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# CHANGES IN THE HYDRAULIC CHARACTERISTICS OF FLUID FLOW IN A PIPELINE WITH A SUDDEN EXPANSION


***Abstract***: *The article presents an analysis of the changes in velocity, pressure, and vorticity of fluid flow in a pipeline with a sudden expansion. The calculated values of the fluid flow parameters are determined relative to the volume of a circular pipe that has a sudden expansion.*



***Key words***: *velocity, pressure, vorticity, volume, pipeline with a sudden expansion.*
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### 1. Introduction

The movement of tool blocks in the hydraulic systems of technological equipment is carried out by changing the flow velocity of working fluid in pipelines with local resistances [1-5]. Local resistances include curved and variable cross-sectional sections of the pipeline, as well as special elements mounted in the inner diameter of the pipe. A sudden expansion of the pipeline is a shortened version of a diffuser and is characterized by the absence of a transition length between changes in cross-sectional area. When the fluid passes through the sudden expansion section of the pipeline, the flow slows down, so the velocity of a support in the technological equipment will correspond to the working feed of the cutting tool [6-7]. Research on the flow in these pipelines using experimental and simulation methods has revealed patterns that affect the efficiency of the hydraulic system as a whole [8-10]. The proposed study aims to describe the change in the hydrodynamic parameters of fluid flow in the pipeline with a sudden expansion under conditions of changing the initial fluid flow velocity and the pipeline volume.

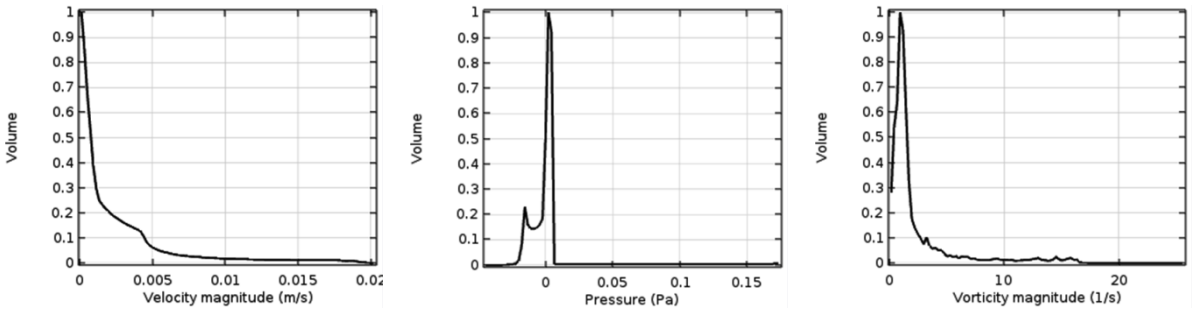
### 2. Materials and methods

The hydrodynamic characteristics of fluid flow in the pipeline with a sudden expansion were calculated using finite element modeling. The problem formulation included a pipeline model in the form of a stepped cylinder, which simulated the flow of water (at room temperature) with various initial velocities (0.01, 0.1, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 m/s). The diameter ratio of the pipeline sections was adopted as 1:2. The fluid flow moved without sliding on the inner walls of the pipeline model. The standard finite element mesh on the pipeline model and the stationary process calculation allowed for an average accuracy of the modeling results.

### 3. Results and discussion

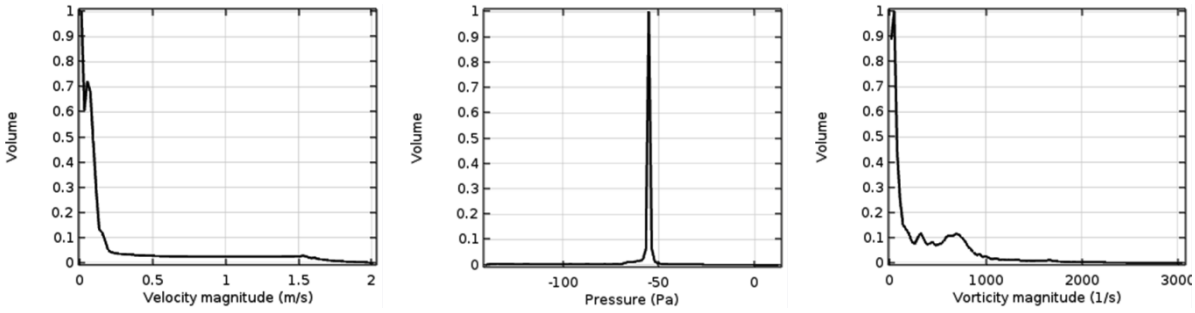
The nature of the change in the velocity, pressure, and vorticity of fluid flow in the pipeline with a sudden expansion is presented graphically and in tabular form in Figures 1-4 and Table 1. The *Y*-axis of the graphs shows the volume of the pipeline sections in relative units, where 0 corresponds to the axial line of the pipeline and 1 corresponds to the largest volume of the pipeline.

The graphs show that as the initial velocity increases, so do the calculated values of velocity, pressure, and fluid vorticity. At the same time, the velocity and vorticity of fluid flow decrease with an increase in the pipeline volume. It can also be seen from the table that the hydrodynamic parameters under consideration have both positive and negative values. Negative values are minimal and indicate a slight slowdown in the flow when the pipeline is filled.



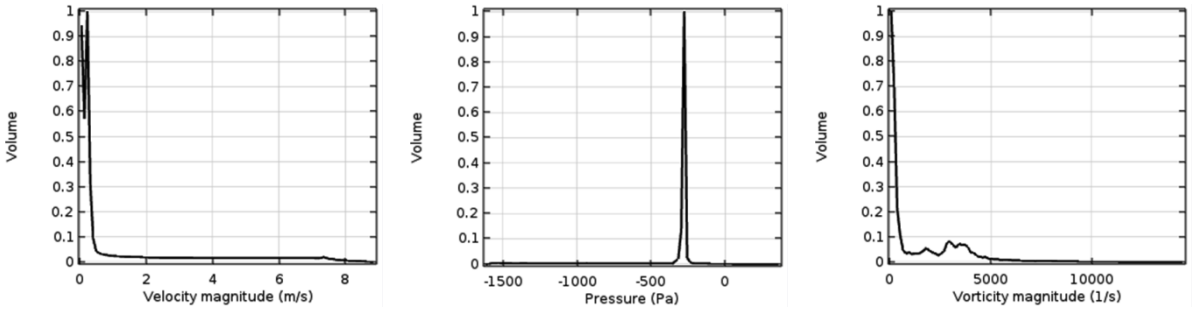

***a*** ***b*** ***c***

**Figure 1. Change in flow velocity (*a*), flow pressure (*b*), and flow vorticity (*c*) as a function of the volume ratio of the sudden expansion pipeline. The initial fluid flow velocity is 0.01 m/s.**



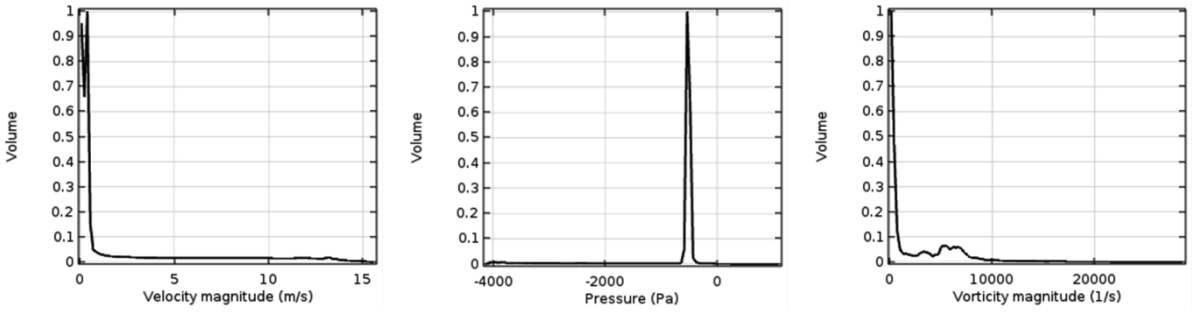

***a*** ***b*** ***c***

**Figure 2. Change in flow velocity (*a*), flow pressure (*b*), and flow vorticity (*c*) as a function of the volume ratio of the sudden expansion pipeline. The initial fluid flow velocity is 1 m/s.**




***a*** ***b*** ***c***

**Figure 3. Change in flow velocity (*a*), flow pressure (*b*), and flow vorticity (*c*) as a function of the volume ratio of the sudden expansion pipeline. The initial fluid flow velocity is 5 m/s.**




***a*** ***b*** ***c***

**Figure 4. Change in flow velocity (*a*), flow pressure (*b*), and flow vorticity (*c*) as a function of the volume ratio of the sudden expansion pipeline. The initial fluid flow velocity is 10 m/s.**

**Table 1. Calculated values of velocity, pressure, and vorticity of fluid flow in the pipeline with a sudden expansion at various initial fluid flow velocities.**

| | **Initial flow velocity, m/s** | | | |
|---|---|---|---|---|
| **Parameter** | *0.01* | *0.1* | *1* | *2* |
| *Velocity, m/s* | $-9.951\times10^{-5}$…0.02041 | $-9.94787\times10^{-4}$…0.20401 | -0.00993…2.03555 | -0.01981…4.06207 |
| *Pressure, Pa* | -0.04609…0.17578 | -1.4556…0.04848 | -141.46352…14.15291 | -545.98199…64.29834 |
| *Vorticity, 1/s* | -0.12571…25.83886 | -1.1266…231.61398 | -15.01147…3080.29248 | -34.22754…7026.53613 |
| | **Initial flow velocity, m/s** | | | |
| **Parameter** | *3* | *4* | *5* | *6* |
| *Velocity, m/s* | -0.02965…6.08062 | -0.03734…7.65699 | -0.04359…8.94031 | -0.04755…9.75239 |
| *Pressure, Pa* | -1186.26538…168.30188 | -1420.88647…289.50928 | -1630.64807…380.60974 | -1674.54187…427.10217 |
| *Vorticity, 1/s* | -55.65918…11420.90137 | -63.65137…13107.68652 | -71.2041…14637.10645 | -73.35938…15129.60742 |
| | **Initial flow velocity, m/s** | | | |
| **Parameter** | *7* | *8* | *9* | *10* |
| *Velocity, m/s* | -0.04323…8.8658 | -0.05647…11.58071 | -0.06762…13.86875 | -0.07668…15.72681 |
| *Pressure, Pa* | -1163.53589…316.91162 | -2087.65454…578.36255 | -3160.87598…869.2373 | -4166.46973…1148.16016 |
| *Vorticity, 1/s* | -58.08984…11980.56055 | -86.1875…17802.50195 | -115.58008…23736.99219 | -140.38281…28892.48633 |

Pressure in the pipeline with a sudden expansion varies over a wide range along the axial line. There is both positive and negative pressure on the axial line, which is distributed along the pipeline length with a sudden expansion. A sudden pressure spike on the graphs is characterized by the transition of moving fluid from one pipeline section to another.

**4. Conclusion**

Based on the analysis of the research results, the following conclusions can be drawn:

1. The calculated values of velocity, vorticity, and pressure of fluid flow in the pipeline with a sudden expansion have positive and negative values. Negative values characterize the braking or divergence of the fluid flow line, in the case of velocity and vorticity, or the hydraulic shock caused by a pressure jump in a fluid-filled pipeline with a rapid change in flow velocity, in the case of pressure.

2. The velocity and vorticity of fluid flow are minimal at the largest pipeline volume and maximal at the smallest pipeline volume. Negative and positive pressures can operate in small pipeline volumes, but only negative pressure operates as the volume increases.

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