INCREASING THE EFFICIENCY OF SEPARATING RAINWATER IN THE CSO CHAMBER BY MATHEMATICAL MODELING.

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ABSTRACT

The paper shows the essence of CFD modeling in sanitary and environmental engineering. Paper includes practical example of assessment of CSO chamber, by using ANSYS Fluent software. This paper also explains the principles, upon which the ANSYS FLUENT software works. Then explains the methodology in creating the model, which is composed of: creating 3D geometry, creating computer mesh, entering of boundary conditions, defining input parameters and finally the actual simulations. In this paper there are also explained methods of modeling, which we use for solving the simulations at the Department of Sanitary and Environmental Engineering.

Key words: *Storm water, CSO chamber, Sewerage network*

1 INTRODUCTION

Mixed rainfall and waste water separated in the relief chambers is a significant source of pollution of watercourses. This fact forces to improve the design and assessment of objects storm water sewerage network with an emphasis on environmental protection. Most municipal waste water treatment plant are treating only domestic sewage and depending on the capacity of the waste water treatment plant can treat part of the rain runoff. The other part of the mixed rainwater and domestic waste water is relieved during the rainfall through the combined sewerage overflow chambers. Domestic sewage carries the bulk of the organic, inorganic and bacteriological pollution but rain water from runoff is also heavily polluted. The main sources of pollution of rainwater in addition to atmospheric pollution are dirt accumulated on the surface of the river basin and to a large extent in the sediments accumulated in the collecting system during without rain periods (Zhu Z., 2017, p. 985). It is necessary to take into account the site, hydraulic, hydrologic, hygienic, economic and operational. The various aspects of this case are linked and influence each other. A method for assessing the effect of lightening the mixed waste water to the recipients developed the Urcikán a wheel on the basis of processing results in the five-year period for 16 ombrograf stations. Slovakia were derived mathematical models yield curves term average rainfall exceeding the average yield curves of rains. Dependence were derived to determine the volume of water relief to the recipient and the duration for relieving summer period (Turi, 1990, p.240, Urcikán 1985). Calculations for the design of CSO chamber and storm water tanks as flow control objects in the sewer network are recommended in standarts (STN 75 6261, STN EN 75). When calculating the designer rainfall and assessing the CSO chamber's workload for the recipient, there are now reservations about using BOD5 as the only indicator of pollution. The above facts but reflect the fact that the standard was left to empirical equation for calculating the yield of the ultimate rain, which was at the time of introduction in our progress compared to previously used the mixing method. In the last decades, no progress has been made in designing and operating CSO chambers. Even with our modern technology is progressing in the design of these objects decade old practice that should be sought primarily from an environmental standpoint and also in terms of operating optimally upgrade this archaic practice.

2 MATHEMATICAL MODELLING

Modeling of hydraulic phenomena are closely related to modeling of some form of movement. Fluid motion is related with the solution of various problems that are contained in the physical models:

- Laminar and turbulent flow.
- Compressible and incompressible flow.
- Stationary, non-stationary and transitional flow.
- Heat transfer, natural and mixed convection.
- Transfer of chemicals and chemical reactions.
- Multiphase flow, flow with free surface, flow with field particles, bubbles or drops.
- Porous media flow and others (Molnár V., 2011, p. 436).

The mathematical model is based on the definitions of the above problems. Given that this is a planar, two-dimensional, and axially symmetric three-dimensional, time-dependent events. They are described in a system of partial differential equations, which are authorized by numerical methods.

It is possible to solve these problems using different commercial software systems such as ANSYS Fluent CFD and more. Constructing a proper calculation model is very important. It contains mathematical, physical and technical principles. For these models, it is necessary to identify all input data of software which are needed for model. In all phases of the creation of these models is necessary re-check of input data. In these models shall be graded all the information about the geometry (two-dimensionally or three-dimensional units), information about external forces, physical data (information on the flowing medium).

Dynamic modelling is based on determining flow equations, which are based on three basic principles:

- Conservation of weight.
- Conservation of momentum.
- Conservation of energy.

These principles are expressed in the form of continuity equation, motion equations and energy equation. They are formulated as a system of partial differential equations (Navier-Stokes equations) (Holubec M., 2013, Hrudka J., 2017)

3 DYNAMIC MODELING OF CSO CHAMBER

Dynamic modeling of the existing combined sewage overflow was carried out at CSO Rudlová, which is located in Banská Bystrica. The detailed dimensions of the object are shown in FIG. 1 and 2. The current state was simulated without the location of the trash rack or the moving wall. The total length of the chamber is 13650 mm and the width is 4950 mm. This is a classic CSO chambers with embedded front overflow.

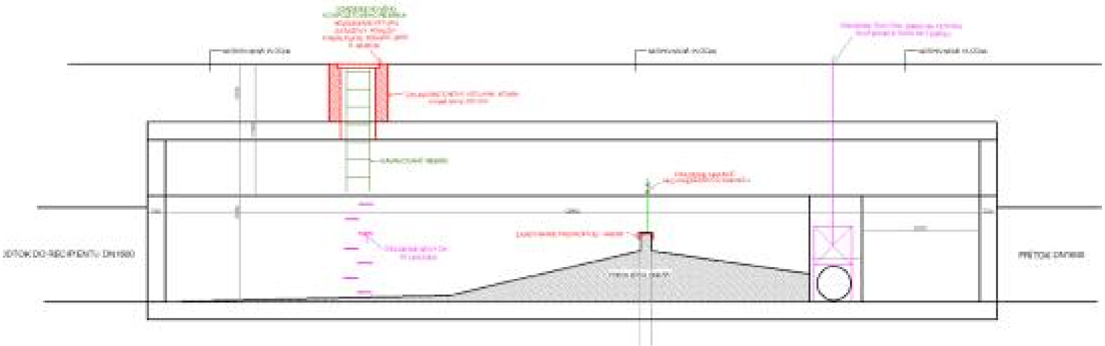

Fig. 1. Cross section of the existing CSO - Rudlava

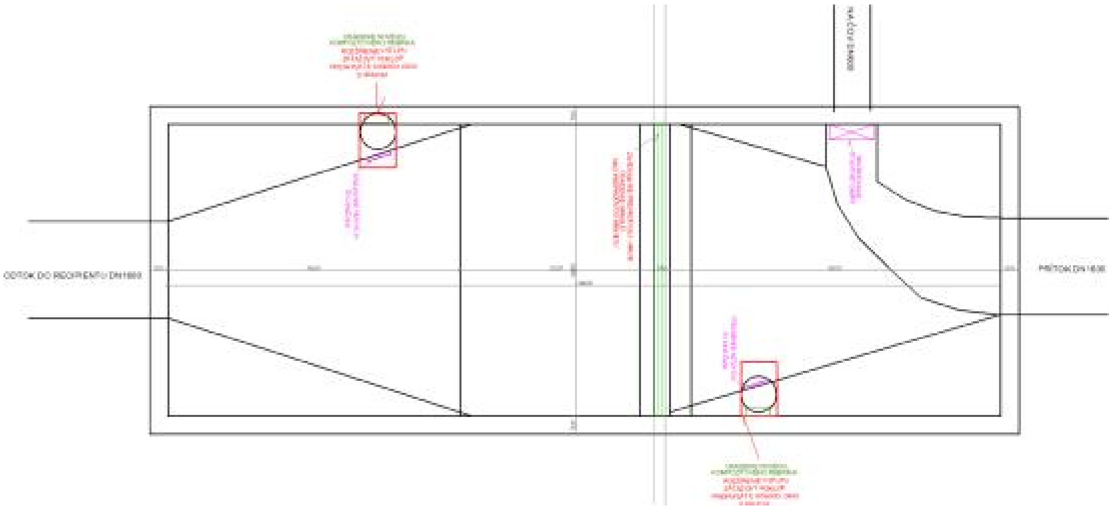

Fig. 2. The ground plan of the existing CSO – Rudlava

4 RESULTS AND DISCUSSION

The simulations were generated with the software ANYSYS fluent. Simulations were performed for real state of the CSO chamber at maximum flow (Fig. 3).

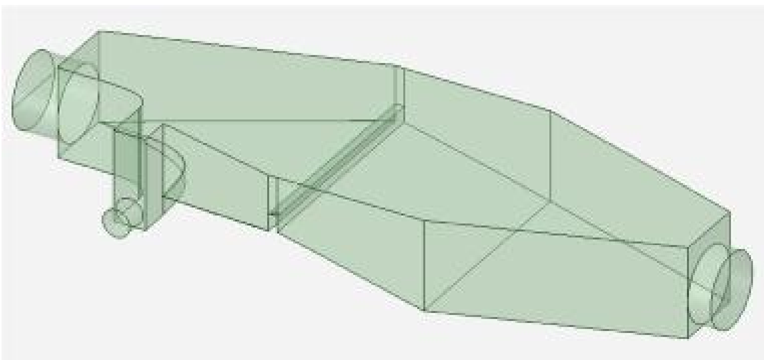

Fig. 3. 3D geometry of an existing object created in Space Claim

3D geometry has also been created for alternate editing of the overflow edge in an object. Such structural modifications include, for example, the installation of rakes on the overflow edge, which are designed to separate floatants (Fig. 4).

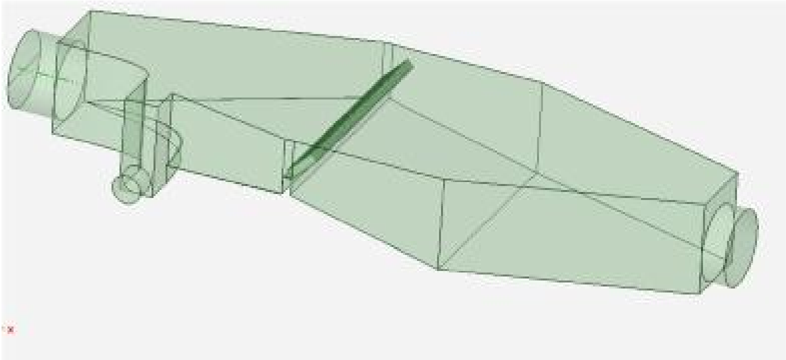

Fig. 4. 3D geometry of object with trash rack, created in Space Claim

The boundary conditions in the mathematical models are shown in Table 1. The mathematical model is based only on a single-phase flow-water simulation.

Boundary condition	Definition
Velocity Inlet -	2 m/s
Wall	0,013 mm
Outflow	Pressure outlet
Solid t -0 s	Air
Solid	H_2O

Tab. 1. Boundary conditions of Simulation

Figure 5 shows the simulation results at maximum flow through CSO. The result is the possibility of optimizing the operation with regard to sewerage operation and recipient protection. On subsequent calibrated mathematical model and subsequent simulations object to shoulder regulatory measures will be realistic to assess the effectiveness and possibility of optimization of that object.

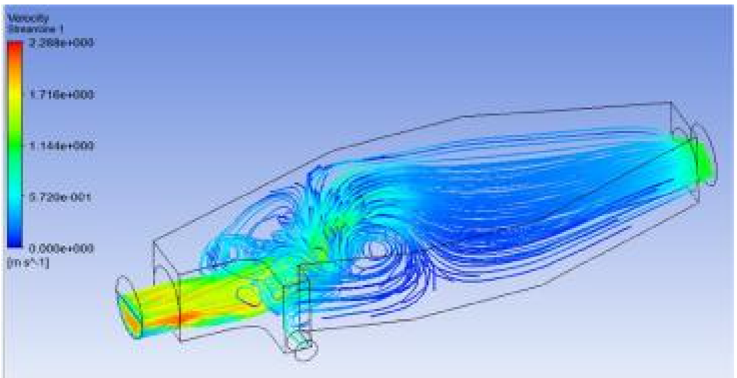

Fig. 5. Streamlines - simulation of maximum flow

The results of the simulation are obvious trend leaching of sediments along relieved water is then transported to the recipient. Improvement of efficiency can then be achieved by the aforementioned control devices embedded in the CSO chamber. However, the first step is to confirm the results of simulations by verification measurements on an existing object in order to ensure the highest degree of accuracy of the results.

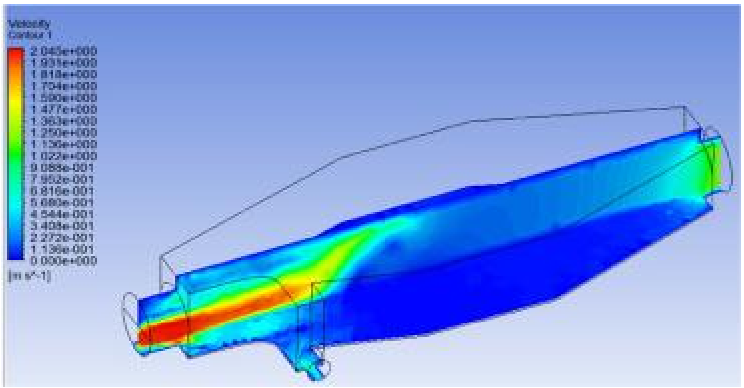

Fig. 6. Contours - simulation of maximum flow

5 ZÁVER

Computer simulations in applications for sanitary and environmental engineering and especially for sewer network objects are very important from a practical point of view and increased attention should be paid to this process. Objects on sewer networks are currently being designed by the empirical formula, which can be verified using mathematical models to improve either the operating conditions or even to improve the environmental impact of the recipient during floods. The operation of the CSO in question currently does not meet the regulatory requirements for effective operation with regard to recipient protection and therefore real-time simulation along with building modification simulations is more than welcome to the operator. The next step solutions research work is to obtain verification and measurement of parameters in real house, in order to confirm the accuracy of the simulation results and because of the subsequent simulation building modifications.

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Literature

1. HOLUBEC. M.,(2013) Využitie CFD nástrojov pre analýzu objektov ČOV, STU, SvF, Slovakia
2. HRUDKA J., (2016) Dynamické modelovanie objektov ČOV, Dizertačná práca, STU, SvF, Slovakia
3. MOLNÁR, V. (2011) Počítačová dynamika tekutín: interdisciplinárny prístup s aplikáciami CFD. Bratislava : Slovenská technická univerzita v Bratislave, ISBN 978-80-81060-48-9.2011, p. 436
4. STN 75 6261 (1997) Dažďové nádrže
5. STN EN 752 (2008) Stokové siete a systémy kanalizačných potrubí mimo budov
6. TURI – NAGY, J., TURČAN, J.(1990) Medzný dážď, jeho stanovenie a použitie. Vodní hospodářství 6/1990, p.238 - 242
7. URCIKÁN, P., RUSNÁK, D., HORVÁTH, J. (1985) Dažďomerné podklady pre navrhovanie odľahčovacích komôr a dažďových nádrží v Slovenskej republike. Záverečná správa výskumnej úlohy, Stavebná fakulta STU, Bratislava
8. ZHU Z., Morales V., H. García M. H., (2017) Impact of combined sewer overflow on urban river hydrodynamic modelling: a case study of the Chicago waterway, Urban Water Journal, 14(9), p. 984-989. DOI: 10.1080/1573062X.2017.1301504