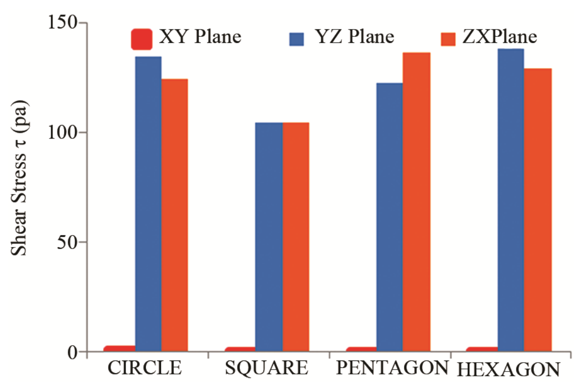

Fig. 14 — Shear stress at a flow rate of 9m^3/h.

of the pipe. When the flow rate is low, the velocity of the fluid is also low, which results in a lower shear stress.

In the present analysis, at low flow rates, the changes in cross-sectional area are also insignificant, which means that the fluid velocity does not change significantly. As a result, the shear stress generated in the diesel carrying pipe remains low, even with different cross-sectional areas considered. When the flow rate is increased, the velocity of the fluid also increases, which results in a higher shear stress. The increase in fluid velocity means that the fluid is moving more quickly through the pipe, which generates more friction and results in a higher shear stress. The shear stress in a diesel-carrying pipe is determined by the diesel velocity and the diesel density, as well as the geometry of the pipe. The shear stress is related to the pressure difference between the inlet and outlet of the pipe, and it acts in the direction perpendicular to the diesel velocity. In a diesel carrying pipe, the fluid velocity is highest in the direction of flow, which is usually considered to be the Z-direction. In this direction, the shear stress is highest, and it acts in the yz and zx planes.

The contours of pressure and velocity for a circular pipe at a flow rate of 3 m^3/h are presented in Fig. 15. The shear stress distribution in a circular cross-sectional diesel pipe at a flow rate of 3 m^3/h is illustrated in Figs. 16 for the shear stresses (τ_{XY}, τ_{YZ}, and τ_{ZX}) in the XY, YZ, and ZX planes, respectively. Similarly, the pressure and velocity contours for a hexagonal cross-sectional pipe at a flow rate of 9 m3/h are shown in Fig. 17, while the corresponding shear stresses in the XY, YZ, and ZX planes (τ_{XY}, τ_{YZ}, and τ_{ZX}) are depicted in Fig. 18.

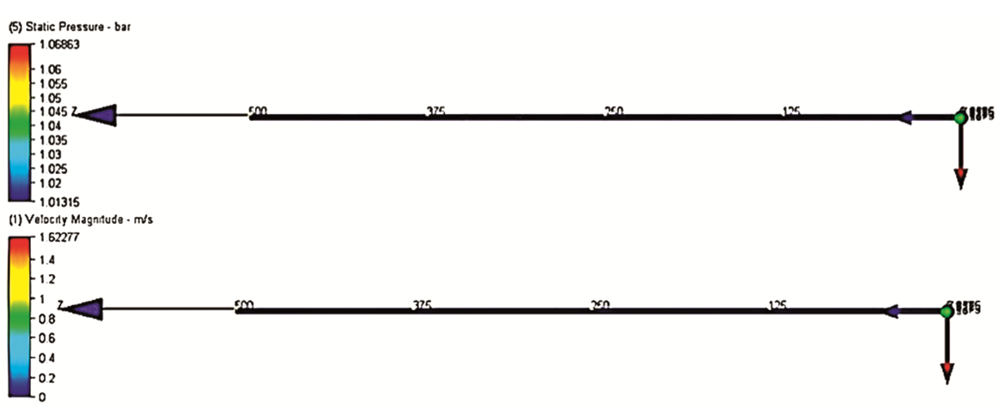

Fig. 15 — Pressure and velocity of a circular pipe at 3m^3/h.

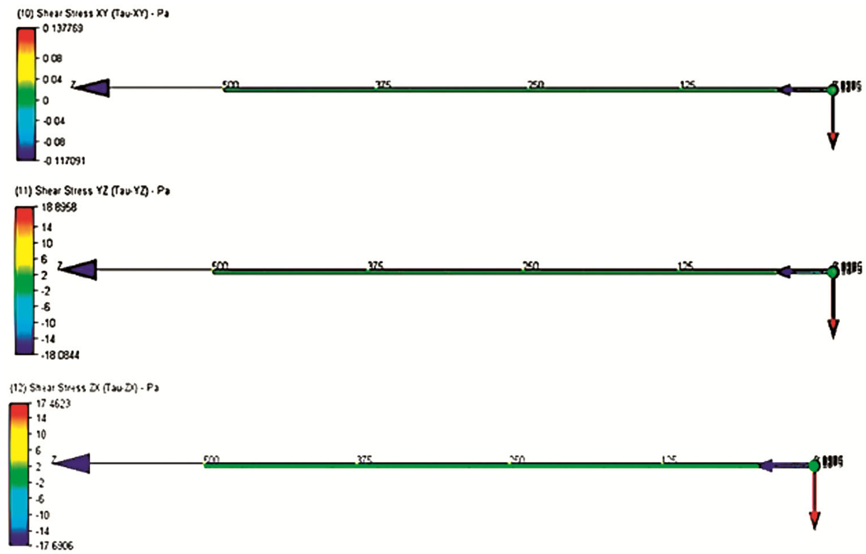

Fig. 16 — Shear stress (τ_{XY}), (τ_{YZ}) and (τ_{ZX}) of a circular pipe at 3m^3/h.

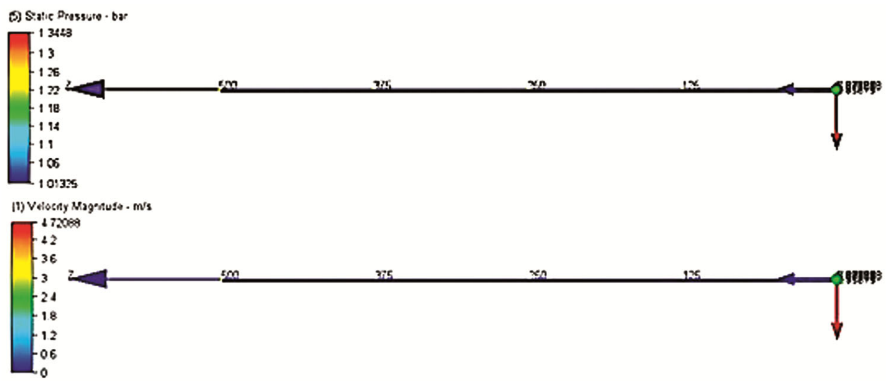

Fig. 17 — Pressure and velocity of a hexagonal cross-sectional pipe at 9m^3/h.

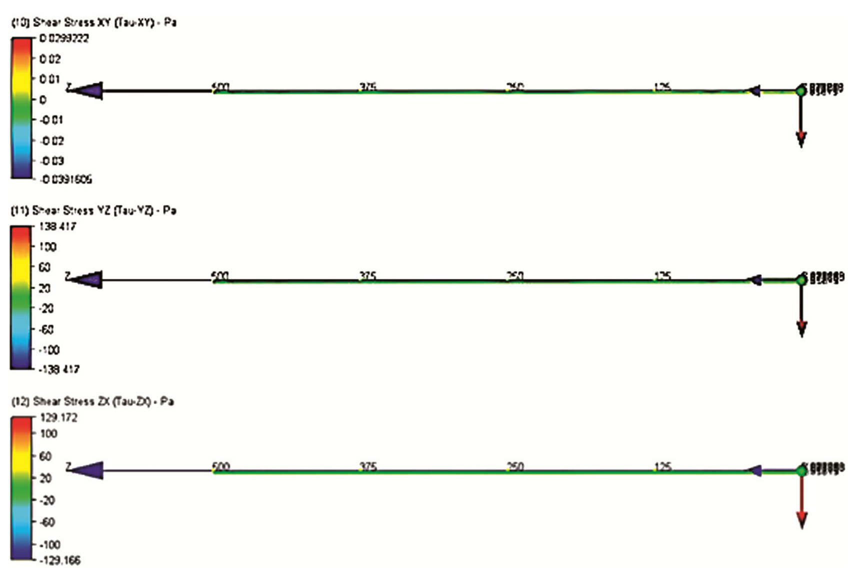

Fig. 18 — Shear stress (τ_{XY}), (τ_{YZ}) and (τ_{ZX}) of a hexagonal cross-sectional pipe at 9m^3/h.

4 Conclusion

The analysis of diesel pipe with different cross-sectional pipes at different flow rates has beenstudied to identify the output velocity, pressure, and shear stresses. The following are the observations made:

1. Changes in velocity of diesel-carrying pipes are more pronounced at low flow rates and become less pronounced at higher flow rates, likely due to the effect of turbulence on fluid flow.

2. The shear stress generated in the diesel carrying pipe remains low, even with different cross-sectional areas considered at a lower flow rate ($3m^3/h$). When the flow rate is increased, the velocity of the diesel also increases, which results in a higher shear stress.

3. At high flow rates (7 m^3/h and 9 m^3/h), a square cross-sectional pipe shows lower shear stress compared to circular, hexagonal, and pentagonal cross sections because of the more uniform fluid velocity profile and the resulting more uniform shear stress distribution throughout the pipe.

4. At a lower flow rate of $3m^3/h$, the pressure difference between the inlet and outlet is low. As a result, the effect of the cross-sectional area on the outlet pressure is more pronounced, and a clear difference in outlet pressure can be observed between pipes with different cross-sectional areas.

5. At higher flow rates, the pressure difference between the inlet and outlet also increases and no significant changes are observed with different cross-sectional pipes.

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